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Promoting renewable energy through green procurement and impact assessment

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Abstract: With urbanization, the construction sector (CS) has been consuming great quantities of energy and contributing to almost 50 percent of the global GHG emissions. Thus, it is imperative for the CS to adopt a sustainable energy system (SES). Renewable energy (RE) is foreseen as a viable option to promote SES. However, adopting RE in CS involves challenges within the areas of both RE development and infrastructure planning (IP). These challenges call for research not only on technology, but also on policy aspects and systems thinking. Thus, the aim of this paper is to understand the scope for incorporating discussions on RE use within the policy instruments (PIs) used in the IP process. The method involved literature review from the perspective of the synthesis of PIs that have the capacities to accommodate discussions on sustainability during planning. The paper highlights a PI called green procurement (GP), which involves procuring services and products that meet environmental requirements. GP could go far to ensure that the energy procured is renewable. The paper indicates that the discussion on procuring RE could be routed through synthesis of GP and impact assessment, which is a PI for evaluating environmental impacts, with the capacity to assist IP.

Keywords: *Infrastructure, urbanization, sustainable energy, impact assessment.*

1. Introduction

The planning, construction and management of major infrastructure projects such as mass transit systems or international airport complexes essentially deals with large scale human-activity centred systems capable of continual growth and expansion [1], involves key players such as the construction sector (CS), and has accelerated urbanization. Consequentially, urbanization has been responsible for substantial consumption of energy, especially by the CS. Significant amount of energy is consumed during manufacturing and transportation of building materials, installation, construction activities [2] and operation. According to the Organization for Economic Co-operation and Development (OECD), the operation of buildings accounts for 25 to 40 percent of the total final energy use in OECD countries [3]. The CS annually generates 50 percent of the global greenhouse gases [4]. The use of non-renewable energy by the sector is one of the causes for its CO_2 emission [5]. However, the emission of CO_2 is noticeable during different phases of a building life cycle, such as, in the construction process, exploitation, renovations, and also during demolition stage [6]. Emissions are also associated with the *use of energy* in construction related activities that precedes site activities, primarily in the construction procurement supply chain [7]. As to what Dimoudi and Tompa [8] highlight, the energy required for construction and consequently, for the material production, is gaining importance. They argue that the selection of materials for the building construction is determinant for the energy required for the construction and for the environmental consequences. It is, therefore, imperative for the CS to adopt a sustainable energy system. Sustainable energy system can be regarded as a "cost-efficient environment-friendly energy system", which efficiently uses local resources and networks, and promotes the introduction of new techno-economic and political solutions [9]. The implementation of such a system by the CS calls for a decrease in the dependency on oil/ other fossil fuels, CO_2 emissions reduction, efforts to curtail social costs and a transition towards renewable energy (RE) such as wind energy or bioenergy.

However, the adoption of RE for construction activities involves challenges both within the ambit of RE development, and in the area of infrastructure planning. Thus, the effort needed to address these challenges and to shift towards a sustainable energy system requires research not only on technology, but also on policy aspects and systems thinking. The two important policy instruments, relevant to infrastructure planning, primarily from an environmental perspective, are *green procurement* (GP) and *environmental impact assessment* (EIA). Due to the links that GP and EIA have with infrastructure planning, this study focuses on them for the promotion of RE in the CS. Further, EIA adopts several analytical tools such as multi-criteria decision analysis (MCDA) in order to achieve its purposes. MCDA is highly suitable for analyzing the intersecting systems of energy and environment [10-13]. Although there is an increasing focus on integration and integrative approaches in EIA [14], the systems perspective needs to be strengthened during its application.

GP, within the context of this study, involves the procurement of construction projects that meet environmental requirements, which must be stipulated such that it facilitates the contractor to comply with them, and further enables verification by the client [5]. In the public sector, GP is termed as green public procurement, which according to the European Commission is a mechanism wherein public authorities intend to procure goods and services with a reduced environmental impact throughout their life cycle [15]. EIA is a process that evaluates the impacts likely to arise from a development project significantly affecting the environment [16], and involves the introduction of mitigation measures to avoid, reduce, remedy or compensate for any adverse impacts [17]. Sánchez and Hacking [18] highlight that ideally, EIA is applied during the planning stage of a new project so as to choose the economically and environmentally feasible technological alternative, and plan management measures to mitigate negative impacts and enhance positive effects. Several authors have investigated the link between EIA and planning (for instance, [19, 20]). The effective *implementation* of strategies and mitigation measures identified through EIA process (during planning), however, remains a challenge [21]. This is where the systems perspective in EIA needs to be strengthened. *In this study, we envisage that integrating GP and EIA could be one way to strengthen the systems perspective. This means that discussions on GP should commence at the stage of EIA. Such integration could be an option to strengthen the link between project planning and implementation.*

GP can go far to ensure that the energy used for construction is renewable and green [15]. It can also involve the procurement of low energy consuming materials for construction. Therefore, the central concern of this paper is to discuss on planning for GP at the stage of EIA. This discussion could be channeled through MCDA, which seeks to identify the plurality of perspectives [17]. MCDA includes “formal approaches” that intend to “take explicit account of multiple criteria” [22] during impact assessment. The decision making procedure under MCDA is based on the concept of making a choice between different actions or alternatives that the decision maker examines and assesses through a set of criteria [11]. These criteria could be defined by objectives or attributes [23], involve qualitative or quantitative data [24], include conflicting factors such as technological, economic, social, risk, and environmental, with different groups of decision makers participating in the process [10]. With these instruments and their synthesis as the focus, the aim of this study is to understand the ‘scope’ within the infrastructure planning process for incorporating discussions on the utilization of RE in the construction sector. The objective of the study is twofold. Firstly, to envisage the synthesis of GP and EIA. During this process, the paper uses the standpoint of “innovation system perspective” (ISP) [25], wherein networks, strategies and institutional mechanisms play an important role. While exploring the role of EIA and GP, this study also attempts to understand the potential role of MCDA in presenting the deliberation on energy inclusive GP. The second objective is to explore the role that the construction sector could play in RE development. The paper also discusses areas for future research from the perspectives of both GP and EIA.

1.1. Methodology

The study is largely based on review of literature and content analysis. The review attempted to systematically examine previous research on innovation system perspective, EIA and planning, drivers and barriers for GP, MCDA adoption in energy planning, institutional mechanisms, and social innovation. This is in order to analyze the state of the art situation, and to investigate the scope for outlining the synthesis of the policy instruments under consideration. The study is explorative, in the sense that the literature has been reviewed from a systems perspective in order to establish how the policy instruments, concepts and institutional settings can allow and shape the synthesis. This also opened areas for future research for further understanding on the synthesis of the (policy) mechanisms. As described by Weber [26], the content analysis method was used to understand the focus in communication content. The European Commission's Communication on public procurement for better environment [15] was analyzed to understand the purview of GP. The method also involved semi-structured interviews, which included open-ended questions (cf. [27]), and were conducted with experts on energy issues. This was a pre-understanding process (cf. [28]) to investigate further on the second objective concerning the role that the construction sector could play. The analysis of the information obtained during the interview strengthened the key findings that emerged during the literature review. These key findings were useful in understanding the potential role of the construction sector.

2. Results

2.1. Synthesis of GP and EIA

In this study, the rationale behind the contemplation of synthesizing EIA and GP has its link with the ISP. Jacobsson and Johnson [25] highlight on ISP for investigating the change in energy system towards RE. The ISP emphasizes that the determinants of technology choice is present in an "innovation system". Such innovation systems facilitate as well as constrain the individual actors making a decision on the technology. In general, innovation systems consist of stakeholders, markets, networks and institutions, and many other components than the relative prices of various alternatives [29]. Innovation is not only about a new product; it could also be the introduction of an improved process, marketing method or organizational method in business practices [30]. As per OECD, dealing with innovation systems is about addressing systemic failures that block the functioning of innovation systems, and obstruct the information flow. These systemic disruptions emerge from institutional rigidities that are based on communication gaps, and lack of networking [29]. Such gaps and lack of integration are evident in the construction sector. The various stages of project development such as design and assessment, construction, operation and maintenance are not yet integrated. There may be considerable difference between project plans (and related EIA reports) and their implementation [30]. The "new environmentally friendly solutions" [31] set during the planning phase need to be effectively communicated at the project implementation stage. Thus, the link between EIA and the structure of the environmental tasks (during project implementation stage) need to be strengthened. For instance, in a Swedish tunnel project, requirements that were based on the environmental impacts identified in the EIA (report) were communicated to the construction contractors through the tender documents [32]. However, planning for GP during the EIA process is still not evident. *Such a planning can be related to* *the integration of project planning and EIA.* For instance, in Sweden, during the first stage of the planning process, a decision is taken on whether the new investment in infrastructure is required or not. This stage is crucial because it clarifies the requirements for the EIA that will be carried out if the planning process proceeds [20]. *These requirements could provide the necessary space for emphasizing on the need for GP planning.* Also, since EIA has a legal mandate, by shouldering on EIA [14], there is an opportunity for GP planning to receive more attention than it receives as a stand-alone policy instrument. In the context of RE, as Gutermuth [33] highlights, legislation can have a direct beneficial effect on the diffusion of RE. Reciprocally, procurement policies have the potential to direct the search process of firms by recognizing the way forward for growth and through guiding the selection of technology [34], which indicates that GP planning within an instrument such as EIA might result in better environmental outcomes. According to the European Commission, green public procurement can be a powerful instrument to stimulate innovation that leads to enhanced environmental performance [15]. *This agenda of the Commission could add value to the integration of GP and EIA.*

This paper proposes a conceptual model (Fig.1) for RE procurement planning within the whole EIA process using a decision process flow chart designed by Haralambopoulos and Polatidis [10]. The first stage in this model should be collection and assessment of data.

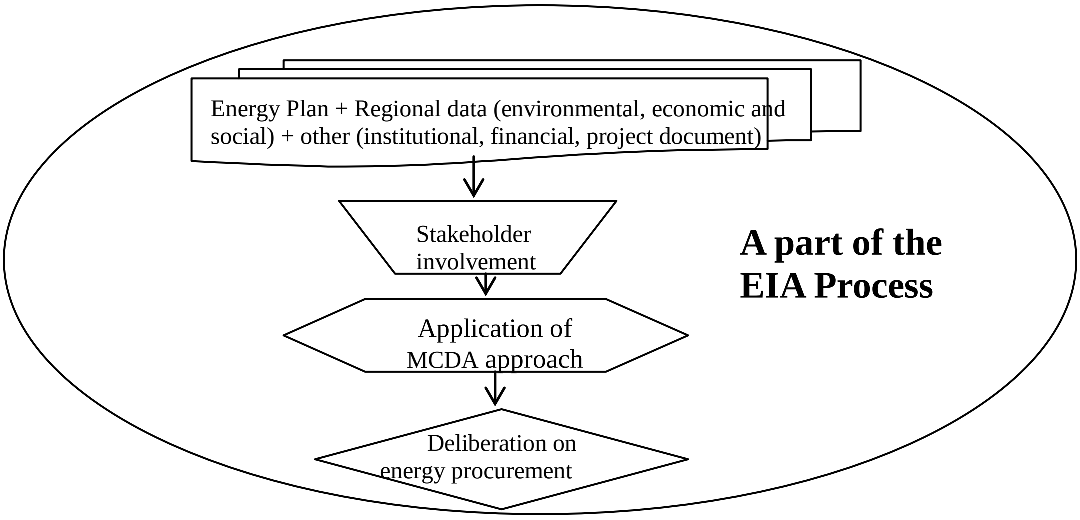

Fig.1. Conceptual model for renewable energy procurement planning within the EIA process.
Source: adapted from [10]

The data includes, inter alia, local energy plan. Tyskeng's [35] study on the Swedish local energy plans reveals that they discuss goals concerning oil reduction and reductions and/or restrictions on CO_2 emissions from a regional and local perspective, and also the use of different energy resources from both regional and local standpoint, energy efficiency, sustainable societies and biodiversity. Subsequent to the collection and assessment of data, the stakeholders need to be identified. The stakeholders consist of several people associated with planning, energy experts, public and statutory consultees, and "have the legitimate responsibility to participate and/or add a socio-political dimension to the decision-making process" [10]. During this stage of the model, it is also important to establish a "planning platform" for incorporating the socio-economic aspects of energy systems in conjunction with their technological attributes [12]. MCDA approach can facilitate the formation of this platform.

2.2. Multi-criteria decision analysis (MCDA) approach and group deliberation

Given the level of conflict that exists between criteria adopted for decision-making (DM), or the intensity of the debate between different stakeholders on the relevancy and the importance of different criteria, tools that seek to facilitate the deliberation and DM process are highly essential. MCDA approach is an umbrella term to describe such tools or methods that take into consideration multiple criteria and assist individuals or groups to explore decisions that matter [22]. It intends to “allow for a pluralist view of society, composed of diverse stakeholders with diverse goals and with differing values concerning environmental changes” [17] and can be an aid in making better decisions. An advantage of adopting MCDA is that it can simultaneously evaluate a number of alternatives, referring to an array of perspectives [11]. In the conceptual model (Fig.1), the MCDA approach has been proposed. However, the various methods that could be used under the MCDA approach needs to be further elaborated. These methods should be such that it can be easily accommodated within the mechanism of EIA integrated with GP. Also, it has to be noted that MCDA is not the only tool that could be used within EIA. There are several other tools such as geographical information systems and life cycle analysis that could be used within EIA (and in certain cases together with MCDA) [23,36]. Further, as Richardson points out, together with stakeholder participation in environmental assessment, there is a need to consider the ethics of practice [37]. *The stakeholder group deliberation on energy procurement, which is the last stage in the conceptual model, should evolve considering, inter alia, ethics and sustainability objectives.*

2.3. The role that the construction sector (CS) could play

The legitimacy of RE technology is a key issue, and might involve a political struggle between the new innovation system and the established one. Such a struggle calls for the participation of politically and financially strong actors, who can have a major influence on the innovation process. These actors can be called prime movers [29]. The CS could be ‘prime movers’ in promoting RE diffusion and development. Prime movers perform four crucial tasks to promote new technology: create awareness, plan and undertake investments, ensure legitimacy and diffuse the new technology. The new technology here refers to new renewables such as wind power and bioenergy that have not yet reached a wide spread market [25]. Carlsson and Jacobsson [38] indicate that if the consumer/user firms possess significant problem-identifying and problem-solving capabilities in the field of new technology and systems integration, then they can facilitate in strengthening the supplier industry. They noticed this type of user-supplier linkage in the system for factory automation in Sweden. The users in this Swedish factory automation example have been argued to be prime movers [25].
The CS as one of the large energy users would need to strengthen its link with the energy suppliers. Considering their financial and political capacities, the CS could contribute to the diffusion and development of RE. However, the influence of managerial concerns and stakeholder pressures play an important role in the contractors’ green innovation [39]. Prime mover may also be cluster of actors if several actors share an interest in promoting a new technology [25]. *Thus, future research should identify other actors for this cluster and investigate the ideal conditions and framework for such a cluster to function effectively*.

3. Discussion

The synthesis of GP and EIA is novel and not a simple task. The conceptual model (e.g. Fig.1) that has been proposed and presented in this paper is a GP planning process that can be accommodated within the EIA process. However, the future questions and challenges are concerned with a strategic mechanism, that is where and how in the EIA should this synthesis with GP occur. EIA has three phases: predecision, post decision and transition [40]. The phase that is of particular interest in the future study is the predecision phase, which involves designing, developing the EIA report, its review and decision-making. The predecision phase could provide the necessary space for RE planning, and this needs future investigation. The effort towards the synthesis of energy inclusive GP and EIA also requires sufficient scope in the local energy plans prepared by the municipality. So the objectives concerning RE in the local energy plans have an impact on the link between energy inclusive green procurement and EIA, which needs to be investigated further. If the CS through the synthesis of GP and EIA is able to push the development of sustainable energy systems, then it has not only demonstrated its role as a prime mover but also intervened with the issue of urbanization. Being a significant contributor to the process of urbanization, the efforts towards transitioning to a sustainable energy system is not optional, but an inevitability for the CS.

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Renewable Energy in Flanders. Current Situation, trends and potential for spatial planning

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Abstract: In its energy policy, the European Union (EU) sets the target of a 13% share of renewable energy sources (RES) for Belgium. Several instruments have been implemented to reach this target. The objective of this study is analyze those instruments and it effectiveness and efficiency. To tackle this objective, we first analyze the current status of RES in Flanders. Second, we compare the situation in Flanders to the national situation in Belgium and to the other EU member states. Then, we analyze the potential of each type of RES. Finally, we discuss the opportunities and problems of RES related to spatial planning.
In Flanders, the main application of renewable energy is electricity production, of which the main source is biomass. An aspect of the Flemish energy policy worth mentioning is the green certificate system, which has stimulated the development of renewable energies. However, a greater effort to regulate this market and to decrease the cost of kWh produced has proven to be necessary.
The RES-electricity share of total consumption has increased by 3.2% between 1994 and 2008. But, compared to others EU countries, the share of RES to gross inland consumption in Flanders is small. Large-scale facilities are necessary to reach the EU targets. The development of large wind, biomass and solar projects is suggested as the preferred option for Flanders.

***Keywords:** Renewable energy sources, EU Policy, Spatial planning, Flanders*

1. Introduction

The term 'renewable energy source' (RES), which is closely linked to sustainable development, is defined as any sustainable resource available in the long term in a simple long-lasting manner, found at a reasonable cost and applicable for any task without causing negative effects [1,2,3]. Several technologies are available for the production of clean, efficient and reliable energy from long-term renewable resources, such as wind, sun, water, biomass and biogas, tides and waves, hydrogen and geothermal energy [1,4].

Worldwide development of RES is currently limited by the high cost for development and implantation, uncertainty on local impact, insufficient funding for research and poor institutional and economic agreements, and limited availability of technological and economic know-how [5,6]. These problems can be solved by technical, economic, market, social and institutional means [2,6], but mainly through policies that incentivize and improve RES access to the power market [1,7].

The annual business volume of the renewable energy market in the European Union (EU) is 15 million €, equivalent to half of the world market, in which the EU is a leading exporter [8]. Furthermore, the EU is the second largest power market in the world (450 million consumers), but the contribution of RES continues to be relatively small, only 6% in 2000 [9,10]. In this context, at the proposal of the Commission, the European Council approved the so-called 20-20-20 goals [11,12]. The RES goals are 20% of EU energy consumption from RES and an increase in the share of biofuels to 10% of the transport fuel mix consumed in the EU by 2020. The EU target set for Belgium is an RES share of 13% [13]. The Belgian National Action Plan, published in November 2010, establishes the Flanders targets related to EU targets and the strategies to reach it in this sense.

The purpose of this study is to analyse the instruments implemented in Flanders to reach the EU RES target, and their effectiveness and efficiency. The analysis was done using available statistical data, and improved by interviews with a large number of people related to renewable energies in Flanders.

2. Renewable energies in Flanders

Solar water heaters, solar panels and wind turbines are becoming well established [14]. However, Flanders produces a lot more renewable energy from many lesser-known sources, such as biomass, biogas and even from waste. In the last years, the energy from wind and sun went through a larger development than the others types (Table 1). In Flanders, the main application of RES is electricity generation, and two-thirds of this comes from biomass [15].

Table1. Renewable energy inventory of Flanders (2005-2008).

Green electricity production (TJ) (net)	2005	2006	2007	2008
Hydropower	8.2	7.5	9.9	13.0
Wind energy	556.0	855.0	1,013.0	1,198.8
Solar (PV)	4.7	11.2	20.0	120.3
Waste incineration	574.3	749.5	922.0	961.6
Biomass	1,537.5	2,904.5	3,033.0	3,942.2
Biogas	800.7	624.2	907.5	954.4
Total green electricity	3,481.3	5,151.8	5,905.4	7,190.3
Gross electricity consumption (GEC)	210,327.8	216,441.1	217,430.6	215,960.9
Net green electricity / GEC (%)	1.7	2.4	2.7	3.3

Green heat production (TJ)	2005	2006	2007	2008
- by CHP plants		2,153	3,074	3,252
- by plants that produce only heat		6,446	6,704	6,960
Total green heat production		8,598	9,777	10,213
Total heat		503,266	466,569	486,359
Green heat / total heat (%)		1.7	2.1	2.1

Biofuels consumption (TJ)	2005	2006	2007	2008
Biofuels for transport	0	0	1,996	2,179
Total road transport consumption	176,477	176,462	179,030	180,630
Biofuels / energy consumption in road transport (%)	0.0	0.0	1.1	1.2

The Flemish Energy and Natural Resources Policy of 2004 and 2009 stipulated that by 2010, 25% of the electricity supplied in Flanders had to be generated by RES and cogeneration. Specifically, for renewable energy from wind, biomass and solar, the energy policy defines a 6% target of. The remaining 19% must be generated by Cooling Heating and Power Plants (CHP) [16]. The current government (2009-2014) decided to continue this policy until a new target for 2020 was drafted. Flanders finalized its Action Plan, and integrated it, and in consultation with the Federal Government, it was also integrated in the action plans of the other regions.

For the Flemish Government, biofuels are not a priority due to current problems with their production and their impact on agriculture, biodiversity, forests and land use changes. The

Flemish Government is looking for other alternatives and new advances in the production of second and third generation biofuels.

2.1. Location of Renewable Energy Facilities in Flanders

Wind turbines, especially large-scale, are usually located near urban or industrial centres, ports (Bruges, Gent and Antwerp) or larger-scale infrastructures such as highways and railways. Most wind turbines have been installed in the provinces of West Flanders, East Flanders and Antwerp. A map of potential areas for installation of future wind energy turbines in these provinces are shown in Figure 2 (in brown). Note that not all wind turbines (in yellow) are currently installed in these potential areas.

Large-scale biomass facilities (in green in Fig. 2) are mainly located near ports (Gent and Antwerp), because most resources required for biomass energy production are imported from other countries, mainly from France. In Limburg, plentiful agricultural resources available led to the installation of small and medium-scale facilities.

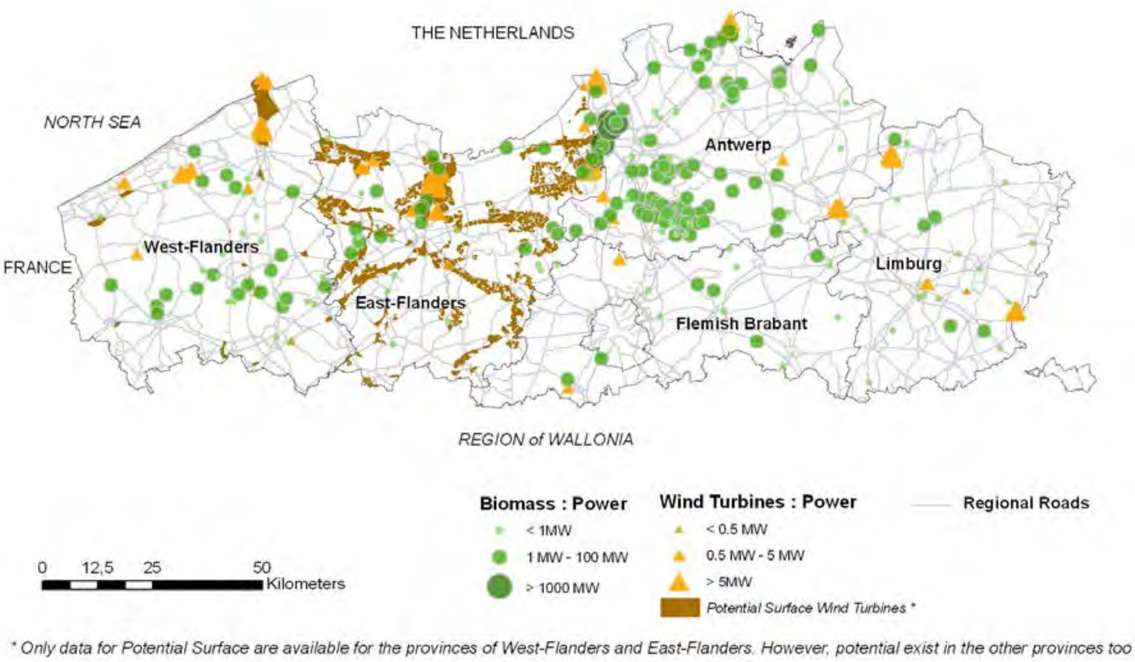

Fig. 2. Location of wind and biomass energy facilities in Flanders.

2.2. Green Electricity

The share of electricity from RES in total electricity consumption has increased to 3.3% in 1994-2008. Absolute values increased from 58 GWh to 1,997 GWh by 2008. According to the Flemish Energy Agency [14], 2,688 GWh of electricity were produced from green energy sources by 2009 (4.8% of total electricity consumption).

In 1994, the electricity from waste incinerators was the main source (Table 2), but in the last five years, the majority of green electricity comes from biomass [14]. Wind power was the second main source in 1994-2008. Although hydropower increased during this period, its share in the total electricity consumption has decreased.

Table 2. Evolution of the share of green electricity in total electricity consumption (1994-2008)

%	1994	1996	1998	2000	2002	2004	2006	2008
Biomass	-	-	-	-	21.8	31.1	56.4	54.8
Wind	15.6	11.6	8.8	9.1	17.1	15.2	16.6	16.7
Waste	78	69.2	77.9	77.4	42.5	21.6	14.5	13.4
Biogas	3.6	16.1	11.9	12.1	17.7	31.8	12.1	13.3
Solar	-	-	-	0.1	0.2	0.1	0.2	1.7
Hydro	2.8	3.1	1.4	1.3	0.8	0.3	0.1	0.2

In absolute terms, green electricity from biomass, wind, solar and hydro energy increased 1,331 times during 2002-2008. Biomass has been responsible for over 80% of green electricity since 2004, especially the selectively collected waste biomass (Fig. 3). In 2009, the electricity generated by biomass (2,160 GWh) represented 80.4% of the total amount of RES-electricity (2,688 GWh).

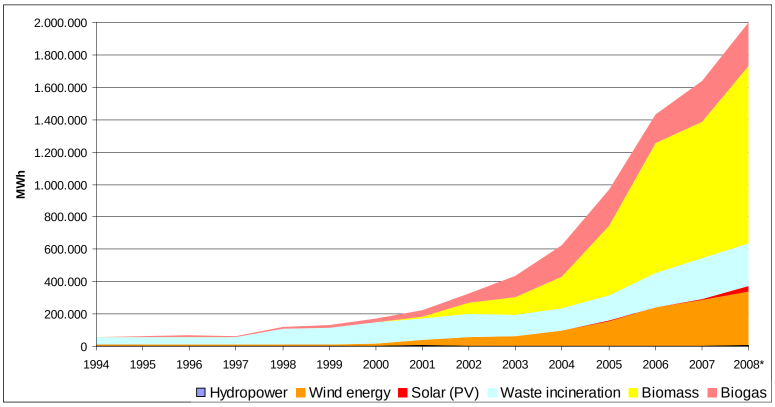

Fig. 3. Evolution of green electricity in Flanders from 1997 to 2008[16].

The largest increase was experienced by electricity from solar energy (6.7 times), but by 2008 it still only represented 1.7% of the total amount of green electricity. Wind energy, which provides almost 17% of the total green electricity production, increased by 750% in 2002-2008 (Fig. 3). In 2009, electricity from solar energy increased steeply to 138 GWh of the 2,688 GWh total green power produced (5%). Almost 3 million m² of solar panels for electricity production were installed. Moreover, 100,000 m² of solar collectors for heat production supplied sanitary water heating for 25,000 Flemish families.

2.3. Green Certificate System

The Flemish Region launched a Green Certificate System (GCS) on 1 January 2002. There are two kinds of green energy certificates, compulsory and optional EUR [14]. From 1 January 2002, all electricity suppliers are required to sell a minimum amount of energy from renewable sources. Strong growth of Flemish RES electricity generation from 0.8% of electricity sales in 2002 to 4.9% in 2007 brought the 2010 6% target within reach (Verbruggen, 2009) [17]. The number of Green power certificates issued in 2002-2007 has increased almost 18 times. The technology with the largest increase is PV, from five certificates in 2002 to 139,489 in 2009. This success is a consequence of high certificate prices in the first years of the system. The number of energy certificates decreased last year due to their lower prices (2,692,904 in 2009 and only 929,792 as of July 2010).

The GCS works better than traditional subsidies and is a relatively good option for developing renewable energies. The system achieved relatively good results right from the start, especially in promoting the installation of wind turbines and PV solar panels. However, the overall performance of the Flemish support system (effectiveness, efficiency and equity) is assessed as poor, despite its good short-term targets, costs and profits [17]. Moreover, there are no clear transition trajectories to a sustainable power system, and RES electricity generation from old waste-processing facilities is of dubious quality (effectiveness). Moreover, dynamic efficiency is spurious because there is no link to a technological industrial policy (efficiency). Finally, the polluter-pays principle is not respected, but jeopardized in the waste management sector (equity).

3. Flanders and EU Benchmarking - Main Indicators

Denmark, Sweden, Finland, Germany, the Netherlands and Austria all made a great effort to reach their EU targets. Flanders had only a of 1.7% share of green electricity from RES in its total electricity consumption by 2005 (Fig. 4), and was still far from reaching the EU target (6.0%) for 2010. However, the whole country of Belgium had a 2.8% share by 2005, and if past performance could be continued in 2005-2010, the EU target would be reached by 2010 (5.3% in 2008).

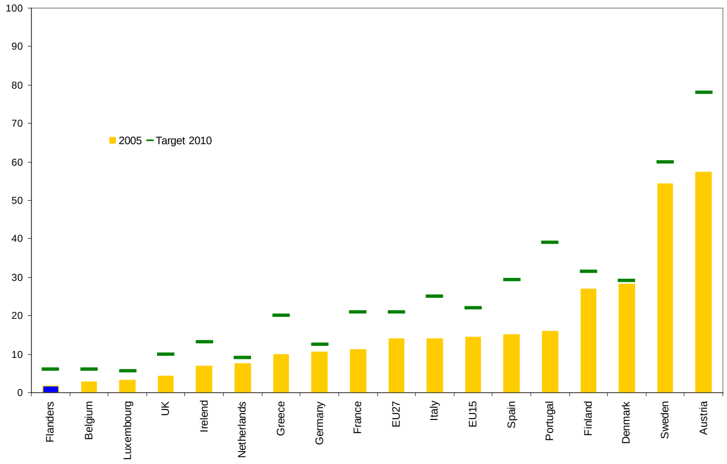

Fig. 4. 2010 EU electricity targets vs. 2005 green electricity production in Europe and Flanders (%).

The share of RES in Gross Inland Consumption in Flanders is small compared to the other EU countries. The relative share of RES-electricity in Flanders is half the relative share of all of Belgium. This means that the Walloon Region produces roughly 3 times more electricity from RES than Flanders. According to some experts interviewed in this study, this difference between the two regions is explained by the greater availability of biomass resources in the Walloon Region. Moreover, the relative Flemish share is only larger than the relative share of Estonia and Cyprus. In spite of this, the significant increase in its share from 0.21% in 2004 to 1.22% in 2007 highlights the effort made by the Flemish Government.

Of the different RES, biomass is the largest in both Flanders and all of Belgium. The share of biomass in Flemish RES production (82.3%) is the second largest in the EU after Hungary. The share of wind energy in Flanders is also relatively large (17,2%), and close to the EU27 share (19.8%). Electricity production from other sources (hydropower, solar and geotechnical) makes up less than 1% and is relatively insignificant.

4. Analysis of the Opportunities and Problems related to Spatial Planning

In the Flemish Region, the development of large-scale energy facilities is mainly limited by its high-density population and related factors, such as concentration of cities and infrastructures (roads, railroads, housing, factories, industrial areas, etc.). Other restricting factors are landscapes values, relief (mainly in hydropower facilities), monuments, natural protected areas, air-restricted areas, and so on. Finally, the aesthetics of renewable energy facilities is an important factor related to public acceptance.

The "Projections on renewable energy and cogeneration to 2020" study [18] examined the potential of different technologies (electricity, heat and biofuels), and compared a business-as-usual scenario (BAU) with a Pro-active policy (PRO). The Flemish Government used the calculated potential in the PRO scenario in its Energy Plan (Table 3).

Table 3. Potential of renewable energies in Flanders.

Technology	2010 (GWh)	2020 (GWh)	Increase (%)
Wind onshore	521	1,905	265
Wind offshore	320	3,841	1,100
Solar energy (PV)	174	935	437
Solar thermal	224	1,193	433
Biomass plants for electricity production	97	217	124

In order to realise the potential of renewable energies in Flanders, the surface required for the installation of new facilities is calculated as follows. To reach the target of 1,000 MW, 300 new 2.5-MW wind turbines (+750 MW) are necessary. Since the current legislation prescribes a minimum buffer distance of 250 m from any dwelling (radius = 250m → area = 20 ha), a surface free of housing of 6,000 ha is required.

To reach the proposed 935 GWh by 2020, VITOº assumes that the efficiency of solar panels will improve from the current 110 kWh m^{-2} per year to 170 kWh m^{-2} per year. Therefore, an additional 800 ha are necessary to install the required panels. An increase in surface of 300 ha for installing solar water heaters is desired by 2020. However, the installation of PV and thermal panels does not require the acquisition of new land, which makes it a good option.

The main environmental problems related to biomass and CHP facilities are the emissions of greenhouse gases (GHG) and the effect of noise and smell, in addition to the visual impact. Therefore, rural areas are the most suitable for the installation of biomass and CHP facilities. For such an installation, the availability of resources and connection to the power grid are essential. Heat facilities have been observed to be the most used in the rural areas. A regulation related to the use of biomass sources (especially pellets) is needed.

Wind turbines have been installed near large structures, such as industrial areas and highways, and near high power grids. The choice of such locations helps reduce the visual impact and the problem of the noise of wind energy turbines. Most past installation projects were medium or small scale (3-4 turbines) because of existing limitations (mainly the available surface). Nowadays, small wind turbines are considered inefficient. The Windplan for Flanders was launched in 2001.It includes potential areas for the installation of wind turbines according to their wind potential way, the provinces of West Flanders, East Flanders and Antwerp made a more advanced multiple-criteria map of potential areas for the installation of wind energy turbines (residential and industrial areas, protected landscapes, agricultural areas, recreational areas). However, these areas are only designated as suitable, and the map is not legally binding.

The installation of solar panels (at small and medium-scale) has seen a boom in the last year, mainly due to its promotion by the GCS and benefits for private promoters. PV panels are the most widespread. The installation of large-scale projects in Flanders (4-6 ha) is generally restricted by the limited availability of surface. The most suitable area for the installation of solar panels in Flanders is the North Sea coast (West Flanders Province). East of the Flemish region, the potential is reduced due to the proximity of higher lands and increased presence of clouds. Belgium is now the 6th most solar PV- intensive country in the world (defined by km^2 of solar panels).Price is the main limiting factor for installation of solar panels. Arestricting technical factor is the shadowing by nearby buildings. Around a 20% shadow on one solar panel suffices to stop the energy production of all the panels connected in the same loop.

5. Conclusions: Trends and Future challenges of RES in Flanders

The electricity generation is currently the main application of renewable energies, while heat production (from heat pumps, wind, geothermal, solar) has the highest potential for further application and development in Flanders. There are currently no concrete projects for developing geothermal energy. Should this be reconsidered, more effort by the regional government will be needed to develop this type of RES in the coming years.

The Flemish Government promotes RES through their green certificate pricing policy. First, wind facilities were promoted, followed by PV installations, and more recently biomass and CHP installations. With theses mechanisms, the Flemish Government strives to reach the EU 20/20/20 energy targets. However, a stronger effort to regulate the green energy market and to decrease the cost of kWh produced is necessary, because there are no clear transition trajectories to a sustainable power system. This situation requires broad agreement between the government, the power industry and the public. The RES market potential may be substantially increased by means of dedicated policies, implemented after consensus, such as, a better qualification system, different subsidies, levies and taxes to shift market prices, lowering the cost of RES, or helping abolish man-made barriers through technological innovation. But support for the development of RES through a modified or better GCS must continue in order to reach the EU targets and real sustainable development.

Benchmarking of relative Flanders and EU RES and RES-electricity consumption indicators shows that most of them are low. Despite this, increase in recent years has been significant and highlights the effort made by the Flemish Government.

Concerning spatial planning, the search for available suitable areas to install such facilities must be a priority for renewable energy policy makers. Ports, highways and industrial zones are priority areas for the installation of wind energy facilities. However, a more participatory approach for the development of renewable energy facilities is necessary, especially for the construction of wind turbines.

The large increase in PV solar energy production is accompanied by problems between producers and distribution companies, and further regulation is required in this field. In addition, a better distribution grid is needed, since the current grid is not well adapted to receive all the renewable energy produced.

In addition, the specific potential and conditions of each individual region should be considered when setting regional prices for green certificates, and installation of renewable facilities in areas with lower potential should be promoted (e.g., wind energy in Brabant-Flanders and Limburg). These measures would help decentralise energy production, bring production closer to consumers and avoid grid losses from long-distance energy transport.

Finally, better regulatory framework co-ordination between governmental departments and the energy is required for the EU, Belgian and Flemish targets to be met.

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Sustainable Cities: Strategy and Indicators for Healthy Living Environments

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Abstract: The impact of climate change on our cities has been clearly manifested. Cities do not only consume most natural resources but also produce air pollution and generate great amount of waste and waste water. This paper focuses on sustainable cities strategies and indicators for the case of Santa Monica city, US using a set of 29 sustainable indicators for some years 1990-2006. The study sheds light on the application of some sustainable development (SD) indicator and suggests more applicable and specific data to further examine other cities sustainable programmes. The six thematic dimensions: sustainable, economic, equitable, social, viable and livable, where 62% of the 29 indicators are presented. Indeed, the review of some of the 29 indicators for Santa Monica shows the various levels of SD before and after the Sustainable City Program (SCP).

Keywords: *Sustainable Cities, Strategies, Sustainable Development Indicators, Santa Monica.*

1. Introduction

Over the past century, cities and towns using various urban systems were developed and built in inefficient ways based on traditional ways of activities and life styles. Consequently, such models drove production and consumption of resources inefficiently. Indeed, the urban sprawl is an urgent and persistent problem when world's natural resources are scarce and pressured by human settlement. Moreover, such pressures particularly related to carbon emissions in urban areas/ cities involve power generation, transport, and waste. Nevertheless, creating buildings and designing cities is one of the most complex and sophisticated tasks.

Cities pressure natural resources and consume large amounts of energy and water as well as emitting air pollutants and generating waste. All these activities pose potential risks to our economic, health and environmental wellbeing and the prime global concern at the present time is the effect of human activities upon climate change particularly related to urban areas. Several studies published by the United Nations Habitat showed that in 2007-2008 a major shift occurred where more than half the world's population was classified as urban dwellers [1,2,3]. Globally, the number of people living in towns and cities at the end of 2008, was estimated at 3.3 billion and this is expected to increase to five billion by 2030 [4,1]. However, the main challenges to such increases are the pressure on natural resources as well as utilities such as on energy, water as well as waste management and mobility. For instance, the recent United Nations Environment Programme (UNEP) data on global energy demand suggested that nearly 45 percent will increase by 2030 [5].

It is vital to efficiently plan our cities to be sustainable by developing strategies and policies to promote sustainability. Significantly, capturing sustainable development indicators at local as well as global levels is relevant since the climate changes and pollutions are global problems. Moreover, emphasis should be stressed when it comes to cities' consumption patterns and their impact on other neighboring regions and ecosystems. Also, the accountability and responsibility for all stakeholders to assist in monitoring consumption patterns and addressing the requirements for a sustainable city is needed. Additionally, adaptive policies to reduce, recycle and re-use consumer goods are important strategies for cities to achieve sustainability pathways [6]. As shown in Table 1, the list depicts some of the sustainable cities according to sustainable city network (SCN) 2007-2011 [7].

Table1. List of Sustainable Cities

Australia & Pacific	Americas	Europe
Adelaide	Ottawa	Berlin
Ballarat	Vancouver	Bristol
Maleny	Niagara	Cambridge
Melbourne	Florida	Geneva
Auckland	Greensburg	Malmö
Wellington	Moraga	Rotterdam
	Santa Monica	Stockholm
	Philadelphia	
	Tuscon	
	San Francisco	
	San Jose	
	Seattle	
	Silicon Valley	
	Bogota	
	Chiapas	
	Curitiba	

In the next sub-section namely sustainable indicators (1.1), we discuss briefly some components of such strategies which some cities have integrated in their mandate to become sustainable.

1.1. Sustainable Development Indicators (SDI)

According to Tanguay, et.al (2010), sustainable development indicators (SDI) are used intensively to illustrate sustainable development pathways particularly applying actual assessment and monitoring systems [8]. The authors also argued that the exploitation of the SDI remains problematic because of general definition of sustainable development as outlined in the Brundtland report (WCED, 1987). SDI varies from one place to another but the main components are listed in Table 2. SDI variation in the present time compared to say twenty years ago can be attributed to the priorities set in meeting the environment, social, economic, political and technological objectives of the local and regional needs. A case in point is in the EU where new and old member countries are requested to revise their National sustainable development strategies (SDS) in line with the renewed EU SDS which is likely to increase the degree of cohesion in defining and monitoring SDIs. As mentioned previously, SDI can differ at local levels but must also be analyzed from a global perspective.

Table.2. Indicators used to measure the sustainability of a city

▪ Sustainable Development Policy & Practice	
▪ Biodiversity	
▪ Climate Change	▪ Social Issues
▪ Energy	▪ Pollution
▪ Environment	▪ Urban Development
▪ Planning	▪ Construction
▪ Transport	▪ Waste Management
	▪ Water

Moreover, sustainable cities may vary due to the countries or regional sustainable strategies. Take the case of US where according to the latest report by the Sustainable Cities Index (SCI) the sustainable cities namely the City of Portland, Oregon, were analyzed according to four major indicators: clean technology, green building development, overall quality of life, and sustainability planning and management [9]. In the case of UK cities, the assessment focused less on the equitable dimension. For Europe, cities can and should not only be highly resource-efficient but also safe, healthy, pleasant, fulfilling and inspiring places to live. Based on a strategy paper (2007–2013) by the European neighborhood and partnership, it concluded that at city level, the local strategies for sustainability require active participation and commitment of the local community who can provide effective actions [10]. Moreover, the challenge for Europe's cities to achieve sustainability objectives their governments must allow cities maximum freedom to apply suitable tools at local level [6]. Indeed, indicators are increasingly developing into a vital tool of communicating information to decision-makers and the public in a straightforward and robust manner.

The motivation of this paper is to review several indicators that measure sustainability of cities by examining one case study found at a local level in the United States. Our attempt is to illustrate the practical application of such indicators at the local levels. In fact, the need to measure sustainable development (SD) is based on robust indicators or evaluation criteria [8]. The comparison of theoretical and practical approaches is essential in illustrating the robustness of such criteria.

In this vein, Shen et al. (2011) point out that among the available urban sustainability indicators there are no single set of indicators equally suitable to all cities or communities. They further suggest the use of consistent indicators for monitoring and comparison purposes due to the fact that such indicators will allow cities to have a common grid to share and apply successful tools and measures [11]. Zhang, He, and Wen (2003) recommend that for urban sustainability indicators (USI), in other words, city sustainable indicators should offer no less than: a) explanatory tools to translate the concepts of sustainable development into practical terms; b) pilot tools to assist in making policy choices to promote sustainable development; and c) performance assessment tools to decide how effective efforts have been established [12]. This paper is outlined in 4 parts: introduction as presented above, section 2, methodology and sub-section focusing Santa Monica city as a case study. Section 3, presents the results and discussions of the application of sustainable development indicators for the case of Santa Monica, and section 4 concludes.

2. Methodology

Many models address sustainable cities in different taxonomies. However, strategy and policy, and appropriate assessment tools at national planning levels should be firmly developed and implemented to improve the key indicators in order to ensure cities are sustainable at the local levels. In Moussiopolous et al. (2010) study, they developed a dynamic tool for the management of environmental, social and economic indicators to evaluate sustainability in urban areas. In their study, the case study of Greater Thessaloniki Area, in Greece was selected with a set of indicators included 88 indicators in 13 discrete thematic areas. Additionally, guidelines were recommended for developing communication among local stakeholders [13].

Shen et al. (2011) critically examined and compared different sustainable urbanization practices when selecting urban sustainability indicators [11]. They further stated that measuring sustainability in urban areas requires strong local socio-economic development and the key challenge for environmental managers and decision-makers is environmental decay. They further caution that indicators selected should be the ones that are essential and likely to produce the most accurate information about the status of practice. Tanguay et al, (2010) defined a number of SDI derived from 17 studies showing diverse conceptual frameworks and choices. In their study, a method, called SuBSelec, where 188 indicators extracted from the aforementioned 17 studies and reduced to 29 SDI. The SuBSelec strategy produced a new perspective to the debate related to the SDI selection. This is seen as a preliminary step aimed for planners and decision makers where a scientifically based and operational SDI Grid is established [8]. The authors acknowledge the subjective nature of this approach and believe that the classification allows the selection of recognized indicators which covers the various aspects of sustainable development broadly. Additionally, their conclusion is similar to Niemeijer and De Groot (2008) in that selection of indicators is invariably subject to arbitrary decisions at one phase of the process or another [14]. Such analyses demonstrate that current practices related to SDI cannot meet standard objectives and the need to obtain indicators which reflect local concerns.

In this study we follow the approach suggested by Tanguay et al. (2010) namely, Survey-based selection strategy (SuBSelec) which refers to 29 indicators divided into six dimensions: sustainable, liveable, equitable, social, economic and viable, for a given city [8]. The focus of next sub-section is to review and compare the Santa Monica Sustainable City Indicators (SCI) as found in SCP to the sustainable development indicators (SDI) given by these authors.

2.1. The case study: Santa Monica

In early 1990's the Santa Monica City Council took bold steps to address sustainability issues in the community adopting a Sustainable City Plan [15]. The Sustainable City Program (SCP) was initially proposed in 1992 by the City's Task Force on the Environment to ensure that Santa Monica could continue to meet its current needs–environmental, economic and social without compromising the ability of future generations to do the same. Such a programme comprised goals and strategies, for the City government and all sectors of the community. As shown in Table 3 (see Appendix) eight indicators' dimension with their respective categories were defined by the SCP. Indeed, the primary reason of selecting this city is because it boasts of comprehensive history to examine and discuss at local level. In reviewing the SCP, a span of several years ranging from 1990 to 2008 was selected, depending on the availability of data. In Table 4 (see Appendix), each indicator and the eight SD dimensions are depicted with the relevant notes for various years. It should be noticed that some indicators were not applied to all. For the comparison purposes the ratio between the years 2000 and 1990 were set to 1 for relative changes but not in absolute terms, this is because in some cases few years were not for 2000 and 1990 as explained above.

3. Results and discussion

This section exhibits the six dimensions: sustainable, economic, equitable, social, viable and livable, where 62% of the 29 indicators are presented. Indeed, the review of some of the 29 indicators for Santa Monica shows the various levels of SD before and after the SCP.

Fig.1 and Fig.2, illustrate the sustainable and economic dimensions respectively where in the year 1990 and 2000 greatly differs, where in 1990s the sustainable and economic situations were less than the year 2000. For the equitable dimension (Fig.3), it exhibits a better performance in 2000 compared to that of 1990 in terms of low crime rates and poverty levels. In Fig.4, the citizen participation increased nearly twice as those in 1990. Also, the rate of participation in municipal elections has slightly increased.

The viable dimension as shown in Fig.5 exhibits this dimension in terms of quantity of waste recycled. In this dimension, the ratio increased from ratio 0.2 (1999) to 1 (2000). This can be attributed to number of waste produced and/or the increase in technology in recycling such waste.

For the livable dimension as shown in Fig.6, both indicators the GHG emission and household waste in 2000 have increased compared to 1990. This maybe explained due to increase in populations or socio-economic activities during this time. Again, the indicators are subjective particularly when population and other economic variables are not considered in the picture.

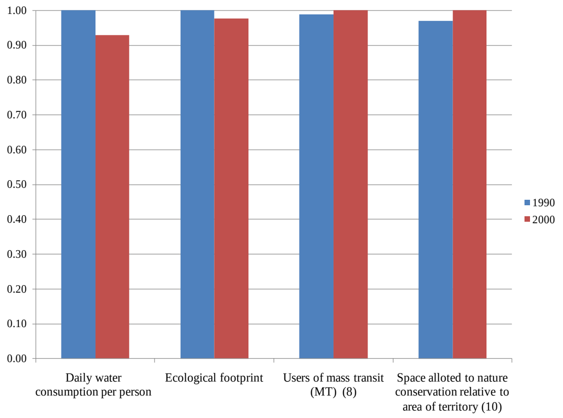

Fig.1 Sustainable Dimension

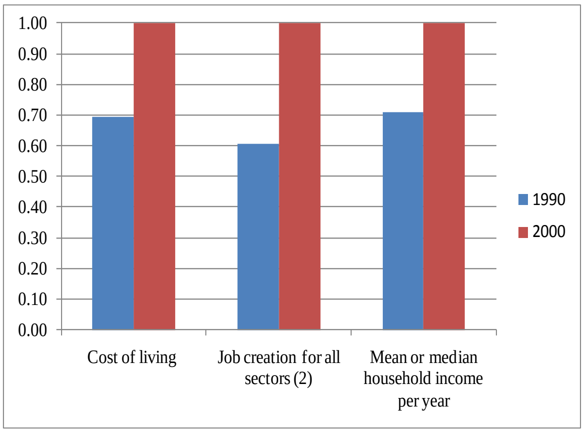

Fig.2 Economic Dimension

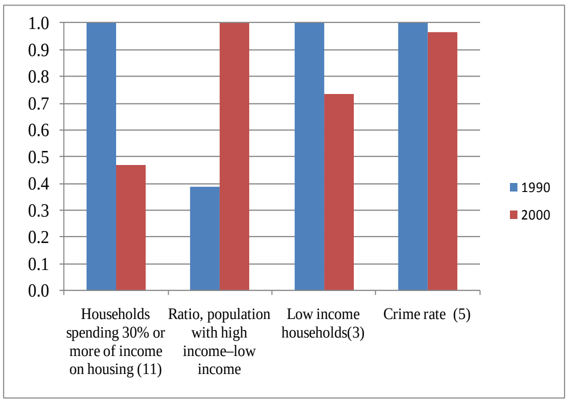

Fig.3 Equitable Dimension

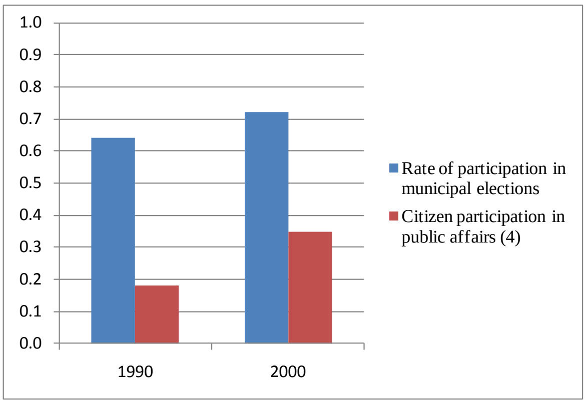

Fig.4 Social Dimension

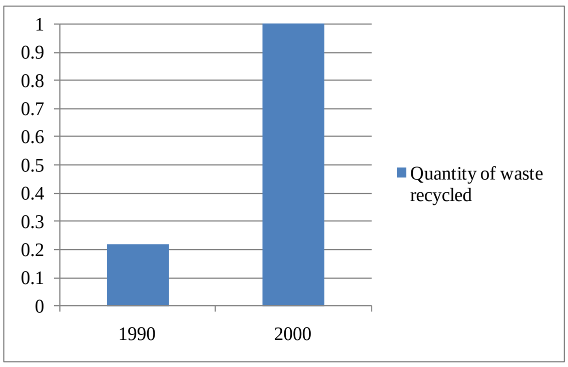

Fig.5 Viable Dimension

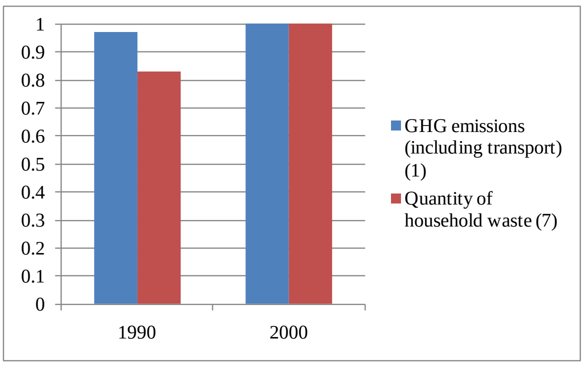

Fig.6 Livable Dimension

4. Conclusions

In this paper, we had used the case of Santa Monica city to review 29 indicators as suggested by Tanguay et al, (2010). The case of Santa Monica has demonstrated that the six thematic dimensions of sustainable development are not sufficient to measure the years between 1990-2000. This exercise suggests that continuous data collection needs to be exploited to assist the development and assessment of indicators to achieve their local sustainable objectives. Indeed, in most cases, these indicators are subjective they can be revised to vary from one city to another. Significantly, there is a need to identify the practical application of sustainable indicators at local levels. This can be a challenge at the present time in some cases, though these challenges can be overcome with the suitable indicators to address sustainability in the future.

Consequently, the development of an appropriate framework for a sustainable city requires a tailor-made model that considers the needs of the locals in the city at the same time meet the sustainable efforts of its participants. On one hand, there are advantages in establishing sustainable indicators but on the other hand, such a task is challenging as stated by Stiglitz et al. (2009) in a dossier [16]. This calls for urban sustainability to include all stakeholders within the local areas and devise appropriate tools and framework. Another challenge facing sustainable indicators is the access to local data available to public and various stakeholders' objectives in communities. In addition, the end-use activities in this case, consumption, which are strongly linked to CO_2 emissions and other pollutants, need specific local information. For instance, detailed data about industries such as manufacturing, oil and gas, roads and buildings in relation to sustainability at the local. Moussiopolous et al. (2010) highlighted one of the challenges in creating an efficient system of indicators is the selections of a manageable list of metrics to better describe sustainability. They further point out that developing indicators cannot be a purely technical or scientific process but should be an open communication and policy process [13]. In sum, it is recommended that future works include other cities in a comparison exercise using consistent sustainable indicators for the purpose of improving sustainable indicators for cities considering the socio-economic, political and environment conditions.

Appendix

Table.3. Description of sustainable dimensions found in Santa Monica progress report

Indicator dimension	Categories	Indicator dimension	Categories
Resource conservation	Ecological footprint	**Housing**	Affordable Housing
	Energy Use		Affordable Housing for Special Needs
	Green Construction		Distribution of Affordable Housing
	Green House Gases Emissions		Green Housing
	Renewable Energy		Livable Housing
	Solid Waste		
	Sustainable Procurement		
	Water Use		
Environmental and public health	Air Quality	**Transportation**	Alternative Fuel Vehicles - City Fleet
	City Purchase of Hazardous Materials		Average Vehicle Ridership
	Farmers' Market		Bike Lanes
	Food Choices		Bus Ridership
	Household Hazardous		Pedestrian - Bike Safety

	Waste		
	Local Produce at City Facilities		Sustainable Transportation Options
	Restaurant Food		Traffic Congestion
	Santa Monica Bay Health		Traffic Impact on Emergency Response
	Toxic Air Containment		Vehicle Ownership
	Urban Runoff		
	Vehicle Miles Traveled		
	Waste Water		
Economic development	Business Reinvestment	**Open space and land use**	Land Use and Development
	Cost of Living		Open Space
	Economic Diversity		Park Accessibility
	Income Disparity		Regionally Appropriate Vegetation
	Jobs - Housing Balance		Trees
	Local Employment of City Staff	**Community education/civic contribution**	Civic Participation
	Quality Job Creation		Sustainable Community Involvement
	Resource Efficiency of Local Business		Voter Participation
Human dignity	Ability to Meet Basic Needs		
	Basic Health Insurance		
	Crime Rate		
	Economic Opportunity		
	Education & Youth		
	Empowerment of Minorities		
	Homelessness		
	Incidents of Abuse		
	Incidents of Discrimination		
	Perception of Personal Safety		

Source: Santa Monica, Sustainable City Progress Report
http://www.smgov.net/Departments/OSE/progressReport/default.aspx.

Table.4. Application of Sustainable development indicators (SDI) for the case of Santa Monica

	Indicator	Description	SD Dimensions	2000	1990
1	SD policies or strategies	yes / no	Sustainable	1	0
2	Density of urban population		Sustainable	n.a	n.a
3	Daily water consumption per person	millions gallon per day	Sustainable	13.2	14.2
4	Ecological footprint	per acres	Sustainable	20.9	21.4
5	State of health reported by population (6)	percentage perception by	Sustainable	16%	n.a
6	Users of mass transit (MT) (8)	percentage of riders	Sustainable		9.10%
7	Space alloted to nature conservation relative to area	percentage of open space to	Sustainable	3.30%	3.20%
8	Cost of living	Cost living $ per household	Economic	79,890	55,300
9	Participation rate for all sectors		Economic	n/a	n/a
10	Job creation for all sectors (2)	number of jobs	Economic	2113	1283
11	Mean or median household income per year	Median household ($ / Yr.)	Economic	50,714	35,997
12	Households spending 30% or more of income on	% Percent of rent-controlled	Equitable	40%	85%
13	Population aged 18 and over with less than a high		Equitable	n.a	n.a
14	Unemployment rate		Equitable		
15	Ratio, population with high income–low income	ratio of high-low	Equitable	92.9	35.9

16	Population receiving social assistance		Equitable	n.a	n.a
17	Low-income households(3)	percentage of households	Equitable	25%	34%
18	Crime rate (5)	per capita crime rate	Equitable	4.35	4.51
19	Rate of participation in municipal elections	%	Social	72%	64%
20	Citizen participation in public affairs (4)	%	Social	35%	18%
21	Annual consumption of energy from renewable	%	Viable	18%	19%
22	Businesses with environmental certification		Viable	n.a	n.a
23	Quantity of waste recycled	tonnes per year	Viable	181,902	40,013
24	Concentration of PM10 particles		Liveable	n.a	n.a
25	GHG emissions (1)	per capita	Liveable	10.6	10.3
26	Population exposed to Lnigh>55 dB (A)		Liveable	n.a	n.a
27	Quality of waterways		Liveable	n.a	n.a
28	Quantity of household waste (7)	tonnes per year	Liveable	333,518	275,842
29	Participation in sports in parks & swimming pools (9)	% of households	Liveable	88%	n.a

Notes:(1) Including transport (2) here only for 2005 (19%) and 2006 (18%) data, here the job creation 2113 (2005), 1283 (2006 (3) less than 25,000K US (4) only for 2002, for the year 1990 without considering other attributes such farmer's market, pier's concert and festivals (5) only for 2006 (4.35%) and 2005 (4.51%) (6) only for 2002, for the other years undetermined (7) for 1995 (275,842) for waste and recycled for 1995 (40,013) (8) for 2007 (9.1) and 2008 (9.2) (9) for 2005 only, not participation but access (10) open space for parks, public gathering, green streets, gardens and other public places 2006 (3.3) and 2004 (3.2%) (11) for 1998 (85%) and 2008(40%).

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Semantic Link with the Natural Environment: Sustainable and Healthy Artificial Environments for Hot-Humid and Warm-Humid Climates

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Abstract: Architectural artificial environment; as a joint product of imagination and technical information and as a combination of ecological, social, political, aesthetical and moral values, is the balancing epistemological systematic for ecology, economics and society which comprises of the future generations and all other living creatures. In ecological architecture, it is essential to design artificial environment as an artificial ecological system. This study asserts regional principles for different climate zones and environmental conditions by determining environmentally-conscious general design principles of ecological and sustainable public housing design. The significance and authenticity devolved on ecological and sustainable public housings and settlements on local, regional and global scales are discussed. As a result, in the light of the foregoing information given on ecological and sustainable process model and climate-weighted ecological and sustainable social public housing design model, related suggestions are made.

Keywords: *Sustainability, Healthy Artificial Environment, Healthy and Sustainable Process Model.*

1. Introduction

In today's world, energy production and consumption are among the most important criteria for development. Since the biggest portion of daily activities occurs in the building, the number of buildings and the level of energy consumption are correlated. However, existing and newly-constructed buildings are the main reasons for some of the major problems of our present and future such as environmental pollution and exhaustion of natural resources. Especially in the 20th century, the effects of both industrial and technological power of mankind over nature have reached its highest levels, even to the extent that it might have destroyed the life on life as we know it.

Incidents such as global warming, thinning of ozone layer, glacier meltdown, diminishing of forest lands, air and water pollution, extinction of species, etc. indicate that today's life style is not only disappointing, but also far away from being an inspiration for the future. Especially, by considering imperative revision of the 20th century's life style, adoption and development of a life style with less energy usage in daily routine and guidance of the society toward that direction are necessary within the scope of interdisciplinary studies. In this context, architecture as an effective discipline for both nature and human life assumes fundamental duties. While human-centric design in architecture was subject to change, environmental consciousness and harmony with nature had become the main criteria for success.

Considering the usage percentages of global resources in buildings, housings clearly take place in life style of the 21th century's information society as prominent means for achieving ecological and sustainable objectives.

Table 1. The Usage Percentages of Global Resources in Buildings and The Percentage of Global Pollution Level caused by Buildings. (1)

Resource	2. % of Usage	Pollution	Relation to Building
Energy	50%	Air Quality (Urban)	24%
Water	42%	Global Warming Gases	50%
Materials	50%	Drinking Water Pollution	40%
Agricultural Areas	48%	Superficial Solid Waste	20%
Coral Reefs	50%	CFCs/HCFCs	50%

Historically, housing is an organized pattern of communication, interaction, space, time and significance. On the one hand, it reflects the characteristics, life styles, behavioral codes, ecological choices, images and time-space taxonometries of ethnic groups it belongs to, and on the other hand it reflects personality and concession of the individual via its users' essential images and propensity of self-expression (2). Housing, a by-product of settled living culture, has survived in different building forms as the result of different climate conditions, cultures in different regions. Artificial environment of traditional architecture had been an output of the balance of the challenge between nature and mankind. However, migration toward urban areas, due to labor demand of industrial system, attraction of urban life and various other factors have eventually disrupted that balance. Public housing became the solution for sheltering needs emerged due to industrialization, overpopulation and urbanization. However, as a result of new building materials, new construction techniques and over-consumption of resources especially with the misconception of cheap and seemingly inexhaustible fossil-based energy sources; hazardous wastes, environmental pollution and artificial environments that fail to meet the users' needs came into existence. Thus, today's housing acquisition policies have reached a turning point. The aim of increasing life quality of housing and environment is on the agenda, rather than the mere effort of providing a huge number of community members with housing facilities. Evidently, related studies and energy issues in accordance with mission they undertake are amongst the most important facts of the future.

2. Sustainable Society and Artificial Environments

Throughout the history, mankind had experienced mainly 3 revolutionary transitions: the first and the longest one; transition to settled life as an agricultural society, the second; the Industrial Revolution, and the third one; transition to an information society(3). Being an information society in the 21th century requires innovation and nurturing of new multi-disciplinary approaches and applicable models aiming for sustainable development for both present and future generations. Society / Economy / Ecology are 3 important components of Sustainable Society Structure (Fig. 1).

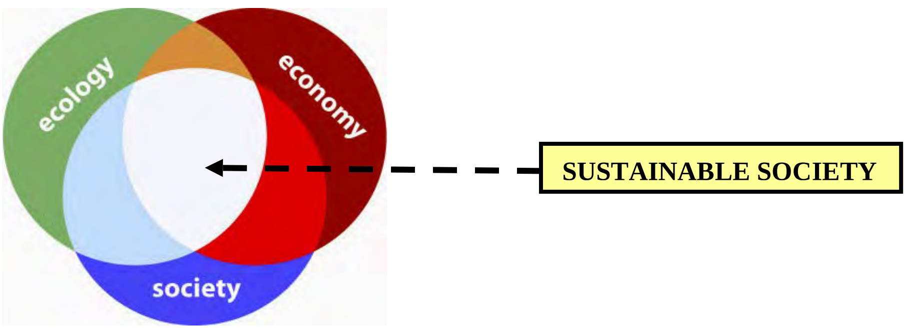

Fig. 1. Sustainable Society Structure (4)

Environmentally-conscious and sustainable artificial environments go through a long process to be formed, from the designing stage that begins with a preliminary sketch to the end of the physical life of building. Architectural artificial environments not only serve to meet sheltering needs of the society, but they also appear as mutual products of imagination, technical information and a combination of ecological, social, political, aesthetical and moral values. They are the balancing epistemological systematic for ecology, economics and society which comprises of the future generations and all other living creatures. They are formed with the moral necessity that requires the society to act as a whole for a common purpose (5).
Considering the role of environmentally-conscious architecture in solving global ecological and energy problems, 3 di mension of the mission undertaken by sustainable artificial environment designs are prominent; economical dimension, social dimension and ecological dimension. "Rationalistic and Salutary Sustainable Artificial Environments'' are present at the common denominator of ecology, society and economy, with an interactive and conscious balance, (Fig. 2).

Fig. 2. Rationalistic and Salutary Sustainable Artificial Environment Model (6)

3. Methodology

3.1. Ecological Housing and Realization Potential for Sustainability

Designing, construction and usage of buildings take a long process and continuous consumption, accumulation of wastes are natural consequences. Therefore, the effects of architecture on ecological problems are present at the stages of designing, production, usage and until the end of physical life of architectural output. Nonetheless, in today's world it is almost mandatory to find new solutions in order to minimize adverse effects, or at least to keep them within reasonable boundaries. Architectural artificial environment should be viewed and designed as an artificial ecological system. Deterioration of ecological environment, as a concrete factor closely related to individual and societal welfare, has both quantitative and qualitative adverse effects on s ociety. In order to get rid of those adverse effects and to develop ecological consciousness, artificial environment design should abide by a series of criteria. These criteria are multi-dimensional social and physical components variable upon t ime and location conditions, covering the whole process from the designing stage of the building to demolition phase.
As of ecological and sustainable studies in general, the following are prerequisites for sustainable environment;

- Rational, productive and minimal resource consumption,
- Usage of recyclable materials and renewable resources,
- Conservation of energy stocks, usage of renewable energy sources which do not cause environmental pollution and,
- Recycling of wastes (7).

Pilot projects introduced as ecological and sustainable approaches are based on mainly 5 basic principles; (7)

i. Salutary Artificial Environment: Harmony with topography is restored, the former natural habitat is revived, and formation of an artificial ecosystem is aimed. Building materials with no toxic raw materials and hazardous gases and construction systems are used. Waste control and recycling are applied without polluting water and air.
ii. Sufficient and Efficient Energy Systems: Necessary precautions should be taken in order to keep energy usage at the lowest level for providing suitable vital conditions.
Heating, lighting and cooling systems are made of energy-efficient methods and products. Renewable energies are utilized as much as possible in active, passive or mixed systems.
iii. Environmentally-conscious Building Materials: In production, application, building materials and products with no hazardous waste that require less-energy are used. Usage of natural materials such as wood requires maximum diligence for energy efficiency. Especially, recyclable products and systems are used.
iv. Environmentally-conscious Form: Building forms and space organization are designed according to the structure of location and climate characteristics of the region. Ecological structure is respected. Interior comfort conditions are provided via rational and productive use of energy. Form is designed in such a way that a harmonic nexus between the user and nature is established.
v. Smart Design: Space usage, circulation, building form, mechanical systems and construction are designed to maintain productive, swift, harmonic and durable operation.

3.2. Ecological and Sustainable Housing Design

Sustainable, environmentally-conscious and energy-efficient public housing design can be defined under 2 headlines; unchanged 'General Principles', and 'Regional Principles' that are variable upon climate conditions of the region (8).

3.2.1. General Principles

General principles of sustainable public housing design also include some basic principles that are valid for all geographical areas. Despite different conditions; these are constant, sustainable and energy-efficient design decisions, which cover design, construction, usage and all other stages throughout the entire physical life of public housings. Following are 10 Basic General Principles;
i. Conception System and Design Principles; Environmental consciousness and energy conservation come into being on the table during the designing stage prior to physical existence of the building.
ii. Ecological Artificial Environment Design and Location Choice; Location choice, accurate interaction with environment, energy conservation and environmental consciousness are among the most crucial phases in sustainable public housing design. Design decisions are subject to have regional differences in accordance with climate conditions of the location.
iii. Construction and Resource Management; Resource and energy consumptions during construction phase have a huge share in total consumption. Thus, this phase has great importance for studies with the aim of sustainability in public housings.
iv. Building Envelope and Building Geometry; Building envelope and building geometry put forth the semantic nexus with natural habitat for consideration. Design decisions are subject to change according to regional differences.
v. Space Organization; Space organization in housing is one of the most important factors which affect the users' health and productivity. Living culture is determinant for interior function. Designing is subject to differ according to regional climate conditions of the location.
vi. Choice of Building Material and its Adequacy in terms of Building Physics; The concept of sustainable public housing combines all environmentally-conscious and energy

efficient methods throughout the entire stages of the building; from designing to the end of its physical life. Usage of sustainable and environmentally-conscious materials and products is one of the most important phases. Appropriate material choice in accordance with regional climate conditions is essential for success.
vii. Air-conditioning Systems; Air-conditioning of housings is one of the most important phases for providing the users' health and comfort, and for managing resource usage and energy consumption. Air-conditioning systems would differ according to regional climate conditions.
viii. Users' Comfort Needs; The concept of sustainable public housing aims to meet the users' comfort expectation at maximum level. Meeting the needs without destroying the environment is top priority.
ix. Waste Management; The adverse effects of wastes on natural environment necessitate sustainable and ecological design. Thus, waste management becomes a preferential objective of design. As a result, unmanageable wastes inflict damage to natural life along with human health.
x. Natural Life and Sustainable Society; Mankind cannot survive without nature. Therefore, the faster we destroy our natural environment, the sooner we approach to our own extinction.

3.2.2. Regional Principles

There are many different climate zones due to various geographic factors such as solar radiation reception, topographic structure and flora. Regional principle are sustainable and environmentally-conscious design decisions which contain regional differences on design, construction, usage and physical life of public housing resulting from variable climate conditions. Different climate conditions cause public housing and artificial environment location choices to be unique to the current region by the help of architectural differences in building envelope, building geometry, space organization, building material and air-conditioning systems. General principles; such as 'Location Choice and Ecologic Artificial Environment Design', 'Building Envelope and Building Geometry', 'Space Organization', 'Choice of Building Materials and their Adequacy in terms of Building Physics' and 'Air-conditioning Systems', contain some additional precautionary measures and principles in accordance with climate conditions of the location (Fig. 3).

4. Discussion

The rise of ecological and sustainable buildings, as an indication of technological improvement in Today's information society, does not only aim to meet people's sheltering needs. Ecological and sustainable design is not merely an arbitrary architectural interpretation from a group of environmentally-conscious architects. Being ecological and sustainable requires taking lessons from environmental catastrophes caused by the 19th century's Industrial Revolution and the 20th century's human-centric life style. A well-planned design is not the final phase for sustainability. It begins with design decisions on the table and continues until the end of physical life of the building. This process can be broken down into 8 phases;

i. Understanding the Location: Ecological and sustainable design begins with self-description of its concrete and abstract value via detailed analysis of the location.
ii. Understanding Natural Process–Respect to Nature: Ecology has a natural balance which provides and protects the continuity of life on earth. There is no place for waste in natural life; the by-product of a living organism serves as a food resource of another. Thus,

artificial environments formed by architecture should act as components of natural systems in order to maintain the continuity of life.

iii. Understanding the People: Architect should be familiar with the users who will be residing within the artificial environment that he/she designs. The users' habits, needs, sentiments, beliefs, cultures etc. should be analyzed and design should be modified in accordance with obtained information.

iv. Interdisciplinary Interaction / Team Work: Sustainable design is a conscious integration of architecture with electrical, mechanical and structural engineering and sociologists. Designer should interact with all other disciplinary fields, regard all related opinions and provide common solutions to problems.

v. Construction Planning: It begins with application of architecture's concrete effects on environment to designed output. Adverse effects of construction sites on the environment such as water, air and noise pollution are minimized and consumption of resources are controlled, so that the damaged portion of nature would be restored.

vi. Planning Tenancy Process: Resource consumption and wastes reach their highest levels during tenancy process of buildings. Systems with minimum adverse effects to environment are designed and used for meeting the needs, comfort conditions. Renewable energy sources are utilized at the highest possible level, while fossil fuel usage and wastes are controlled and minimized. Low-cost with high-efficiency is aimed.

vii. Conscious Society/Global Action: Success of ecological and sustainable studies depends directly on cooperation of societies and a global participation. Especially the countries which cause more global pollution should be more responsible for taking active roles in these studies.

viii. Foreseeing the Future: It is essential to preserve resources to be passed on to usage of future generations. For this purpose, rational and planned consumption of resources and recyclable material choice are foreseen. At the designing stage, physical lives of the buildings and demolition phases are predicted.

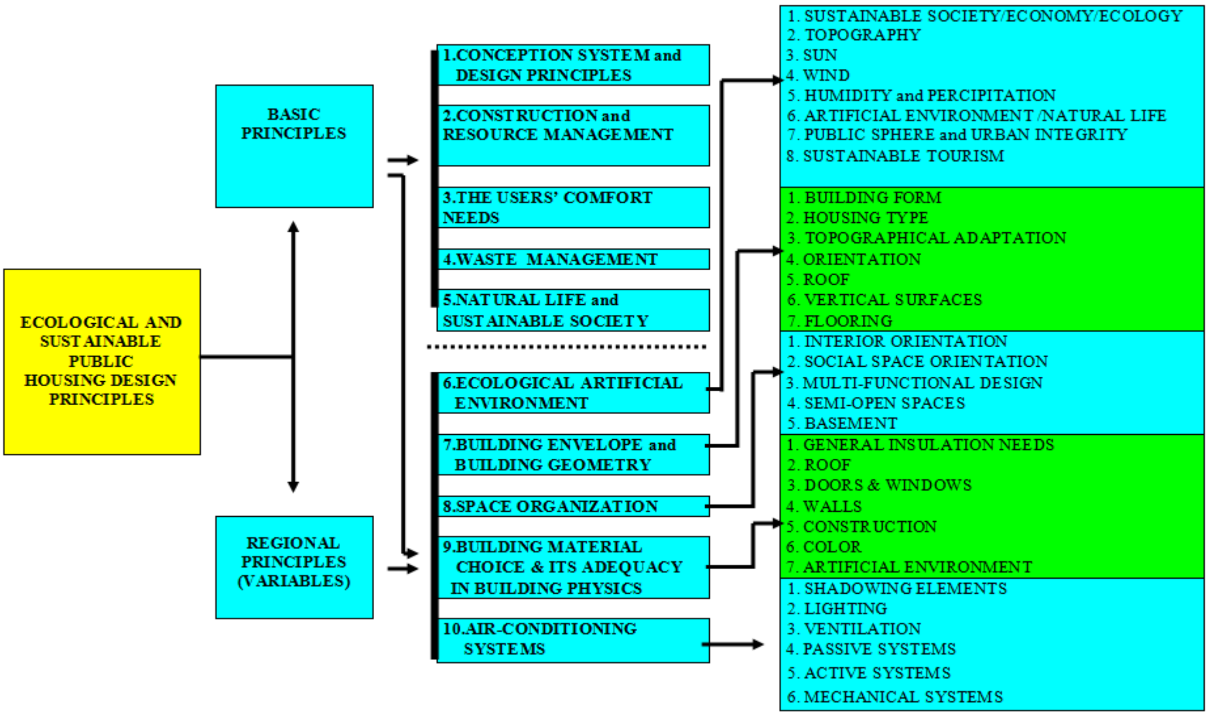

Fig. 3. Climate-Weighted Design Model in Ecological and Sustainable Public Housing (8)

5. Conclusions

Ecological and sustainable design is neither merely a style nor an architectural conception of a group of architects. Being ecological and sustainable is nominated as life style and understanding of the 21st century's information society accessorized with past experiences from environmental disasters caused by the 19th century's Industrial Revolution and the 20th century's economy-based and human-centric industrial society. After all, it is well-understood that human-kind would not exist without nature. That is to say, the faster we destroy our natural environment, the sooner we go extinct. Ecological and sustainable approaches aim to balance social, economic and environmental aspects of our present and future actions. The undertaken mission concerns a matter of existence or extinction, beyond any further achievement.

The users should be aware of characteristics and purposes of organizational, structural and factual design which brings existential integrity to architectural objects in architectural ecological artificial environment by the help of ecological and sustainable public housing design. For this purpose, every environmentally-conscious architectural innovation should be set up along with all its objective values with their abstract and concrete realities on sound basis. Local-regional-global significance and realities of ecological and sustainable public housing toward today's information society and future generations, namely, relative realities can be examined in 4 categories;

i. Existential Reality; is simply mankind's need for sheltering and protection against outer nature conditions. This reality involves the interdependence between the living organism and its habitat and sentimental and sensorial connections with domicile.
ii. Material Reality; is the provision of all necessities and objective needs as the basis for sensual perception and biological convenience in order to provide the most appropriate conditions for the users' health, productivity and comfort.
iii. Ideal Reality; is the formation of an artificial ecological environment along with architectural artificial environment by making appropriate design decisions and maintaining a balanced interaction between artificial environment and natural environment.
iv. Basic Reality; is the formation of environmentally-conscious and sustainable life style for the 21st century by establishing a rationalistic balance with respect to ecology-society-economy triangle within local, regional and global dimensions.

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Green Sustainable Island by Implementation of Environmental, Health, Safety and Energy Strategy in KISH Trading-Industrial Free Zones-IRAN

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Abstract: The sustainable development of green islands for implement Environmental, Health and Safety Management Systems for free trade zones required to confirm to ISO 14001, OHSAS 18001 and ISO 50001 standards. The Standard development of policy and strategy for business and tourism requires, in first instance, a vision. It needs to trace down what are the main threats, where do they come from, and what can be done about it. The green economy has been growing globally at great pace over the past five years. This is all the more impressive considering the severe global downturn of years 2006-2009. Ireland has, in recent times, gained a presence in this exciting sector, with enterprise opportunities in a wide variety of areas.

Sustainable development considers Social, Economic, Energy and Environmental needs. Trading-Industrial Free Zones (TIFZ) purposes and duty must be met in sustainable ways. However, TIFZ have a good track record of finding sustainable solutions whilst balancing these purposes and duty.

The method used in this article is comparative and matching method, by using ISO 50001 standards which is approved by ISO, and HSE-MS which is structured by Oil and Gas Production (OGP). Jointing of Energy management by HSE-MS is the main objective of this paper.

This case study has attempted the Implementation of EHSE Strategy in Kish Islands which is in Persian Gulf of Iran. EHSE modeling will overarch strategic document and central to the future of the Kish. It shows co-ordination and integration with other plans, strategies and actions in the Kish where they affect the TIFZ purposes and duty. It indicates how the TIFZ purposes and associated duty will be delivered through sustainable development. Matching requirements of the environment with energy safety and health is the ultimate goal of this research. In fact, the clean environment, with safe and healthy quality and with optimum energy consumption pattern, is the most ideal strategy for the management of a green region. Surely this concept of sustainable Green Island will be achievable in the near future. According to the result of this research, successfully management system in the way of sustainable development, is to attached and used efficiency all of the parameters such as Environment, Safety, Health and Energy in the same way and with the total carrying capacity. Such sensitive development at Green Island will ensure that resort guests and day visitors will continue to enjoy a quality nature based experience within a magnificent rainforest and reef environment.

Keywords: *Sustainable Islands–Environmental, Health, Safety and Energy Policy– KISH ISLAND*

1. Introduction

The man is the main pivot in the sustainable development. Possibility, planning, and implementation of any project or plan which include even technical or economical advantage, if there were any disadvantages or if the principles of health, safety and environmental rules were in danger, it is not advisable to be recommended. Thus, the national and international standards are generated [4. Sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present, but also for future generations. The term was used by the *Brundtland* Commission which coined what has become the most often-quoted definition of sustainable development as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs."[11][10]

The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and sociopolitical sustainability. (fig.1)
Requirements for health and safety and of environmental topics in the world are proof for anyone.In addition to, Energy has been playing an important role in the economic development all over the world. World population is expected to double by the middle of this century, and economic development will continue at a faster pace in the developing world than that in the developed world.[12]

Considering the matching of four mentioned subjects and their inevitable relations, in addition to their advantages of implementation, such as reducing the taxes and costs and being timesaver nowadays health, safety, environment and energy are studied and considered as a united group.If the system does not have an Environmental, Health, Safety & Energy Management System (EHSE-MS) in place now, it may be required to implement one soon.[7]
Free trade zones are domestically criticized for encouraging businesses to set up operations under the influence of other governments, and for giving foreign corporations more economic liberty than is given indigenous employers who face large and sometimes insurmountable "regulatory" hurdles in developing nations. However, many countries are increasingly allowing local entrepreneurs to locate inside FTZs in order to access export-based incentives. Because the multinational corporation is able to choose between a wide range of underdeveloped or depressed nations in setting up overseas factories, and most of these countries do not have limited governments, bidding wars (or 'races to the bottom') sometimes erupt between competing governments. Free Trade Zones are also known as Special Economic Zones in some countries. [5]

TIFZ look like live Company size, resource availability or markets served will not necessarily dictate when and if implementation will happen. And even though organization may have many of the components in place already for an easy transition to ISO 14001 or OHSAS 18001 or ISO 50001 (fig.2), the road to an effective EHSE-MS can be fast, furious and paved with various pitfalls.There are many reasons why organizations implement Environmental Health Safety & Energy Management Systems that conform to ISO 14001 and/or OHSAS 18001 and ISO 50001 standards. Identifying occupational health and safety hazards and risks and the environmental impacts and also the procedure of usage the energy and also the energy efficiency of your company and employees is a given. However, more and more customers are demanding EHSE-MS as a requirement for doing business.

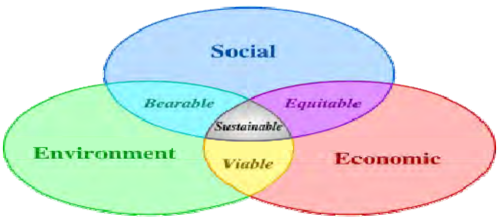

Fig.1- Scheme of sustainable development: at the confluence of three constituent parts.[4]

1.1. Location (Kish Island)
Kish is a resort island in the Persian Gulf. It is part of the Hormozgãn Province of Iran. Due to its free trade zone status it is touted as a consumer's paradise, with numerous malls, shopping centres, tourist attractions, and resort hotels. It has an estimated population of 20,000 residents and about 1 million people visit the island annually.[4]

The area of the island is 91.5 km². Kish Island is the purported to be the third most visited vacation destination city in the Middle East, after Sharm el-Sheikh and Dubai.

1.2. Geography and Environment

Kish is located in the Persian Gulf 19 km from mainland Iran and has an area of around 91 km² with an outer boundary of 40 km and a nearly elliptical shape. Along Kish's coast are coral reefs and many other small islands. The Island is positioned along the 1359 km long Iranian coastline north of the Persian Gulf, at the first quarter from the Hormuz entrance to the Persian Gulf. Its longitudinal and latitudinal positions are 26.32N and 53.58E degrees. The Island is 15.45 km long from west coast to the east coast (the distance between Mariam Complex and Hoor field). (See Pic.1)[8]

Picture1: Kish Island, Persian Gulf.

1.2.1. Kish, a Scenery coral Reef

The corals are considered as herbal and cylinder shaped animals which are mostly living as colony. Their Heads are located above cylinder in a way that a broad and wide screen exists in bottom part. These cells emit lime materials with the aim of fixing coral on a board. By emission of these materials, lime base will be created for coral. Aggregation and accumulation of corals and lime emissions from them, have played a very key role in various geological eras in appearance of Kish Island. Coral Islands and cylindrical forests enjoy the highest biodiversity in world ecosystems.[7][11]

1.2.2. Kish Large Recreational Jetty

Kish Large Recreational Jetty has been constructed by Iranian experts and engineers with the method of pipe driving and wooden deck with four- spacious satellite design. As long as 437 meters with 18 meters width and as large as 10,000 square meters, this jetty and quay has not any destructive effect on marine habitat in a way that tourists and sea voyagers can enjoy while standing on deck of this jetty and have a very pleasant time on visiting sceneries and breathtaking view of coral coasts of Kish Island.[9]

1.3. Human impact-Major Kish Island Projects

1.3.1. International oil bourse

The International Oil Bourse is a commodity exchange which opened on February 17, 2008.

1.3.2. Dariush Grand Hotel

Dariush, a $125 million five star hotel with over 200 guest rooms, is located near the eastern sandy beaches of the island. The hotel was built to be a reminder of Persepolis, a symbol of the glory and splendor of the ancient Iranian civilization. The hotel was designed and developed by the European-Iranian entrepreneur and hotel tycoon, Hossein Sabet, who owns and manages several tourist attractions and hotels in the Canary Islands.[6]

1.3.3. Kish Hidden Pearl

In 1999, a project to build an underground complex was begun by 300 artists and excavation workers. After deep excavations rigid coral ceilings were discovered, and this was included in the final design. Once completed, the city will include restaurants, tourist resorts and underground therapeutic mud pools.

1.3.4. Kish Dolphin Park

The Dolphin Park is 10,000 square metres large and is surrounded by over 12,000 palm trees. The park includes a Dolphinarium, Butterfly Garden, Silkworm Compound, Exotic Bird Garden, Artificial Rain Forest, Volcanic Mountain, The World of Orchids and Cactus Garden.

1.3.5. Solar Powered Hotel

Hossein Sabet owner of the Sabet Hotels Group which includes the Dariush Grand Hotel and many other hotels on the island is set to build the first solar powered hotel in the Middle East on the island. Cyrus Hotel will be 7-star costing $520 million and will have 500 rooms, 23 floors in an area of 100,000 square meters. The hotel is set to be complete in October 2009.[7][6]

1.4. Extant Industries in Kish Island

These industries are located in five industrial townships as follows:

- ✓ Electricity and electronic industries
- ✓ Home appliances industries
- ✓ Metal and car manufacturing industries
- ✓ Oil industry technical and engineering services and logistics industries
- ✓ Garment and textile industries
- ✓ Food, pharmaceutical and hygienic industries
- ✓ Wooden and cellulose industries
- ✓ Mineral and non-metallic industries
- ✓ Chemical industries
- ✓ Heating and cooling industries
- ✓ Packing industries[12]

2. Methodology

The method used in this article is comparative and matching method, by using *ISO 50001, ISO 14001, OHSAS 18001* and *OGP for HSE-MS*. All of these models are an international model, but the main goal is to match the requirement of energy management in Health, Safety and Environmental Management. Important in this research is how to use and the 4 components of sustainable development goals. [2][3][6][14]. Therefore, in order to implement this right and fundamental components relying on international standards on the one hand and the principles of sustainable development other hand, this model has been proposed.

3. Results

According to the investigations and analyzing the requirements of ISO 50001, ISO 14001, OHSAS 18001 and matching to the main HSE Standards, this result has been proposed.

Following reviews carried out and matching of four main components environment, health, safety and energy, the proposed resulting model includes the following main axes: (Fig. 2)

1. Leadership and commitment
2. EHSE Policy and strategic objectives
3. Organization, resources and documentation
4. EHSE Risk Evaluation and management
5. Planning
6. Implementation and monitoring
7. EHSE Auditing and reviewing

Fig.2- A proposed Model contain Environmental, Health, Safety and Energy part for Island.

4. Discussion and Conclusion

By definition EHSE, sustainable development will run by Health, and Safety (social), Energy (economic) and environmental needs. Kish Island purposes and duty must will be met in sustainable ways. However, Kish has a good track record of finding sustainable solutions whilst balancing these purposes and duty in EHSE ways.

To provide and describe the characterization of EHSE Strategy, the full description of every stage has been provided step by step:

4.1. Leadership and commitment

It addresses Top-down commitment and company culture, essential to the success of the system: The Kish Island (KI) Management should create and sustain an organization culture that supports the EHSMS, based on:

- Belief in the Kish Island's desire to improve EHSE performance;
- Motivation to improve personal EHSE performance;
- Acceptance of individual responsibility and accountability for EHSE performance;
- Participation and involvement at all levels in EHSEMS development;
- Commitment to an effective HSEMS.[10]

4.2. EHSE Policy and strategic objectives

It addresses corporate intentions, principles of action and aspirations with respect to environment, health & safety. The Kish Island's management should define and document its EHSE policies and strategic objectives and ensure that they:

- are consistent with those of any parent company;
- are relevant to its activities, products and services, and their effects on EHS;

- are consistent with the Kish Island's other policies;
- have equal importance with the Kish Island's other policies and objectives;
- are implemented and maintained at all organizational levels; are publicly available;
- commit the company to meet or exceed all relevant regulatory and legislative requirements;[9]
- apply responsible standards of its own where laws and regulations do not exist; commit the Kish Island to reduce the impacts, risks and hazards to health, safety and the environment of its activities, products and services to levels which are as low as reasonably practicable;
- Provide for the setting of EHSE objectives that commit the Kish Island to continuous efforts to improve EHSE performance.

4.3. Organization, resources and documentation

It addresses Organization of people, resources and documentation for sound EHSE performance.
The Kish Island should define, document and communicate—with the aid of organizational diagrams where appropriate—the roles, responsibilities, authorities, accountabilities and interrelations necessary to implement the EHSE MS, including but not limited to:

- provision of resources and personnel for EHSE MS development and implementation;
- initiation of action to ensure compliance with EHSE policy;
- acquisition, interpretation and provision of information on EHSE matters;
- recording of corrective actions and opportunities to improve EHSE performance;
- recommendation, initiation or provision of mechanisms for improvement, and verification of their implementation;
- control of activities whilst corrective actions are being implemented;
- control of emergency situations.

4.4. EHSE Risk Evaluation and management

Risk is present in all human endeavors. This section addresses the identification of EHSE hazards and evaluation of EHSE risks, for all activities, products and services, and development of measures to reduce these risks.
The essential steps of hazard management:

1. Identify hazards and effects
2. Establish screening criteria
3. Document significant hazards and effects and applicable statutory requirements
4. Evaluate hazards and effects
5. Implement selected risk reduction measures
6. Set detailed objectives and performances criteria
7. Identify and evaluate risk reduction measures

4.5. Planning

This section addresses the firm planning of work activities, including the risk reduction measures (selected through the evaluation and risk management process). This includes planning for existing operations, managing changes and developing emergency response measures. The Kish Island should maintain, within its overall work programmer, plans for achieving EHSE objectives and performance criteria. These plans should include:

- a clear description of the objectives;

- designation of responsibility for setting and achieving objectives and performance criteria at each relevant function and level of the organization;
- the means by which they are to be achieved;
- resource requirements;
- time scales for implementation;
- motivating and encouraging personnel toward a suitable EHSE culture;
- mechanisms to provide feedback to personnel on EHSE performance;
- processes to recognize good personal and team EHSE performance
- mechanism for evaluation and follow-up.

4.6. Implementation and monitoring

This section addresses how activities are to be performed and monitored, and how corrective action is to be taken when necessary.
Activities and tasks should be conducted according to procedures and work instructions developed at the planning stage—or earlier, in accordance with EHSE policy:

- At senior management level, the development of strategic objectives
- and high-level planning activities should be conducted with due regard for the EHSE policy.
- At supervisory and management level, written directions regarding activities (which typically involve many tasks) will normally take the form of plans and procedures.
- At the work-site level, written directions regarding tasks will normally be
- in the form of work instructions, issued in accordance with defined safe systems of work (e.g. permits to work, simultaneous operations procedures, lock-off procedures, manuals of permitted operations).[10]

Management should ensure, and be responsible for, the conduct and verification of activities and tasks according to relevant procedures. This responsibility and commitment of management to the implementation of policies and plans includes, amongst other duties, ensuring that EHSE objectives are met and that performance criteria and control limits are not breached. Management should ensure the continuing adequacy of the EHSE performance of the Kish Island through monitoring activities. [10]

4.7. EHSE Auditing and reviewing

This section addresses the periodic assessment of system performance effectiveness and inherent suitability.[9]
The Kish Island should maintain procedures for audits to be carried out, as a normal part of business control, in order to determine:

- Whether or not EHSE management system elements and activities conform to planned arrangements, and are implemented effectively.
- The effective functioning of the EHSEMS in fulfilling the company’s EHSE policy, objectives and performance criteria.
- Compliance with relevant legislative requirements.
- Identification of areas for improvement, leading to progressively better EHSE management.[10]

And at the end, as final conclusion, according to the proposed EHSE-MS model, it can improve environment, health, safety and energy performance resulting in pollution prevention, safer workplaces and fewer injuries in the islands. But even more than that, these systems are being used by organizations to gain a competitive edge. And as corporate social responsibility initiatives gain momentum, EHSE-MS takes on an even more critical role within the organization.

The main purpose of this model is to plan the EHSE model for other island such as Kish, to show the established overarching strategic document and central to the future of the TIFZ. It shows co-ordination and integration with other plans, strategies and actions in the TIFZ where they affect the TIFZ purposes and duty. It indicates how the TIFZ purposes and associated duty will be delivered through sustainable development by improve EHSE performance resulting. In addition to, this is the first research that shows the intergradations of this for main subject in one model in the world.

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An Analysis of two Sustainable projects in the light of the LEED-NC and LEED-ND rating systems

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Abstract: The methodology used in this paper consists in studying how the 5 environmental categories of the LEED New Constructions and Major Renovation plus the 3 categories of the LEED Neighbourhood Development apply to the architectural and urban design strategies of two projects: Masdar City and "Forwarding Dallas". We chose two very different but at the same time similar projects which claim to be environmentally conscious. On one end, there is the self-intituled "world's first carbon-neutral city", Masdar, designed by Foster + Partners and one of the largest and most ambitious developments of its kind. On the opposite end, and in a significantly smaller scale, there is the "Re-Vision Dallas" competition winner project, "Forwarding Dallas", designed by a collaboration of two Portuguese architecture practices: DATA + MOOV. This competition promoted the idea of transforming a vacant inner-city block in Dallas into a carbon-neutral neighbourhood, creating, for that purpose, a prototype for an innovative, sustainable urban community.

This paper strives to highlight, through the comparative analysis of these two projects, how the desire to meet high standards of sustainability not only affects the practice of architecture and urban design, but might also generate a particular architectural language with identifiable physical characteristics.

Keywords: *Carbon-Neutral, Masdar City, Forwarding Dallas, LEED, Renewable Energy*

1. Introduction

This paper presents part of a research developed by a research unit, named "*+E-CO2*", or "*More Energy, Less Carbon*", based in Lisbon, at *Faculdade de Arquitectura da Universidade Técnica de Lisboa*, which pursues the goal of understanding how the carbon neutral challenge is changing present day's urban design and architectural practices. Our purpose is to focus on the design process in order to assess two key questions: 1) How does the desire to meet high standards of sustainability affect the practice of architecture and urban design? 2) Will this global concern with a carbon-neutral future generate a particular architectural language with identifiable physical characteristics regardless of location?

2. Methodology

We have determined as research methodology for our *+E-CO2* research project the analysis of self-acclaimed carbon neutral and/or carbon reduction projects in order to detect how the carbon neutral challenge is affecting the practice of urban and architectural design. The projects which claim to be carbon neutral are the most relevant for our research because, in these projects, the practitioners are guided by the clear purpose of configuring architecture and urban space so as to meet the carbon neutral challenge.

Our analysis derives from the comparative process of design strategies in light of fixed criteria, enabling us to highlight specific design differences and/or resemblances in between the projects. For this paper, we have chosen as fixed criteria the 5 environmental categories of the LEED New Constructions and Major Renovation [1] plus the 3 categories of the LEED Neighborhood Development [2]. In light of these 8 categories, we analyze and compare two very ambitious projects in what regards the carbon neutral challenge.

The first project is the development of a block in Dallas designed by a collaboration of two Portuguese architectural practices (MOOV+DATA), which obtained the first prize in an international architectural competition promoted by the American non-profit organization named "Re-vision". The competition's brief challenged architects to design a project able to become LEED Platinum. Most information regarding the project has been provided by António Louro, one of the architects/partners managing the project [3]. The project's brief was to redesign an urban block in Dallas, including mostly housing, but also commercial spaces and urban equipments.

The second project is the Masdar City development designed by Foster+Partners which aims to become the first carbon neutral city to ever be built. The Masdar City development is located in Abu Dhabi, close to the international airport and was conceived to be carbon neutral, zero-waste, car-free city for 40,000 residents and 50,000 daily commuters. The city is designed for an area of six million square meters. Even if the city is currently under construction (the completion of the first building was announced in November 2010), its scale and ambitious program as a research and institutional hub dedicated to Renewable Energies make it a most relevant project to follow, as noted by Reiche [4]. Data cited in this paper has been gathered from other papers, from the information provided by the company responsible for the development, the Abu Dabhi Future Energy Company [5], by the architects responsible for the masterplan at Foster + Partners [6], and by articles included in architectural magazines [7]. Papers reviewed regarding Masdar City relate to specific technological innovations in the energy field [8], to policies supporting the development [4] or to specific buildings [9]. Prior to this paper, we have presented a paper on the possibility of using some of Masdar City's renewable energy strategies in a "bottom-up" type of development [10]. For the current paper, our approach is different as we aim to highlight the impact of the carbon neutral challenge on architectural and urban design.

We have determined as primary data the information coming from the practitioners or from the entities commissioning the projects. This data must be taken as a set of design guidelines which might not be possible to complete or might change with the project's development (as it has already happened in the Masdar City development with the experimental transport system, originally elevated and currently underground).

We chose to use the LEED categories as fixed criteria due to this rating system's holistic approach and to the system's ability of evaluating projects worldwide; however, unlike the LEED rating system, which aims to provide a quantifiable benchmark to compare each project's efficiency, we aim to assess the impact of the carbon neutral challenge on architectural design; hence, some categories might have no effect on architecture (such as the efficiency of appliances), while others will change the configuration of the city of the future. In Table 1, we present the relationship we created in between the LEED categories and the architectural and urban design strategies of the two case-studies selected. We created a rating system measuring the Impact on Architectural Design (IAD), presenting five classes ranging from IAD 0 to IAD4 where: IAD 0 classifies the strategy as having no or low direct impact on architectural design; IAD 1 classifies the strategy as affecting architectural surfaces using existing design strategies; IAD 2 classifies the strategy as affecting architectural surfaces using new technologies and/or innovative design strategies; IAD 3 classifies the strategy as affecting architectural form using existing design strategies; and IAD 4 classifies the strategy as affecting architectural form using new technologies and/or innovative design strategies.

Table 1. Relationship between LEED categories and architectural and urban design strategies

LEED Environ. Categories (NC=NewConstruction; ND= Neighborhood Development) *The categories which, on both case-studies, did not apply or had NINF were excluded for this paper*	Architectural and Urban Design Strategies *(NA=does not apply; NINF=not enough information; IAD Impact on architectural design 0-4))*	
	Forwarding Dallas	Masdar City
NC - Sustainable Sites		
Construction Activity Pollution Prevention	IAD 0	Impacts assessed + mitigation actions predicted [10] IAD 0
Site Selection	Block within built neighbourhood. IAD 3	6km, built mostly on former plantations land. IAD 3
Development Density and Community Connectivity	Optimizes pedestrian public space + connectivity public space for pedestrians+ bicycles inside the block. IAD 3	Optimizes pedestrian public space + connectivity public space for pedestrians+ bicycles inside the block. IAD 3
Alternative Transportation	No public transport system available. Promotes cyclable public spaces, car-pooling and bicycle parking. IAD 3	Car-free city. New transport system, 2 levels: LRT (aboveground), PRT (undergound). IAD 4
Site Development	Use of native vegetation in public spaces and rooftops. IAD 4	Compact footprint and limited, or walled, perimeter. IAD 3
Stormwater Design	includes vegetative roofs and pervious pavements IAD 4	NINF
Heat Island Effect	Roofs covered with vegetative surfaces. IAD 4	Roofs with shading structures covered by photovoltaic panels. IAD 4
LEED NC – Water Efficiency (WE)		
Water Use Reduction	Rainwater collected and used in agriculture + graywater used in toilets IAD 4	Rainwater collected +graywater used in toilets and cooling of public spaces. IAD 4
Water Efficient Landscaping	Native plant use + drop-by-drop irrigation system + on site measurements to assess irrigation needs. IAD 4	Native Plant use+ Intelligent irrigation systems. IAD 4
Innovative Wastewater Technologies	On-site waste water treatment by gravity-driven mechanical systems + sand and UV light filtration. IAD 4	NINF
Water Use Reduction	NINF	Initial use of desalinized water and recycling of most water in the system. IAD 3
NC -Energy and Atmosphere		
OptimizeEnergy Performance	High energy performing	NINF

	appliances + LED technology IAD 0	
On-site Renewable Energy	On the rooftop - Solar thermal energy + photovoltaic + wind energy. Roof design expands surface to maximize production. Solar cells on the façade. IAD 4	On the rooftop – almost 80% of the consumed energy will be solar. The entire city covered with panels. IAD 4
Enhanced Commissioning	Specialized consultants included. IAD 0	Specialized consultants included. IAD 0
Enhanced Refrigerant Management	Non-mechanical methods of ventilation (cross-ventilation in every apartment). IAD 3	Traditional methods of cooling (such as cooling chimneys) + mechanical cooling. IAD 3
Measurement/ Verification	IAD 0	IAD 0
Green Power	IAD 0	IAD 0
NC - Materials and Resources		
Storage and Collection of Recyclables	Includes area for Storage and Collection of Recyclables. IAD 0	50% waste will be recyclable, 17% will become fertilizers and 33% will not be recyclable. IAD 0
Construction Waste Management	100% pre-fabricated building systems to reduce on site impact and waste. IAD 2	NINF
Recycled Content	Recycled Wood. IAD 2	Materials with a 30% recycled content predicted. IAD 2
Regional Materials	Use of locally produced materials. IAD 1	NINF
NC-Indoor Envirn. Quality		
Minimum Indoor Air Quality Performance Required	Non-mechanical methods of ventilation (cross-ventilation in every apartment). IAD 3	Traditional methods of cooling (such as cooling chimneys) + mechanical cooling. IAD 3
Environmental Tobacco Smoke- Control Required	IAD 0	IAD 0
Outdoor Air Delivery Monitoring	IAD 0	IAD 0
Controllability of Systems—Lighting and Thermal Comfort	Operable Windows and Window Protections IAD 2	NINF
Thermal Comfort—Design/Verification	Northeast façades in high thermal mass straw walls. IAD 2	NINF
Daylight and Views	Block designed to maximize daylight and views. Windows consider southern orientation and permanent shading	NINF

	devices. IAD 3	
NC/ND -Innovation in Design		
Innovation in Design	Educational project IAD 0	Educational project IAD 0
LEED Accredited Professional	Goal to obtain LEED Platinum IAD 0	NINF
NC/ND-Smart Location and Linkage		
Smart Location	Block within existing neighborhood in Dallas. IAD 3	New development on previously planted land close to national transport infrastructure (airport). Max. walkable distance from the planned PRT stops is 150m. IAD 4
Imperiled Species and Ecological Communities	NA	Loss of existing habitats predicted. Mitigation actions predicted. IAD 3
Wetland and Water Body Conservation	NA	No significant effects predicted in the initial stages. IAD 0
Agricultural Land Conservation	NA	Located predominantly on abandoned plantations. IAD 3
Preferred Locations	Existing City. IAD 3	Located predominately on abandoned plantations – new infrastructures considered. IAD 3
Locations with Reduced Automobile Dependence	Included in city with high automobile dependence. IAD3	Car-free city. IAD 4
Bicycle Network and Storage	Predicted. IAD 3	Mostly walkable distances. IAD 3
Housing and Jobs Proximity	Mostly residential (dwellings and support areas = 303658 sq.f; commercial, equipments and greenhouses 101828 sq. f, parking 68867 sq. f). IAD 3	Mixed-use development (30% residential; 20% tax-free enterprises; 10% commercial services; 3% cultural equipments, 3%university , 34% with parking, services, recreational spaces, and other areas). IAD3
Site Design for Habitat or Wetland and Water Body Conservation	NA	Loss of existing habitats predicted. Mitigation actions: creation of new habitats with native species through the greenfingers + retention of desert habitat outside citywalls + healthy native plant specimens translocated to Masdar's nursery. IAD 3

Restoration + Long Term Conservation Management of Habitat or Wetlands and Water Bodies	NA	Mitigation actions predicted. IAD 3
ND-Neighborhood Pattern + Design		
Walkable Streets	Pedestrian space within the block. Ground level with commercial and other equipments with glass façades. IAD 3	Car-free city. Most of the transport system is underground to free public space for pedestrians. IAD 4
Compact Development	Increases footprint IAD 3	Compact footprint with rigid physical limit perimeter to prohibit urban sprawling. IAD 3
Connected and Open Community	Block designed (sectioned) to increase existing connectivity. IAD 3	Requirement to place every pedestrian at a distance of 150m from a PRT station in any given location increases connectivity. IAD 4
Mixed-Use Neighborhood Centers	NA	Mixed-use. Centers related to transit system. IAD 3
Mixed-Income Diverse Communities	Dwellings range from studio to 3 bedroom flats IAD 3	NINF
Reduced Parking Footprint	Reduced surface parking IAD 3	Parking outside city walls IAD 3
Street Network	Block designed (sectioned) to increase existing connectivity. IAD 3	Every pedestrian at a distance of 150m from a PRT station in any given location. IAD 4
Transit Facilities	Promotes cyclable public spaces, car pooling and bicycle parking. IAD 3	Car-free city. Underground Urban Transit to free public space. IAD 4
Transportation Demand Management	Promotes vehicle sharing. IAD 0	Use of Urban Transit System. IAD 4
Access to Civic and Public Spaces	Public space inside the block. IAD 3	Due to the underground characteristic of the transit system, most public space will be passive. IAD 4
Access to Recreation Facilities	Recreational facilities within the block. IAD 3	NINF
Visitability and Universal Design	Several types of dwelling units /concern with mobility. IAD 3	NINF
Community Outreach and Involvement	Calls for an holistic design approach. IAD 0	NINF
Local Food Production	Includes local food production on the rooftops. IAD 4	Includes local food production outside city perimeter IAD 3
Tree-Lined and Shaded Streets	Tree-lined streets. IAD 3	Main streets are tree-lined; other streets are shaded and

		narrow. IAD 3
ND-Green Infrastructure + Buildings		
Certified Green Building	Goal:LEED Platinum. IAD0	Goal= Carbon Neutral IAD 0
Water-Efficient Landscaping	(= LEED NC IAD 4)	(= LEED NC IAD4)
Minimized Site Disturbance in Design and Construction	NINF	Mitigation actions predicted. IAD 0
Heat Island Reduction	(= LEED NC. IAD 4)	(= LEED NC. IAD 4)
Solar Orientation	East-west axis 5xlonger than north-south axis. Block orientation greater than 15º from the geographic east-west. IAD 3	Narrow streets and compact design. IAD 3
On-Site Renewable Energy Sources	On the rooftop – Solar thermal energy + photovoltaic + wind energy. Roof design expands surface to maximize production. Solar cells on the southwestern façade. IAD 4	On the rooftop – almost 80% of the consumed energy will be solar. The entire city covered with panels. IAD 4
Solid Waste Management Infrastructure	Organic waste used as fertilizer (predicted). IAD 0	Organic waste used as fertilizer (predicted). IAD 0

3. Results

Two types of results can derive from Table 1. The first result is that all items classified as IAD 4 (with one exception) regard either the use of rooftops or the planned transport system (e.g. Table 1). The second result is a high frequency of strategies classified as IAD 3, followed by IAD 4 and IAD 0, with only a few items classified as IAD 1 or 2 (e.g. Fig.1).

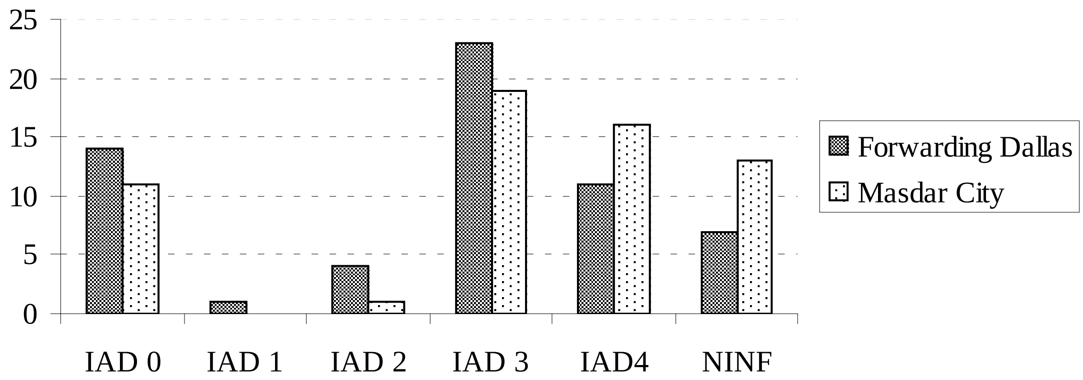

Fig. 1 Frequency of IAD (Impact on Architectural Design) according to classes (IAD 0 to IAD 4)

4. Discussion and Conclusions

Based on these results, we can argue three conclusions. The first conclusion is that two new technologies which might become a trademark of the city of the future are: the increased relevance of the rooftop as a “productive surface”, with the potential to collect energy and rainwater, and to provide spaces for plantation; and the inclusion of intelligent urban transport systems, allowing public space to be car-free. This conclusion is based on the indication that almost all strategies classified as IAD 4 are related either to rooftops or to the urban transport system. The second conclusion derives from the low frequency of IAD 1 and IAD 2, indicating that fewer design strategies are related to the surface of the architectural object (or to the architectural skin) as compared to the configuration of the architectural from. Most strategies used by the selected practitioners to comply with the LEED categories fall under IAD 0, IAD 3 or IAD 4; hence, there is either no impact on architectural design (IAD 0) or a profound impact on the configuration of architecture (IAD 3 and IAD 4). The third conclusion derives from the high frequency of strategies classified as IAD 3 (e.g. Fig.1), indicating that the selected practitioners are using existing or traditional design strategies to relate architecture effectively to climate and location.

What we believe to be particularly interesting about these results is that the first conclusion has the potential of becoming global in its application as practitioners all over the world (literally) turn their projects to the sun and build intelligent urban transport systems, while the third conclusion indicates a promotion of local characteristics; hence, the carbon neutral city of the future might present an architectural language which incorporates both global and local design characteristics, a language where tradition meets technology to achieve a most efficient architectural design.

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Energy demand and available technologies analysis for district heating cooling applications in a Science and Technology Park (PTA) in a Mediterranean country

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Abstract: The purpose of this paper is to present the results of the feasibility study for a district heating-cooling network to cover the energy demand in a Science and Technology Park under Mediterranean climate conditions. To evaluate the energy demand a bottom-up strategy has been followed: a building inventory has been carried out to define several building types according to use, envelope and glazing. Energy + has been used to obtain heating and cooling demand profiles for each building type and orientation. According to municipal development plans for PTA and forecast in business growth, the energy demand evaluation in a 10-years timeframe has been carried out.

Most appropriate technologies has been analyzed and evaluated: Cogeneration (gas turbine and alternative internal combustion engines), biomass boiler and conventional technologies have been evaluated with TRNSYS to obtain consumption profiles, consumption rates, efficiency indicators and energy losses. Finally an economic analysis has been done to technologies in a 20 years period to evaluate technology that better economic results address.

The main objective of this work is the promotion of the efficient and effective energy supply in areas with high energy consumption. DCH technology is widely used in the North of Europe and this paper try to demonstrate that this technology could be apply in Mediterranean areas successfully.

Keywords: *District heating cooling: DHC; building energy analysis; energy demand; technical and feasibility study, district energy, thermal energy generation..*

Nomenclature (Optional)

A effective area of supply .... m^2
EUI energy demand…………………………. *kWh*
R effective building type surface ratio……………………………... m^2*/building*
ATE artificial thermal efficiency
E_{el} *electric energy produced* .... *kWh*
$E_{input\_by\_fuel}$ *energy introduced in engine by fuel* .... *kWh*
H heat amount provided to users .... *kWh*
η *efficiency level, ratio between useful output and input amount in plant components*
P_{term} *thermal demand* .... *kWh*
E_{el_cons} *electrical energy consumed by the facility* .... *kWh*

1. Introduction

Currently, as a result of improved quality of life for both, developed and developing countries, global energy demand grows at very high rates. For this reason, the responsible use of energy resources is crucial for a sustainable model to ensure power supply without compromising the natural resource depletion.

Energy system, as known today, is responsible for large energy losses. These losses result from the different transfer processes taking place from production to consumption points, resulting in an overall process inefficient.

Within this framework, district heating and cooling, DHC in advance, is an alternative technology that improves power distribution processes as it is a local generation technology, and allow to incorporate different sources of energy supply (CHP, use of waste heat or solar thermal), thus constituting a technology that increases the efficiency of the complete cycle generation-consumption.

This paper presents the feasibility study of a DHC network to supply thermal energy to a group of companies located in Technology Park located in Málaga (Spain). It is remarkable the adaptation of this technology to Mediterranean climates in which winters are mild.

2. Methodology

2.1. Demand characterization

Energy demand evaluation is the starting and the most critical point to face a problem of this type, since it allows to determinate which are the heating and cooling needs in the consumption points to supply. The complexity in determining the demand for air conditioning in a group of buildings is not easy because the modelling a set of buildings is a complex tax. Several authors, such as Gustafsson [4], Heiple [5], Huang [6], Pedersen [7] or Segen [8] have developed various methods to solve this problem. In these papers, two types of strategies for estimating the demand could be found:

Top-down strategy: it is based on statistical methods for predicting the demand for a set of buildings based on aggregate data in large communities (cities or regions). Under this approach Pedersen [7] presents a method for calculating the demand for heat and electricity power planning adapted to large areas where heat demand is based on a regression analysis that uses the outdoor temperature as independent variable.

B**ottom-up strategy:** this case is the opposite that previous method, ie the starting point in this case is the estimated demand of different building types and total demand is calculated as the sum of the demands of each of the buildings that comprise. An inventory of buildings that are in the area of study is needed to use this method because each building is assigned to a "building type" that will carry the energy demand mean values. Mathematically:

$$Demand = \sum_{i=1}^{N} (A_i \cdot \sum_{j=1}^{M} EUI_j \cdot P_{ij})) \qquad (1)$$

Where A is the net surface in each building, EUI_j is annual energy demand for each building type (M different types) and P_{ij} is the matrix that set the relation between net building surface and building type.

Heiple [5], Huang [6] and Segen [8] have developed methods based on statistical data and numeric simulations with the aim of getting energy demand profiles for a set of buildings according to their location, envelope and use. In the same line, Chow [9] addresses the design of a distribution network by simulating energy demand for each building type using EnergyPlus [21] and analysing global system with TRNSYS software [22].

In this case, a bottom-up strategy has been chosen. Although it is unknown use and type of each actual building, it is known the surface of the extension (651,334 m^2), the % of the area for each use, the net area of each parcel and it is known that the type of construction is not very different from the buildings that are currently operating in the PTA (according to the municipal development plan).

A deep study has been developed for the buildings currently in the PTA to get the main characteristics that define each building type and that will allow to define the thermal behaviour of the new buildings, the characteristics that have been identified are:

- **Envelope characteristics.-** due to the large variety used in PTA, the minimum values according to actual laws have been taking.
- **Glass surface.-** Up to three categories based on the % of glass in the façade have been defined: low glazing (<10%), medium glazing (10-75%) and high glazing (>75%).
- **Orientation of buildings.-** defined by the final orientation of the building.
- **Use.-** considering the current business in PTA and the allocation for the several uses according to the partial plan, the following uses have been defined: hotel with shopping centres, babysitting, light industry and offices.

Several building types have been developed using Energy Plus based on these characteristics, this has allowed to obtain the hourly profiles for heating and cooling demand of each of them. In order to ensure the model convergences, the following conditions have been established:

- Load and temperature convergence tolerance value: 0,1.
- Heat balance algorithm: conduction transfer function [20].

The results obtained with the simulations have been validated and adjusted to reference values for the same purpose buildings that have been previously published by other authors [10], [11] and [12]. For instance table 1 show some reference values:

Table 1. Reference data consumption for buildings.

Use	Mean Consumption (kWh/m^2)	Cooling %	Heating %
Offices	131,57	42	4
Hotel	312,66	28	12

Once the different models of buildings have been adjusted in terms of thermal behaviour, the possible location of different types of building have been allocated according to the uses defined in the partial plan and the main characteristics of actual buildings in the PTA. This division has allowed evaluating the total demand of all buildings according to equation 1.

Another point considered in the analysis of the demand is the change in the occupation of parcels over time, this analysis will reveal the annual demand of thermal energy and thus affect the economic valuation of the proposed solutions. It has estimated by regression techniques based on the evolution experienced by PTA from its inception to the present. The result is shown in Figure 1:

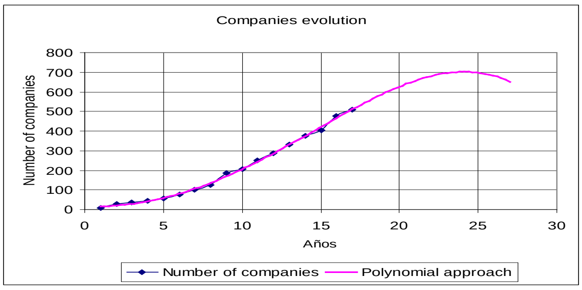

Fig 1. Number of companies installed in PTA

The regression curve of order 4 which adjusts the actual data with a regression coefficient of 0.9978 is:

$$y = -0{,}0031 \cdot x^4 + 0{,}0482 \cdot x^3 + 1{,}853 \cdot x^2 - 1{,}2072 \cdot x + 14{,}605 \qquad [2]$$

The energy demand values for each type of building together with the annual distribution of occupation of parcels allow to establish energy demand scenarios with a horizon of 10 years and make a more realistic assessment and economic valuation of the investments required.

Distribution system design has been calculated using peak demand values. DHC network is composed by a set of infrastructures that allow getting energy from producer to end-users. The design has been done considering the peak demand in year 10 because the infrastructure will not change during the entire period of operation thereof. The following components have sized: pipes, accumulation tank and pumping equipment.

2.2. Generation technology alternatives

After presenting the methodology for calculating demand, next question to ask is how the needed energy will be generated to cover the estimated demand. TRNSYS software will be used to study the different generation technologies; this will help to evaluate the efficiency and consumption parameters. The convergence of the models developed in TRNSYS to study the different technologies has been ensured by mean of energy balances. These balances guarantee good results from the models.

Previously, different technologies have been analyzed based on the work of Cardona [13], Marimon [14], Ortiga [15] and Söderman [16]; this analysis has permitted to reject those technologies that do not properly fit for the future expansion of the PTA and to work in-depth analysis of those technologies that fit better. Technologies that have been discussed are:

Biomass boiler.- the system includes a 20 MW biomass boiler for hot water production that feeds heating network, and the cooling-generating system. As support systems a 9 MW gas boiler and 6 MW electric chillers is selected.

CHP.- cogeneration gas turbine and reciprocating internal combustion engine (ICE in advance) are the two types of systems that has been analysed, in both cases a 2 MW rated power equipment has been selected. Sizing has been performed considering the recommendations made by Cardona [13], Ortiga [15] and Söderman [16], using that system that maximizes the area under the aggregate demand curve. Besides Spanish legislative frame[18] should be ensured. The 2 MW rated power guarantees both the system efficiency and the legislative requirements. In both cases, use waste heat from the engine or exhaust gases to generate useful heat will be used to heat water that will allow, in one hand, meet the demand for heating and hot water, and in the other hand, feed the cooling-generating system. As support systems a 9 MW gas boiler and 6 MW electric chillers is selected.

Waste treatment.- this technology has not been considered because there is no waste treatment plant close to the park that could serve as energy source to feed the DHC network.

Solar thermal energy.- it has not been considered as an alternative in order to supply the energy required. Both, the high costs associate with this technology and the high free spaces required mean that technology economically unfeasible (Bruno [17]).

Cooling generation technology.- double effect LiBr-water absorption chillers technology has been selected to cover cooling demand; this choice has been based on the analysis of advantages and disadvantages conducted by Marimon [14]. In all cases, a double effect absorption (BROAD 500) of 5.8 MW cooling capacity has been selected for cold water production. Additionally a water tank of 15,000 m^3 has been selected.

Finally, this paper has been focused on biomass boiler and CHP technology, these three technologies have been evaluated and compared with using conventional technologies, in which the cooling demand is satisfied by chillers and demand heating is covered by a gas boiler.

The following ratios are considered to quantify the results of the different technologies modelled in this paper:

For CHP technologies the following ratio will be used: ATE artificial thermal efficiency defined as:

$$ATE = \frac{E_{el}}{E_{input\_by\_fuel} - \dfrac{H}{\eta_{boiler}}} \qquad (3)$$

Net primary energy consumption (NPEC).- it's defined to compare different technologies consumption rates. The mathematical expression for NPEC is:

$$\text{NPEC} = (E_{el\_cons} - E_{el}) \cdot \text{C}_1 + (E_{input\_by\_fuel}) \cdot \text{C}_\text{i} \qquad (4)$$

where C_1 and C_i are the conversion coefficients for final energy (electric, gas and biomass) to primary energy in Spain; its values are 2,67, 1,06 y 1,25 respectively [19].

$COP_{instlallation}$ defined as:

$$COP_{installation} = \frac{P_{term}}{E_{el\_cons} - E_{el}} \qquad (5)$$

These ratios will allow, in one hand, ensuring that minimum standards required by Spanish Royal Decree 661/2007 [18] are met and, in the other hand, knowing the overall performance of the system. This will facilitate the subsequent economic evaluation.

2.3. Economic analysis

The economic analysis has been performed considering the following topics:

- Depreciation cost for investments.
- Maintenance cost.
- Operating cost (energy, human resources, overall costs).
- Revenues from energy sales.

These topics have permitted to evaluate investments in terms of return on investment (ROI in advance), payback period and cumulative cash flow.

3. Results

Results obtained in the evaluation of demand, technology and economic assessment are as follows:

Energy demand and DHC Network design parameters.
Hourly profiles were obtained for heating and cooling demand in all buildings under study, considering the evolution of demand along the time as the occupation of the parcels is increasing. The monthly annual evolution for heating and cooling demand in the first 6 years is shown in Figure 2. It has been supposed that new buildings will be operative in the first six years. So, for years 7 to 10, the demand does not suffer modifications.

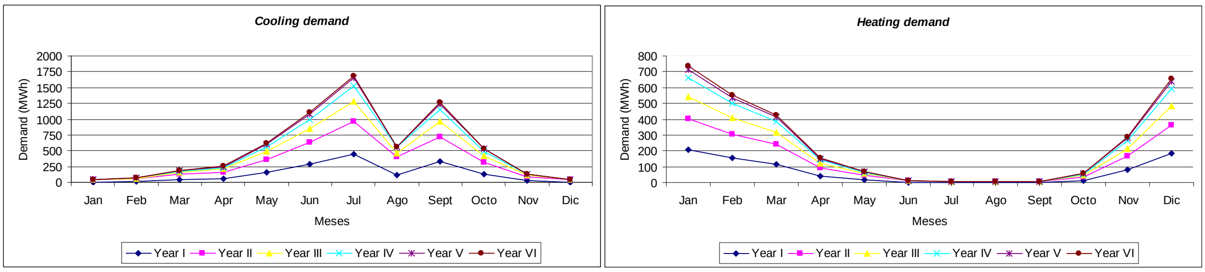

Fig 2. Cooling and heating demand evolution

As we can see, the cooling demand is highly reduced in August, since has been estimated the vacation period in this month.

In figure 3 the aggregate demand curve for heating and cooling in the year 10 is shown, this curve is very useful for sizing CHP equipment.

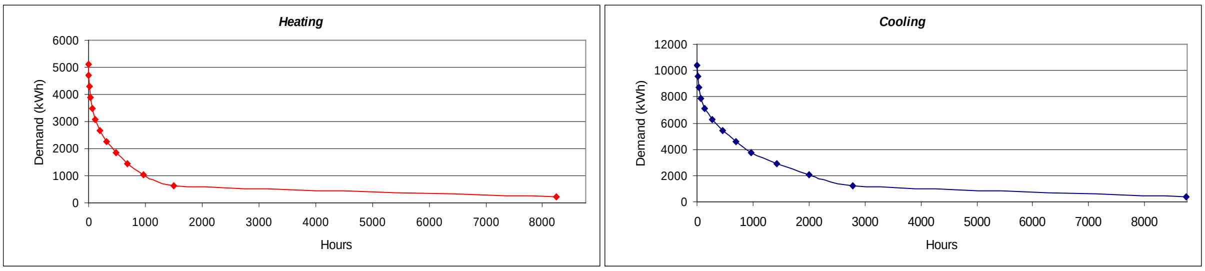

Fig 3. Aggregated demand curve for cooling and heating

As it is shown in the above figures, peak demand for year 10 has been set to 7.77 MW for heating and 12.22 MW for cooling. With those maximum power values and considering a temperature drop for heating of 30 ºC and 8 ºC for cooling, the maximum network flow is obtained: 61.8 kg/s for heating and 364.6 kg/s for cooling. These values along with the requirements of pressure loss in the network, and energy loss have led to size the diameter and thickness of insulation for the main pipe network and pumping system. Table 2 shows the design values of each of the components:

Table 2. Design DHC network parameters.

	Pipes DN (mm)	Isolate thickness (mm)	Power pumps (kW)	Tank volumen (m^3)
Cooling	600	7,1	315	15.000
Heating	350	5,6	75	-

Technologies evaluation

Table 3 show the results for technologies performance ratios calculated using TRNSYS.

Table 3. Design DHC network parameters.

	Net primary energy consumption (MWh)	COP installation	ATE
Conventional tech	27.030,55	0,353	-
Biomass boiler	29.117,90	0,328	-
Gas ICE	14.332,39	0,666	0,566
Gas Turbine	22.533,64	0,424	0,589

Economic analysis

Table 4 show the economic analysis for each of the technologies evaluated and figure 4 show cumulative cash flow for each technology:

Table 4. Economic analysis.

	ROI	Payback (years)
Conventional tech	< 0%	12,5
Biomass boiler	< 0%	16
Gas ICE	9,63 %	8
Gas Turbine	1,69 %	10

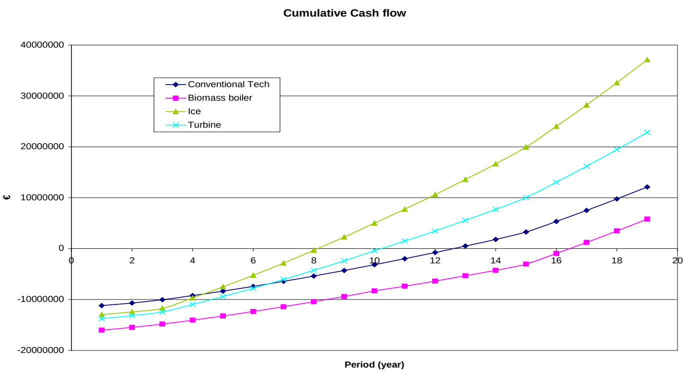

Figure 4. Cumulative cash flow analysis

4. Conclusions

As it could be seen in table 5, the technology that offer the minimum pay back period is the Gas ICE following by the Gas Turbine, this fact is consequence of the electricity production associate with those technologies that offer economical benefits. For Gas ICE, the benefits begin to be positive since year 8. It is obvious that infrastructure costs are very high in DHC. Economic figures are critical in the early years when buildings begin to establish in the technology park network and the energy demand is low.

The economic results showed support the implantation of a DHC network under the considerations done. The limitation for the feasibility resides in the future evolution of the new building openings. In this case the funding model of this type of technology must go through a public-private hybrid model in which the government support with soft credits to be repaid at the rate of new companies in the PTA are incorporating to DHC network, it will help owner company to obtain an acceptable incomes in the early years of operation.

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Sustainable Parameters for Latin American Cities

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Abstract: Over the last few decades, Latin American cities have been undergoing a rapid process of population increasing. With scarce investments in infrastructure, they are unable to meet the demands. Some of the consequences of this excessive population growth include a failure of the transport system, inefficient public services, the formation of urban heat islands, among other consequences, all of them contributing to a steep fall in life quality and energy consumption increasing.
Given the precarious conditions observed in large Latin American cities, especially in metropolitan areas, and the disconnection between the urban built and natural environment surrounding them, there is a call for action, from intervention in the territory already consolidated, to the development of future cities through sustainable urban criteria.
This paper presents some parameters to guide contemporary urban design criteria in the planning of sustainable cities. It started from a theoretical approach guided by international authors with different views on such parameters. The methodology is based on a qualitative study considering urban design issues relating to sustainability, such as urban management, adequacy of climate and place, regionalism, physical limitations of the city, the mixed uses, productive city, integration between urban and rural, and no polluting mobility.

Keywords: *Sustainable Cities, Sustainable Parameters, Urban Design*

1. Introduction

The environmental problem today is a much discussed subject in academic circles. However, this theme is not introduced in the social consciousness as a result of scientific papers, but by the effect of environmental disasters aggravated by the unsustainability of current cities, mainly, in the metropolises of South America. Furthermore, the typical living standards are incompatible with the process of regeneration of the environment, the wide variety of population's consumption patterns of different countries and the increasing rate of social inequality in many of them contributes to the increased awareness of various social sectors on the need for new forms of intervention in the environment.

The possibility of actuation in existing cities and in the formation of new cities more sustainable guides this work, that have the purpose of thinking about urban design environmental parameters. Thus, it is proposed some categories that contribute to the systematization of the study: limiting urban environmental management, network of cities, regionalism, diversity of land use and productive cities. From the analysis of these categories it was searched to implement environmental parameters for urban actions in small and medium cities, and also in the formation of new cities.

The vast majority of developed countries, as much as those in development, are exploring the capacity of their natural resources to the limit. Depending on the level of industrialization of each country there are different problems. In developed countries, the migration of people from urban centres to the outer suburbs, which offer a natural more prosperous environment, has led to an increased use of automobiles, resulting in traffic jams and air pollution. Already

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in Latin American developing countries, environmental and social problems are intensified by the excessive growth of cities, the result of a centralist model of urbanization without accompanying infrastructure to support such increase.

The effects of global climate change brought environmental problems and put in focus the search for new solutions to the urban development process. The rational use of natural resources, consumer awareness, and social and environmental justice began to be treated as guidelines for urban planning, even if sometimes only theoretical.

Urban sprawl without limitation on the territory brings disastrous consequences for the environment, for example the reduction of the surrounding areas for agriculture and natural reserves, and also the intensified and confined use of natural resources without respecting the carrying capacity. Without urban limitation, the disastrous effects can be observed also for the population, such as failure of adequate services and infrastructure of several structural problems such as mobility, access to health and education.

Life in cities is the current preference of the vast majority of the population and cities are seen as centres of knowledge and culture. Thus, it is important to think about these urban agglomerations in a global and sustainable way, especially with regard to planning and urban design. It is believed that urban design can be a key ally to the possibility to plan more sustainable cities, besides the need for an urban management consistent with sustainable urban parameters.

2. The aim of the paper

The Latin American countries have experienced the swelling of their cities. This process guided by a centralist model of urbanization, coupled with a growing shortage of infrastructure and perspectives - as cities move far away from large centers, promotes the emergence of mega cities, full of big problems. The idea in this work is, starting from more sustainable principles, to seek parameters to point out the way to formation of new towns, and the acting in small and medium cities.

3. Methodology

From the theoretical framework relevant to the subject, from theories and information contained in different references on the general problems experienced by cities in the world today - due to lack of actions that are concerned with sustainable development - it was possible to define categories that deal with urban sustainability. From these categories it was developed a qualitative study looking for the determination of relationships among them and with the urban design, covering issues relevant to the development of a sustainable urban design for cities in Latin America.

4. Results and Discussion

It was possible to identify seven major categories that can delimitate the urban design and assist in their preparation. These categories are: urban management (consistent with sustainable development), limitation of the city, regionalism, mixed uses, productive city, integration between urban and rural, and mobility.

4.1. Urban Management

The first raised category was the **promotion of policies and actions** that might be able to generate a sustainability committed to social justice, focusing, therefore, on the rights and basic needs of citizens. Through public policies and actions it is possible to reduce inequalities and ensure access to urban services. It is expected that a socio-political planning assures a decent income and a sustainable and balanced social and economic development and, in addition, combating speculation and privatization of natural resources. For this, the **society participation in the policy making** and in the oversight of government activities is of paramount importance. The democratic management oriented by sustainability paradigms requires responsible action of social actors.

The planning criteria that seek for sustainable development must be considered as one of the main objectives of the socio-economic balance of society, besides the improvement in quality of life, the management responsible for environmental preservation and rational use of the territory (The European Chart for land management - CEOT/CEMAT, 1983). Furthermore, it is necessary to **strengthen local autonomy** for the municipal power to manage the financial assets of the city, gearing to investments that ensure a **more just and secure city.**

For Rogers (1997), for the city to be sustainable the economic and sociology factors should be interwoven and integrated into urban planning. Moreover, the motivation of citizens and their participation in public decisions and policies must be guaranteed (the sense of belonging and democracy). In this regard, it is necessary to the actuation of technician expertise, and the diffusion of educational activities and the implementation of information tools to empower and enable the society activities with the State.

It is important to promote the citizen participation in shaping the territory seeking from the beginning, the major motivation of actors in policy making and urban areas, allowing greater community awareness about its urban space and educating the population on environmental problems.

4.2. Urban Limitation

It is important to call attention to that environmental impacts are interrelated and urban poor planning, or its lack, as well as an inadequate urban design can bring undesirable consequences in sequence; as, for example, public policies for urban periphery and the designs that emphasise the private automobile. Urban sprawl intensifies the need for automobile use, which increases the demand for infrastructure (roads) and fossil fuels. A lack of limitation may also contribute to urban deforestation, causing erosion and consequent siltation of rivers.

To ensure good governance and a population access to political decisions it is necessary to limit the size of the metropolis (CORBELLA, 1998). It is believed that the city should be limited by legislation to control land speculation. Moreover, the government should encourage investment in different areas, so that from a certain size of the first city the construction of another city should be encouraged. This capacity of the government allows it to act on local issues, focusing on the common good, linking capabilities, and regional and global needs. If, for example, other surrounding areas are encouraged and every city has around it a "green belt" of protected land speculation, used for both food production and for environmental conservation, urban areas will be delimitated[2].
These measures cannot be applied in large cities already moulded, but can be used in small and medium shape cities, preventing them from growing out of control [3]. The structure in

2 The green belt was firstly proposed in 1904 by Howard (HOWARD, 1996).
3 A deep analysis of the unsustainability of megacities was made by NEIRA ALVA (1998).

smaller cities connected together in a network is much more sustainable than large cities. The smaller number of inhabitants, and consequently, infrastructure, facilitates the public administration and increases society control over political power, reducing corruption.

However, it is no use limiting the city area to preserve the soil and facilitating the movement of pedestrian, and then densify it. It is necessary to refer both to limit the area built as well as the population. A small town, but still very dense, continues over-consuming and polluting with the same intensity.

One of the “so called sustainable” principles in recent years, mostly widespread by Rogers, is the formation of dense cities (ROGERS, 1997). However, densification may even represent an attempt to soften the urban and environmental problems caused by the macro scale, but at the same time, it causes new problems such as intense vertical cities, affecting ventilation and natural lighting, and the concentration of air pollution. Furthermore, in the case of the tropical Latin American cities, there is the issue of high temperatures, also improved by the lack of ventilation, allowing heat islands (BARBOSA, DRACH and CORBELLA, 2010).

It is known that large scattered cities generate big problems, but the densification of cities does not guarantee sustainability, although is still an attempt to avoid environmental problems in these cities. From the bioclimatic point of view, in the humid tropics, as stated above, the compact city promotes the formation of heat islands, with the consequent increase in electricity consumption for air conditioning and the production of pollution (BARBOSA, DRACH and CORBELLA, 2010).

Rogers (1997) considered that the "densification" of a city can bring ecological benefits, such as reducing air pollution by cars, that did not need to move large distances, the greater safety of urban centres, the reduction of the city expansion over the natural landscape and the integrated planning, that optimize the use of energy resources and reduce pollution. But if this city offers a quality of life for its city dwellers, it will soon undergo an exponential growth that will take out all the benefits achieved by its promoting big density.

Consequently the problem is not compactness, but the lack of physical limitation. The creation of limited new cities could help curb the population growth and to endorse the healthy migration from the unsustainable megacities. This design conception brings all the possible advantages of compact cities, without the problems caused by macro-scale, and it also promotes a better society participation in the policy decisions. A small city may be socially diverse, in which different social and economic activities can multiply and society could integrate more easily (MOORE, 1998).

It is appropriate that the city to be organised through reduced nodes (districts) to form a circular system that enables interaction between them. Still, resources and services all over the city and its surrounding territory should be redistributed, decentralizing services and urban equipment and creating a network of activities and information to assist in the reduction of dislocations with cars through polycentric neighbourhoods. This organization contributes to solve one of the serious problems of current planning - the linear cities that normally follow a highway. Linear growth can be avoided if other surrounding areas are encouraged. In addition to the internal network of the city neighbourhoods, a network of cities that fosters exchange of resources and services through a polycentric system should be considered.

4.3. Regionalism

The considerations about the natural and urban environment cannot be separated from social and political issues. Cities can be interpreted as parasites that absorb the region resources in order to survive, or can be designed to absorb the population growth and provide opportunities, instead of harming the region future. For this, we need to understand that the Earth is a system that took millions of years to accumulate resources such as fossil fuels and water and that these resources should be used rationally and sustainably.

For many years, especially in the last hundred years, these resources have been extracted and consumed without any criteria and, thus, producing pollution that causes serious environmental problems as acid rain and global warming. Remarkable is the "circular metabolism**"**[4] for cities, where consumption is reduced, improving performance and increasing the reuse. Cities today have a 'linear metabolism' in which there is an inflow of resources like energy and food, and the consumption of such materials within the city presents, in sequence, waste production and emission of toxic gases (Figures 1 and 2).

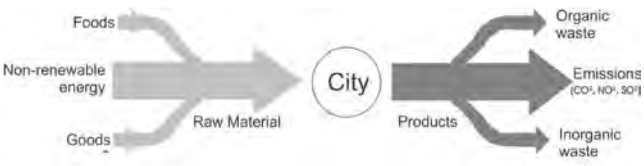

Fig. 1 – Linear Metabolism.
Source: Adopted from Rogers (1997)

Fig. 2 – Circular Metabolism.

The proposal for a "circular metabolism" is based on materials recycling, reducing energy consumption, the conservation of exhaustible energy and the use of renewable energy. These circular processes reduce waste and pollution, and improve the use of resources enabling the better use of consumer goods. To achieve a circular system, the best way is environmental sustainable urban planning. Also, we should promote the solution of environmental problems at every stage of the cycle from the beginning (incomes) to the end (exit of waste). By focusing on the "circular metabolism" through the conservation of energy and materials and by encouraging recycling, urban sustainability is promoting.

Environmental planning establishes a sustainable concept of integration between the built environment (buildings and cities) and the surrounding natural environment (climate, geomorphology, flora and fauna), in order to minimize the negative environmental consequences such as pollution of the environment and excessive production of solid and liquid wastes (HIGUERAS, 2006).

A detailed study of environmental and climatic characteristics of each place is the active part of this process of decision making and concrete proposal of planning. Regionalism is vitally important for a successful environmental planning. It is essential to profit the place weather characteristics to design and build the various components of urban and architectural elements as bioclimatic (CORBELLA and YANNAS, 2009). It must also be considered the issues on the territory that is analysed, about society, about the urban environment in question and also about the urban plans made earlier in the region.

[4] Concept addressed by Herbert Girardet (1993).

4.4. Incentives for mixed uses

The Zoning, heavily used by the modernists, tends to avoid the urban complexity by reducing the cities to simple divisions to obtain a greater ease in their management, from legally and politically point of view. But at the same time it prevents a healthier relationship between man and the environment and his fellows.

The work areas are normally located in urban centres that are deserted and dangerous at night, and housing and leisure are situated in more distant neighbourhoods connected by highways to the city centre. The environmental impact caused by this zoning is much greater than the impact of plans in which work, leisure and residential environments come into close, and often shared, places.

It is necessary to enhance the mixed use to mitigate energy consumption by reducing the distances between activities. This way of planning a city not only diminishes the excessive energy use and pollution, but also reduces the uncertainty in the urban centres for citizens to exercise control over their habitat.

4.5. Productive Cities - Work and Income

Another important category for a sustainable urban design is its conception as a productive city (MOORE, 1998). This condition gives characteristics of stability and sustainability to the city: the best way for a human being to settle down in a place is when he gets his livelihood from it.

It is essential that the population produces part of its food and its material needs, because it promotes pertinence as well as lowers transport spending and brokering, and it generates income and employment for the local society. It is important to balance food production and consumption, and also the need for all the cities to produce at least the basic and essential food for the local population. The incentive for production activities and services geared towards the promotion and preservation of the natural environment is an urban strategy that emphasizes both human welfare and nature. In rural areas it is important to enable people to work with agro-ecology and eco-tourism education.

It is essential the promotion of diverse manufactures of the productive cities, following the regional vocations in which different activities will inspire and promote a vital and dynamic community. The planners should understand, with the participation of citizens, the complex relationship between population, services, transportation policy and energy generation, as well as the impacts of these relationships on both the immediate surroundings and on the wider geographical domain.

As a result of the economic restructuration produced by globalization, a reduction of jobs has been produced and, this way, changed the urban landscape with the rise of the informal work. To enable productive cities that create jobs and income it is required: 1- policies for micro and small enterprises; 2- the encouragement of cooperatives in all branches of the system and the multiplication of business incubation; 3 - the training of different actors of society; and 4 - the encouraging the small farmer agriculture.

4.6. Integration of the natural environment, rural and urban

Nowadays there is a dichotomy between basic conditions in the city and the countryside, not only for the change in quality, velocity and temperature of the air, but the expectations of humans, who prefer the city and move to it. The integration of the natural, rural and urban environment is then proposed as an improvement of the environment by introducing natural vegetation and creating regional corridors, and with the same importance in urban areas, promoting the balance between nature and city, preserving the natural cycles and putting green areas into the urban fabric. Thus, it also limited processes of uncontrolled urban sprawl, allowing a urban regeneration ecology.

The urban open spaces are very important because they serve as recreation areas and social use, in addition to provide more pleasant climates. These should be enlarged and properly designed to serve the people and to ease the negative urban environmental conditions. There is a necessity for properly planned urban spaces to allow the meeting and social exchange (VASCONCELLOS and CORBELLA, 2008). Hitherto such spaces, besides an architecture of quality, promote most beautiful cities. The quality of urban life can be encouraged through appropriate urban design, public safety and encouraging healthier environments, ensuring the physical and mental health of residents.

4.7. Mobility

In the traditional system of zoning, the automobile became the most important factor for urban planning. In the distribution of public spaces, all streets and avenues, and many times also parks, are designed to meet the needs of cars and not for pedestrians. The street, which was previously a local of exchange and social gatherings, today has been taken over by cars. To change this picture, besides the planning of mixed neighbourhoods it also must be encouraged public transportation or alternatives as cycling or walking to their own service, that are essential for a sustainable urban planning (CORBELLA, CORNER and BARBOSA, 2008).

The planning of smaller cities requires the end of the dominance of the automobile and the enhancement of pedestrian and public transport alternative. The city must grow through joint centres with mixt activities connected by public transportation with good quality, constituting an agglomeration of neighbourhoods with their own shopping areas and public parks.

5. Considerations and Recommendations

Over the past fifty years all the Latin American countries have experienced the problem of excessive growth of their cities. This swelling generated by similar processes and their problems were magnified by the growing scarcity of infrastructure and perspectives, a phenomenon that is incremented as cities move away from the big cities, and led, and continues to lead, to the formation of mega cities, full of great problems.

The assessment and determination of categories for the achievement of specific cases depend on the physical conditions of the region, the available place and the cultural and socioeconomic characteristics of future inhabitants, and with their participation it will be possible to define the solution of many issues related to sustainable cities. Most of the quantitative problems to be solved for the construction of sustainable cities have no general answers for the fact the solutions depend on the statement of the regional characteristics: the particularities of the region determine the numbers of local individuals who take in each category of analysis. Several factors are involved in these dynamics, and every minimal alteration of each of them may change the whole relationship of the structure.

The possibility of public power to intervene in the cities through policies and actions that promote the common good, paying attention to sustainability issues, makes it the greatest ally in attempts to introduce strategies that are beginning to be delineated. The categories suggested here for the systematization of the study indicates a strong connection: limiting urban environmental management, network of cities, regionalism, mixed uses, productive cities, relationship between rural and urban mobility. Thus, by pointing out the strategies or environmental parameters for action in urban cities that are designed to be sustainable, the focus is related to finding ways for an effective public involvement.

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Urban microclimates and renewable energy use in cities

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Abstract: This paper presents an experimental measurement campaign of urban microclimate for a building complex located in London, the United Kingdom. The experiment was carried out between 19 July and 16 August, 2010 at the Elephant & Castle site. The wind and solar energy distributions within the London urban experimental site were assessed in detail for their potential use in areas of high-rise urban building complexes. The climatic variables were measured at every five minutes for the air temperature, the wind speed and direction, the air humidity and the global solar radiation for a period of four weeks. The surface temperatures were also measured on the asphalt road, pavement and building walls at every hour for the first week of the campaign period. The effect of the building complex on the urban microclimate has been analyzed in terms of the solar radiation, the air temperature and velocity. The information and observation obtained from this campaign will be useful to the analysis of renewable energy implementations in dense urban situations.

Keywords: *London, Urban Climates, Measurement*

1. Introduction

Effective urban planning and building design can have a beneficial effect on the urban climate and contribute towards reducing the intensity of urban heat island, improving living space, directly reducing the peak cooling load of a building and exploring potential implementation of renewable energy. Passive solar heating of houses in winters and passive cooling in summers provide low cost and sustainable solutions for these preferable outcomes. However, to achieve these solutions in high-rise and densely built urban environments are challenging due to the obstructions at close proximity and existing orientations of roads. Knowledge of microclimatic variables, particularly the urban wind and solar radiation can be used for developing better design options for renewable energy technologies within urban environment or determining their efficient operational conditions in cities.

In the literature, however, the microclimate within an urban complex is reported mainly in the context of air circulation and temperature distribution within urban street canyons, only. In these studies, the geometric characteristic of the urban layout is idealized as infinite parallel walls of street canyons. Santamouris et al. [1] studied the thermal characteristics in a deep (H/W=2.5) pedestrian canyon with a NW-SE axis, under hot weather conditions in Athens, during summer 1997. It has been observed a surface temperature difference of up to 19 °C, between opposite building walls. Air temperature difference near the two opposite facades varied up to 4.5 °C due to the impact of convection heat transfer from adjacent wall surfaces.

Similarly, Niachou and et al. [2] also reported an experimental study of a typical street canyon (H/W=1.7) oriented in ESE-WNW direction in Athens, again under hot weather conditions in 2002. The measured surface temperature difference across the street reached almost 30 °C and this caused the overheating of lower air levels. The microclimate in urban street canyons is also investigated by numerical studies [3, 4, 5,], with emphasis on pedestrian comfort, pollutant dispersion and natural ventilation. For an urban district, an experimental

investigation for the distribution of solar energy and wind energy for a general, random city layout was not available in the literature.
The present study investigates - unlike a simple layout of a street canyon, a general geometric characteristic of urban layout with high-rise and intensely spaced building complexes that are mixed with middle-rise buildings. The main objectives of this experimental investigation are: to quantify the temporal and spatial distribution of microclimatic variables for an urban site; to study the impact of the layout and orientation of buildings on these variables; and to assess the availability of the solar and wind energy within an urban building complex for their potential use, either actively or passively.

For this purpose, within a London urban district of the Elephant & Castle, the accessibility to the renewable energies- both the solar and wind energies, was studied experimentally by a field measurement campaign between 19 July and 16 August, 2010. The air temperature, the wind speed and direction, the air humidity and the global solar radiation were measured at four locations within a high rise building complex at the London site. The maximum distance between the measurement locations was 130m. Effects of the urban building complex on the thermal and airflow characteristics of the resulting microclimates were analyzed in detail. The surface temperatures of building walls and ground were also measured at these locations. The observed characteristics of urban microclimate at the London experimental site and the findings of the present study are presented in this paper.

2. Experimental method

2.1. Experimental site

London is located in the south of England, UK. , and has an elevation of 24m. It enjoys a temperate marine climate. The Elephant & Castle site has a global location of $51^o 29'$ N and $0^o 06'$ W. Figure 1 displays the London urban experimental site and the measurement points: 3, 4, 5 and 6. The experimental site was chosen for its high rise buildings and contrasting street layouts. The physical characteristics of the urban space are presented in Table 1. The London South Bank University Southwark campus occupies the central part of the experimental site. At the time of the experiments, a 32m high K2 building of the campus (Fig.1) had replaced previous low-rise buildings at the same location.

Four automatic weather stations (WS) were installed to the street-lighting columns that are located at the Ontario Street (3), Keyworth Street (4), the Thomas Doyle Street (5) and the Borough Road (6). The Keyworth Street (4) represents an urban street canyon linking Ontario Street (3) and Borough Road (6), and has a length of 230 meters. The weather station 3 that was installed at the dead end of Ontario Street faces the back of the surrounding buildings in every direction. The street level views of these four streets are displayed in Fig.2.

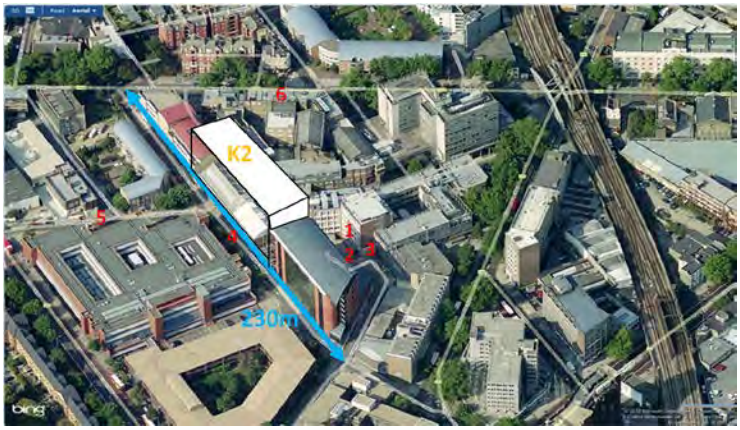

Fig. 1. London urban experimental site at Elephant & Castle (locations of weather stations: 3, 4, 5, 6)

Borough Road (WS-6)

Keyworth Street (WS-4)

End of Ontario Street (WS-3)

Thomas Doyle St. (WS-5)

Fig. 2 Street views of the London experimental site at Elephant & Castle Borough

Table 1. Characteristics of four streets at the London experimental site.

Street name	Street orientation	Weather Station No	Traffic conditions	Vegetation
Ontario St.	SSW to NNE	WS-3	Access only	None
Keyworth Street	SE to NW	WS-4	One way, low traffic	Trees at one side
Thomas Doyle St.	SW to NE	WS-5	One way, low traffic	None
Borough Road	WSW to ENE	WS-6	Two way, main road	Trees at both sides

Table 2. The geometry and material information of London experimental site

Street name	W(m): Street width	H/W: Ratios of building heights {H} to W	Building materials	Albedo
Ontario St.	14	0.57 – 2.00	Bricks, concrete	0.10 – 0.35
Keyworth Street	12	0.75 – 2.66	Bricks	0.20 – 0.35
Thomas Doyle St.	14	0.64 – 0.87	Bricks	0.20 – 0.35
Borough Road	22	0.45 – 0.68	Bricks	0.20 – 0.35

In table 2, for each street, the spacing between buildings (W) across the street including the pavements and the ratio of building heights (H) to spacing between the buildings (W) are listed alongside the type of building materials and their albedo values. The range of H/W ratios at each street represents all buildings along the street.

2.2. Parameters of measurements

At each measurement location (3, 4, 5 and 6), the air temperature, the wind speed and direction, the air humidity and the global solar radiation were recorded by an automatic weather station – Davis Wireless Vantage Pro2, Fig.3, which was attached at a height of 4m to a street-lighting column. The weather station 3 (WS-3) is located at the-dead-end of the Ontario Street, but, the other columns are positioned at the mid-distance of the streets. The accuracy of the integrated sensor suite (ISS) of the weather station for measuring each climatic variable is 0.56°C for air temperature, ± 5% for the wind speed, ± 7 deg for the wind direction, ± 3% for the air humidity and ± 5% for the solar radiation. At each street lighting-column location, the surface temperatures were also measured on the asphalt road, pavement and building walls at every hour. A K-type thermocouple digital thermometer – Model WK026, is used for the surface measurements.

Fig. 3 A view of the automatic weather station, positioned at 4m.

2.3. Duration of field measurements

The measurement campaign was carried out between 19 July and 16 August, 2010. The microclimatic variables were measured at every five minutes during the campaign period. During the first week of the campaign: 19 – 23 July, the surface temperatures were also measured every hour, over a period of five days.

3. Results

The experimental observations of the microclimatic variables at the London urban site are presented here for the air temperature, the air speed and the solar radiation. Figure 4 displays the evolutions of air temperatures at four locations over a 24 hours period from the midnight to midnight on 24 July 2010. During the day time, the air at the dead end of the Ontario Street (WS-3) is generally warmer than the air at the Borough Road (WS-6). The air temperatures at other locations remains between these bounding values of WS-3 and WS-6 However, the air temperatures at all locations get closer each other's value at the night time. The pattern in Fig.4 has observed also for the other days of the experimental campaign period. For example, Fig. 5 displays the air temperature evolutions at the locations of WS-3 and WS-6 for an interval of one week, between 2 and 8 A ugust 2010. The factors affecting this pattern are discussed in section 4, below.

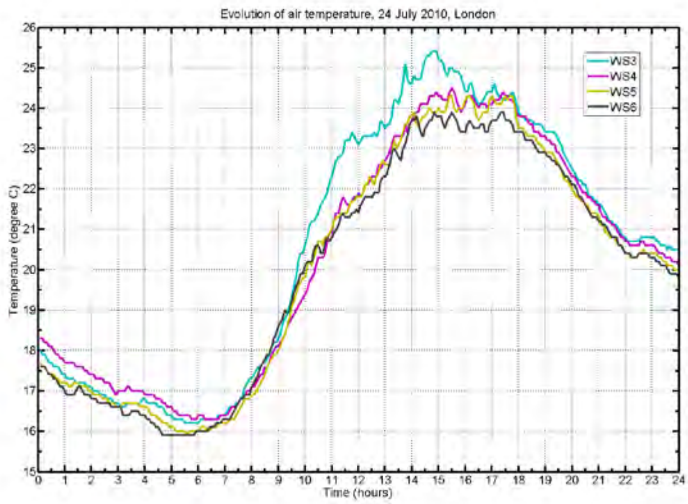

Fig. 4 Air temperature distributions at the London experimental site on 24 July 2010

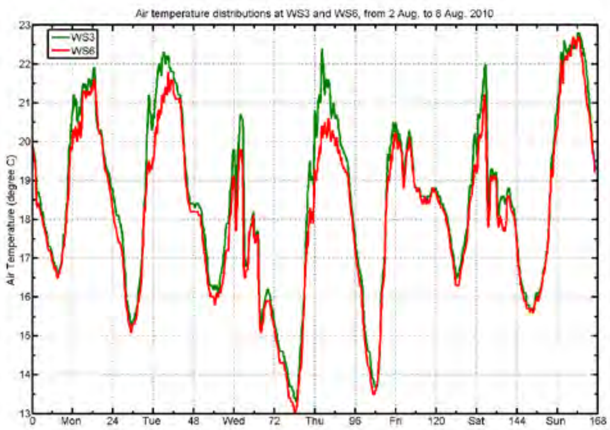

Fig. 5 Weekly air temperature evolutions at the dead-end of Ontario Street (WS3) and the Borough Road (WS6), 2 – 8 August, 2010

4. Discussion and conclusions

The layout of buildings and their orientations interact with the wind and the solar radiation and this interaction forms the different microclimates at each location. As is observed from these experimental results, Figs 4 and 5, the variation of air temperatures from location to location is an outcome of this interaction. Similarly, in an urban environment, the renewable energy use – solar or wind energy is also affected by spacing between buildings, building heights and their layout and orientations. For the measurement points of WS-3, WS-4, WS-5 and WS-6, the variation of the daily solar energy received by a horizontal surface over a period of one week and the variation of daily windiness over the same period are displayed in Figs. 6 and 7. Two new derived variables are calculated for this purpose; theyare wind run and the solar energy received at a given location over a time period.

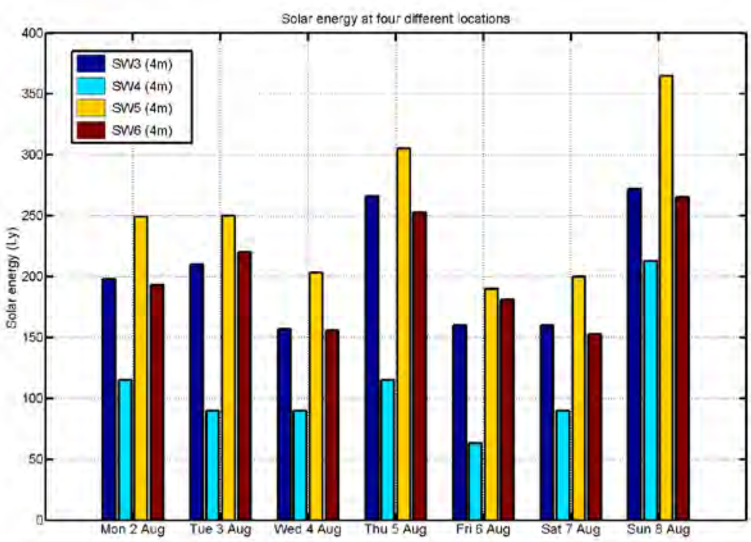

Fig.6 Daily solar energy variation at the London experimental site, from 2 to 8 August 2010

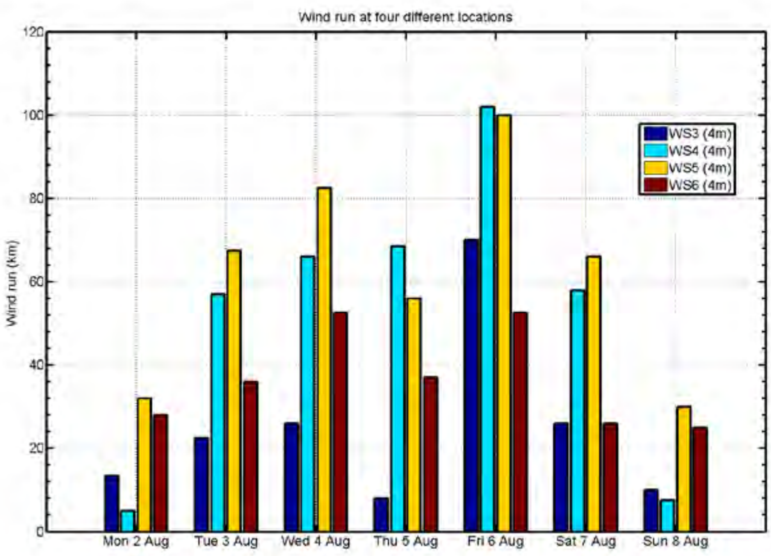

Fig. 7 Windiness of the London experimental site between 2 and 8 August 2010

Wind run presents the "amount" of wind passing the location of the weather station during a given period of time, expressed in "kilometers of wind". It is calculated by multiplying the average wind speed for each archive record by the archive interval of five minutes. By taking into account the variation of the solar radiation arriving at a location due to the position of the sun in sky, the passing clouds and shade movements, the resulting solar energy received over a time interval is also calculated. The average value of the solar radiation (watt per square meter) for each archive record is multiplied by the archive interval of five minutes to calculate the solar energy for the archive interval. The solar energy is measured in Langley (Ly): 1 Langley = 11.622 Watt-hours per square meter.

On Friday, 6 August, the dominant wind direction above the roof of K2 Building (32m) was in the SE direction, which coincides with the axis of the Keyworth Street (WS-4). As a result, WS-4 reaches the highest daily wind run value for this week, Fig.7. During the week, the dead-end of Ontario Street (WS-3) was the most sheltered one, and also having high values of the solar energy. As a consequence, the air at the dead end of Ontario Street (WS-3) warms up the most among all the locations, as was observed in Figs.4 and 5.

On the other hand, while the Thomas Doyle St. (WS-5) also receives a high value of solar energy due to the less obstruction against the sun light, this street also a windy one. As a result, the air at WS-5 does not warm up as much as like the air at Ontario Street (WS-3). The urban street canyon effect at the Keyworth Street (WS-4) can easily be observed from Fig.6 as the reduced solar energy at there.

In this paper, the results of the experimental measurement campaigns for studying urban microclimates for high-rise building complexes in London are presented. Implications on using the solar and wind energy in urban environments are analyzed. It has been demonstrated that the layout and orientation of buildings cause the variation of microclimate from one location to another. While, the tree-lined road was relatively cooler, the urban street canyon received the direct solar radiation only for a limited period, thus also remained relatively cooler. Whereas, the air in the non-green area has trapped the most heat and the air temperature has reached its highest value. It can be concluded that the buildings are operating against their own individual microclimatic variables rather than the meteorological weather data and that a buildings microclimate is affected by the existence of other buildings.

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Development of a concept for ecological city planning for St. Petersburg, Russia

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Abstract: The aim of EcoGrad, a research project conducted by VTT Technical Research Centre of Finland, was to develop a concept for the design of appropriate ecological neighborhoods for the city of St. Petersburg, Russia. A criteria list for ecological residential areas was developed together with local partners. Some differing aspects between Finnish and Russian criteria are pointed out in this paper. These are among others the attitude towards high-tech solutions, the norms regarding placement of services, and the lack of well functioning service concepts for operation and maintenance of facilities. Three pilot cases were also studied. A rough plan was made for the pilot areas including placement of buildings and services and transport solutions. Different scenarios for energy consumption and production systems were modeled and compared. Also emissions during the entire life cycle of the energy production processes were calculated with Global Emission Model for Integrated Systems (GEMIS). One of these pilot cases is described in this paper. During the project a questionnaire for residents in St. Petersburg was also made. It showed, among others, a poor willingness to pay for renewable energy and good indoor air. One of the major findings was a lack of policies and knowledge for certain renewable energy technologies and improved energy efficiency of buildings.

Keywords: *City planning, Russia, Energy-efficiency*

1. Introduction

In Russia the ecological planning is still in the early stage of development. Energy production based on renewable energy sources is also a quite unknown solution. However, there are already some regulations that support the guidelines of ecological urban planning. One of these is the regulation that orders maximum allowed distance from residences to the daily used services, such as day care centre, school, shops and health care centre.

The aim of EcoGrad, a r esearch project conducted by VTT Technical Research Centre of Finland, was to develop a concept for the design of appropriate ecological neighborhoods for the city of St. Petersburg, Russia. Local features of the areas, such us Russian regulations, social and culture facts as well as local environment and weather conditions, formed the base data for the case studies. The project started in the beginning of 2010 and lasted until the end of the year 2010. The research report of the EcoGrad project will be published in English in the publication series VTT RESEARCH NOTES [1]. The objective of this paper is to present the development process used in the project and highlight some specific differences in ecological city concepts developed for Russia compared to Finland.

As partner on the Russian side was the Coordination Center for International Scientific-Technology and Education Programmes. The most important reason for having a Russian partner was to develop the contacts to the local government. Another reason was to get help with collecting necessary basic data. In addition a student from Saint-Petersburg State University of Architecture and Civil Engineering made a one month visit to VTT in order to help with data collection. A rough examination of the Russian building norms was made.

One of the guiding principles in the planning process was Globally Optimized, Locally Designed (GOLD) principle. Practically this means that the local conditions are taken into consideration, when applying global optimized solutions into the EcoGrad concept. The aim was to find suitable solutions for Russia from those globally studied and applied technologies and concept solutions that are already approved to be sustainable, and suitable for ecocities.

The project included three pilot residential areas locating in St. Petersburg. A rough city plan was drawn and different energy systems were modeled and calculated. These plans included different building types in the area (residential, services and offices), floor areas of each building type, number of residents, the energy consumption level of buildings, green areas, suitable transportation solutions, and the structure of the area.

Based on the findings from the pilot studies and negotiations with the local authorities, a criteria list for an ecological city plan was made, presented, and iterated. It included aspects from the international LEED and BREEAM criteria and national Finnish criteria. The criteria list is divided into following sectors: energy, buildings, transportation, the structure of the area, land usage, landscape, waste and water solutions. There are three categories in the criteria list: general level criterion, details and specifications of the criterion and special notices from Russia. [1]

2. Methodology

2.1. Progress and collecting data

The approach was in the beginning to collect basic data and directly create plans according the EcoGrad concept for pilot areas. The general data needed was the energy efficiency level of houses being built today, ventilation systems normally used, energy prices and tariff systems, building norms, city planning process description, other relevant local regulations (such as distances to the daily services) etc. Case specific data needed was: existing transport solutions, maps of the areas, the stage of the city planning in the area, expected amount of inhabitants, etc. However, it turned out to be very difficult to get reliable base data, because it is hard to get energy consumption data on a single building level. Therefore the approach was changed. First a basic concept, based on Finnish base data, was developed. It was presented to the local authorities and adjustments were made based on the feedback received. The concept was made in more detail by adjusting it to three different pilot cases. The detailed concepts were again presented to locals and adjusted. The development process could be called an iteration process. As a result, the minimum emission saving potential in Russia could be evaluated. However, even larger emission savings may be achieved in St. Petersburg, since it is probable that the current Russian buildings consume more energy than buildings in Finland.

2.2. Questionnaire study for residents in Russia

Together with Finec, the St. Petersburg state university of Economics and Finance, a questionnaire for residents was made. The questions were made by VTT, and the questionnaire was performed by Finec. The questionnaire had 750 answers, 600 per email and 150 per telephone interview and face-to-face interviews. The survey was devoted to the living area conditions opinions, which included answers regarding the housing, buildings and living areas, transport etc.

The main finding was that almost all respondents (92 %) said that it is of no value for them to have their house heated with renewable energy. Less than half of the respondents (40 %) are willing to pay extra for good indoor quality, even though 80 % answered that they consider good indoor quality important. Security issues could also be highlighted, 72 % said that they do not feel safe in their neighborhood, which can be compared to a study made in Finland that showed that 81 % of Finnish people living in urban areas felt really or quite safe [2]. The respondents want big apartments, over 100 m2, and they want to want to see parks, green areas and water when they look from their window. What also can be noted was that a rather big part, 44 % of the respondents do not own a car, mainly due to economical reasons.

2.3. Modeling of pilots

For each pilot case, a plan of the area was done, including the structure of the area, building types and location of services as well as transportation solutions. Different energy systems were modeled and compared. At first step, the base data was collected and a plan of the area was done. Number of inhabitants, buildings and necessary service spaces were settled.

At the second step, energy consumption of the entire area was calculated in different scenarios: base case scenario, low energy building and/or passive house level. The consumption level of base case scenario was assumed to correspond to the energy consumption level of Finnish building regulations in 2008, be cause reliable sources about Russian consumption levels were not available. Consumption level of low energy and passive houses were also based on Finnish definitions [3; 4]. The energy consumption of each type building was calculated using the WinEtana program which has been developed by VTT. WinEtana calculated the consumptions of different building types from the base data: the volume of the building, number of floors, the types, areas and U-values of ceilings, windows, roof and base floor, electrical equipments and their efficiency. These values for low energy and passive building levels are expert estimations by VTT.

Different options for renewable energy production were studied. Suitable production technologies were recognized, and then emissions produced during the entire lifecycle of the energy production process were calculated using the Global Emission Model for Integrated Systems (GEMIS), which is developed by The Öko-Institut e.V. The distribution losses were also included in the calculations. Results were compared with each other. According to IEA electricity transmission losses are 10 % and heat distribution losses 7 % [5].

Each pilot has its own characters and special aspects. First pilot was a residential area for 20 000 inhabitants. It was developed together with Pöyry Oy. The plan included different building types: one family houses, row houses and high rise buildings. The focus was on the factors affecting to the eco efficiency of the area (such as public transportation and walking and bicycling, green corridors, different building type areas, cultivation plots, placement of services and the entire area etc). This pilot has been presented shortly in this paper.

The second pilot was a residential area for 10 000 inhabitants, with residential high rise buildings. It was developed with a local building company. One starting point was to develop an ecological city plan without creating any extra investment costs. Focus was therefore put mostly on non-technical solutions, and the best suitable heat energy production was district heating with woodchip boiler. The third pilot was a smaller one, including only two blocks and less than 2000 r esident and the focus was on t he development of public-private partnership business models. It locates in the coast, on t he Vasili island, in central St. Petersburg. Therefore, the water heat pump solution was considered interesting, since it could also be utilised for space cooling. The electricity could be produced with building integrated solar panels as well as with small building integrated wind turbines. However, most of the electricity demand should still be bought from the national grid. As another options solar collectors were also modeled.

3. Results

3.1. The EcoGrad concept

The EcoGrad concept was developed in the EcoGrad project. The target of the EcoGrad concept is an ecological urban planning process, which takes into account local Russian operational environment. A result of this process is to achieve an urban area, which is as eco efficient, functional and comfortable place to live, as possible. The fields included in the EcoGrad concept are: dense structure of the urban area, local environment and basis, energy efficient buildings, renewable energy production, sustainable transportation solutions, waste and water management and social facts. The aim is to utilize the concept also in the future projects in Russia.

One of the key issues of EcoGrad concept is an integrated planning process. This means that all urban planning fields are taken into consideration together already from the beginning of the planning process. In other words, the continuous co-operation of experts of different fields is really important. Then it is possible to find the solutions that are best for the entire system both environmentally and economically as well as functionally. [5]

In an energy system of the EcoGrad concept, the primary aim is to minimize the total energy consumption of the area. The main focus has to be concentrated on t he energy usage of buildings as well as transportation, which are the most significant energy consumers. The energy consumption of buildings can be remarkably reduced with low energy and passive building technologies. On the other hand, the energy that is really needed in the area should be produced mainly from renewable energy sources. The optimization of the entire energy system, including heating, cooling, and electricity consumption and production, is important.

3.1.1. Factors affecting to the implementation of projects in Russia

The Russian building regulations can be found from the SNiP documents. The name is in Russia: СНиП - Строительные Нормы и Правила, which means Construction Rules and Regulations. SNiP is a set of regulations in the field of construction, enacted by executive state authorities, which contain obligatory requirements. SNiPs set general provisions, design requirements, rules of carrying out works and work acceptance, cost estimate guidelines. There are a l arge number of SNiPs, and each of them concentrates on one specific field. According to the Russian partners, the building regulations are under development process, which aim is to develop regulations toward European standards. In Russia, it is critical for all operations and projects to have knowledge about building codes and operation models.

Nowadays it is quite difficult to arrange the maintenances services of residential buildings in St. Petersburg. This is due to unclear ownership and management structures of facilities, as well as a poor level of the feature information of real estates and poor supply of services. It is unclear who should pay for the service and that often leads to the situation that the service is neglected. This needs to be considered when design includes technical aspects. This is one of the drivers that increase the interest for various Public Private Partnership business models.

Some solutions of EcoGrad concept are so multifaceted that it is necessary to have a private partner for maintaining and operating those. Without skilled private operator it cannot be assured that technical solutions operate efficient and ecologically enough, as planned. This is due to the fact that most of the solutions need special know-how and maintenance also after the construction phase. Depending on t he used public private partnership model, private partner can also be responsible for financing, investing, designing, building, and owning of services or necessary facilities. When designing and choosing suitable business model, it is important to consider ownership, responsibilities of the various parties and financial control.

3.2. The concept for the first pilot case

As an example the energy system, calculations of the first pilot are briefly introduced below. The plan of the first pilot area and the volumes are presented in the Figure 1. The planned number of inhabitants in the area is 20 000. The residential area is 30 m^2 per inhabitant, which means in total 600 000 m^2 floor area. There are five different building type areas: dense, low and dense, detached houses and villas. The inhabitation is most dense in the center of the area, which is really close to services and railway connection to the centre of St. Petersburg.

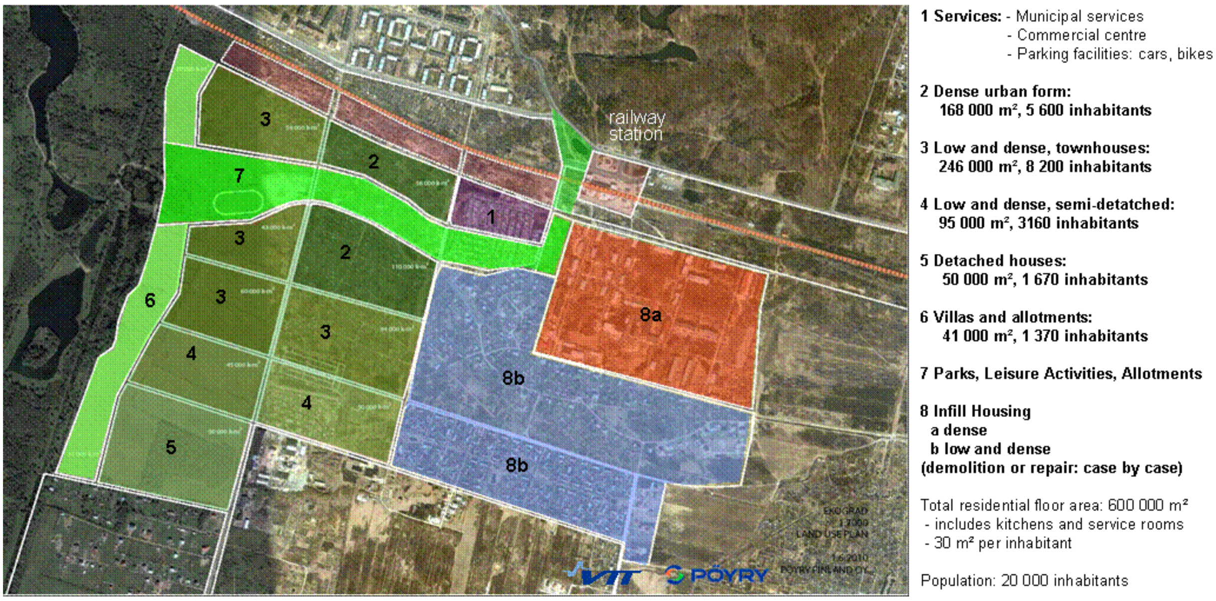

Fig. 1.Plan of the first pilot

The energy consumption has been calculated in three different scenarios: base case, low energy and passive building levels. The results can be seen from the Figure 2. M ost significant improvements are related to decreasing the heat consumption of buildings, and especially the heat consumption of space heating. It is more difficult to affect to the electricity or hot water consumption, because they depend more on the habits of the residents.

Next, different energy production options were studied. First option was quite ultimate with the target of using only renewable energy sources and achieving as low emission level as possible. That meant ground heat pumps, building integrated solar panels and wind power.

Heat collection pipes could be mounted on the golf court locating close to the pilot area. It was assumed that the COP of the heat pumps is 3, and the heat yield is 35 kWh/m2/a. One of the challenges was the fact that heat pumps consume electricity, which is also supposed to be produced within the area. If was further assumed that the entire area of roofs could be utilized with building integrated solar panels. It was calculated that the yield of solar panels would be 17 700 MWh/a. This means that there should also be a lot of wind energy: in a base case 28 804 MWh/a (the power capacity being 14,4 M W), low energy building level 20 200 MWh/a (with the power capacity of 10,1 MW) and passive building level 17 796 MWh/a (with the power capacity 8,9 MW). Power levels of wind power are calculated with a capacity factor 23%. In this option the target was to produce as much energy as is consumed in the area, but it is assumed that the area is connected to the national electricity grid, which smoothes the differences between the production and consumption continuously.

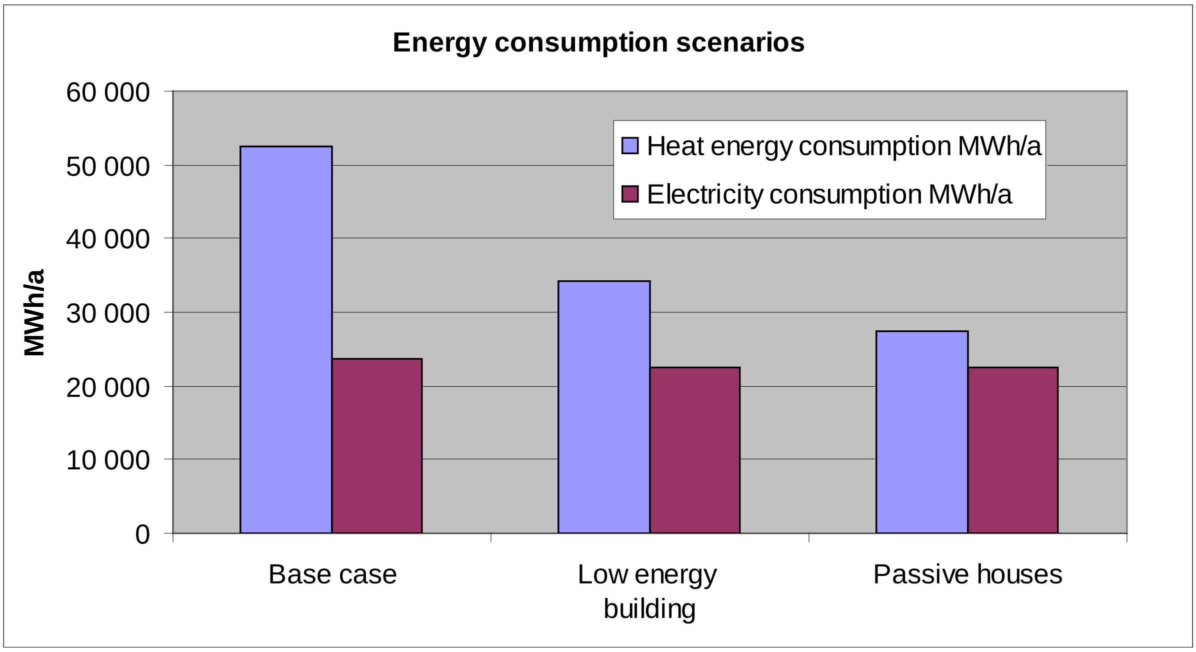

Fig. 2. Energy consumption of the pilot area in different scenarios

The second option was combined heat and power production (CHP) plant that is fuelled with woodchips. The third option was also a CHP plant, but it was fuelled with biogas produced from the wastes. It was assumed that the CHP plant is operated according to the heat demand in the area, as usual. In addition, it was assumed that the plant produces 80 % of yearly heat consumption, and the rest of the heat demand is covered with reserve plants, for example natural gas boiler. The used CHP processes were calculated with the information of real existing plants from the database of the GEMIS software. The plant using wood as a fuel produced 2 MWh of heat per 1 MWh of electricity, with the electrical efficiency of 27,5 % and operating time of 6000 h/a. The biogas CHP plant produced 1,5 MWh of heat per 1 MWh of electricity, and the efficiency and operating time were the same as the woodchip CHP plant.

The green house gas emissions of these different energy production options are presented in Fig. 3. The emission calculations include the emissions produced during the entire life cycle of their processes (including for example construction and transportation). These results were also compared to the base case, which represents the current situation in Russia. According to IEA, in Russia buildings are heated most commonly with district heating, in which the heat is produced from natural gas. The emissions of base case electricity are calculated with GEMIS from the base data of IEA [6].

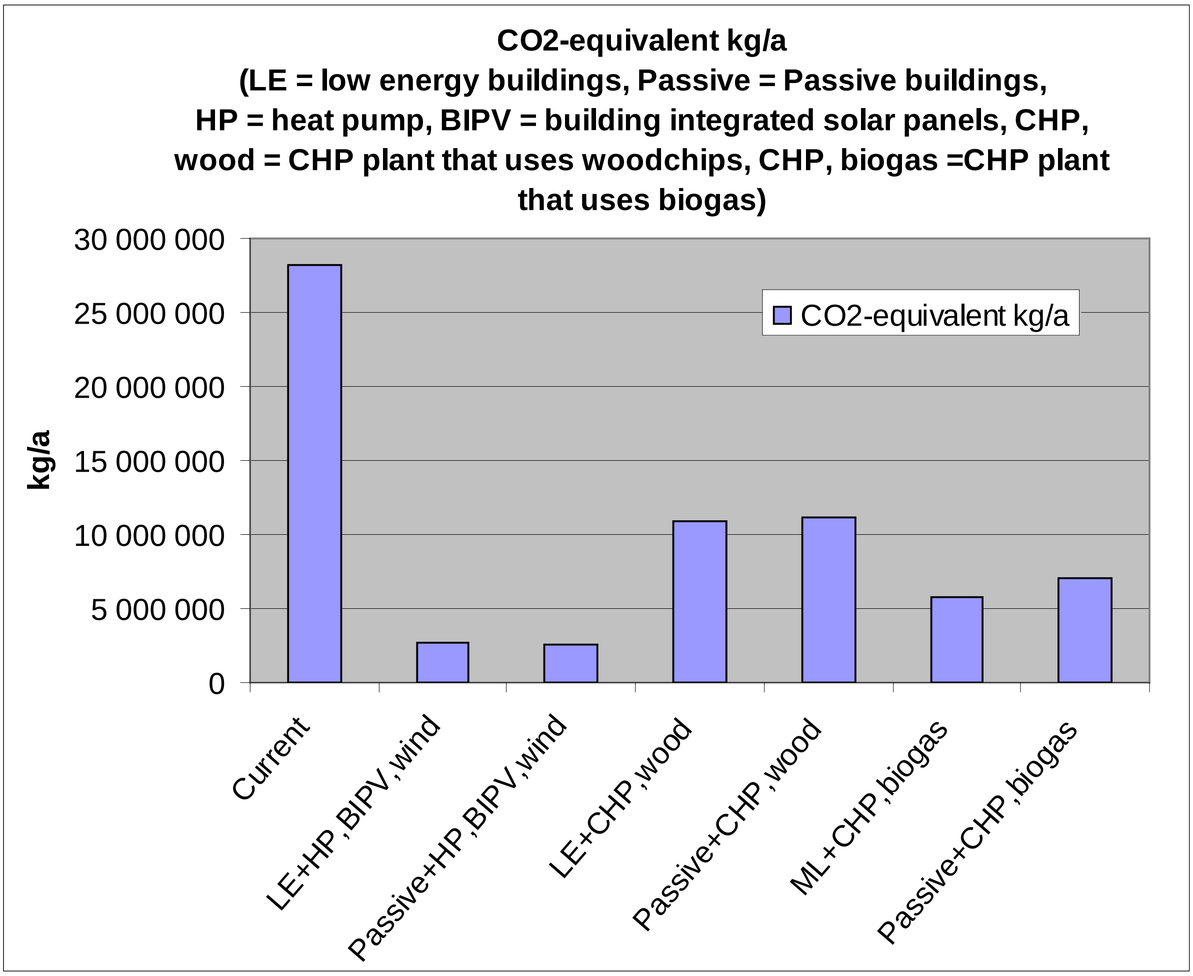

Fig. 3. Green house gas emission from different energy production options in the first pilot case. (LE = low energy buildings, Passive = Passive buildings, HP = heat pump, BIPV = building integrated solar panels, CHP, wood = CHP plant that uses woodchips, CHP, biogas =CHP plant that uses biogas)

4. Conclusions

After the whole project it can be concluded that ecological city planning principles can be applied in Russia. Ecological city plan was done for three pilot areas in St. Petersburg, and the energy consumption and production scenarios were modeled. One of the major findings was that it is important to aim buildings' energy consumption towards passive building level. Next, emissions during the entire life cycle of energy production process were calculated for each scenario with Global Emission Model for Integrated Systems (GEMIS). As a result a significant energy and emission saving potential was found. However, while modeling can be done, there are several issues that have to be considered in the planning process, and they need to be resolved before results of these modelings can be fully implemented. One of the most important further development steps is the actual implementation in these pilot areas.

It seems that there is a lack of knowledge and policies regarding renewable energy as well as technologies that improve the energy efficiency of buildings. The development of renewable energy systems is not yet common enough in Russia. Policies need to be clarified, for example the buffer zones for bio energy plants were not known by Russian partners. It was also unclear whether local legislation allows energy wells to be drilled for heat pumps. And as another example, an important part of the passive house concept is the mechanical ventilation with efficient heat recovery. It needs to be emphasized that buildings cannot be built airtight and well insulated unless proper ventilation is insured. However, this is quite unknown solution according to the survey for residents, and the implementation may be difficult due to local policies. Generally speaking, the issues related to base data issues, ownership and operating conditions in existing buildings have to be resolved. Future efforts should be put on exporting knowledge and best practices about these issues. With better knowledge the local norms can be developed in a sustainable way and it will also support the development of the city planning process.

Taking the criteria developed in this project into the planning process is the next step in the development of new ecological areas. In contrast to similar studies conducted in Finland, the survey results suggested that while renewable energy is not a priority for Russians in new neighborhood developments, there is an interest in indoor quality and larger living spaces. Revealed challenges include the unwillingness to pay for improvements and low safety in neighborhoods, suggesting underlying economic and social issues that need to be addressed in addition to providing energy and environmental opportunities. Generally speaking, it seems that passive solutions that are not very technology dependent are valued higher in Russia. Technological solutions are not considered ecological. Smart metering systems for electricity consumption raised interest, but were still considered with skepticism.

During the project it was noticed that it is very important to have an active local partner in this type of development project. The local partners need to have their own funding for the project to ensure that the work is being prioritized. In addition, the results of the questionnaire made for residents in St. Petersburg imply that residents should be more involved in the planning process. This is another possible future implementation of the EcoGrad project.

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Challenges for developing a system for biogas as vehicle fuel – lessons from Linkoping, Sweden

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Abstract: Biofuels are being employed in nearly all the EU member states to fulfill the targets set up by the European Directive 2003/30/EC to have a 5.75% share of renewable energy in their transport sector by 2010. In Sweden ethanol is the leading biofuel, while biogas mainly depend on local initiatives with the city of Linköping as a case in point.

Our purpose with this article is to analyze the development of biogas in Linköping within a framework of technological transition theory. To this we add a set of concepts from large technical systems-literature to address and re-analyze two earlier studies on the biogas development in Linköping to achieve a deeper understanding of this success story. We argue that the establishment of a development trajectory for biogas depended on the ability of the involved actors to establish and nurture their social network, to create learning processes and stimulate the articulation of expectations and visions. It was also important that these three factors were allowed to influence each other for the system to gain a momentum of its own.

Furthermore, the biogas development in Linköping is found to be interesting in that the triggers for the development came from a variety of levels and angles. Initially, the rising fuel prices after the oil crises in the 1970's resulted in an increased interest in renewable fuels in general. Second, an anticipated national pipeline for natural gas planned through Linköping was considered a huge potential for methane exports. A part from these external energy incentives, the local trigger was the bad urban air quality caused by the public transport authority's bus fleet. The breakthrough came when it was discovered that by-product biogas from the wastewater treatment facility could be used as a fuel for transport.

When the plans for the national pipeline were rejected, a fruitful co-operation between the municipally owned production facility and the public transport authority was set up to meet the constructed demand from public transport. This cooperative pair-arrangement was the starting point for the biogas niche trajectory as other actors subsequently were enrolled to increase the size and agency of the network.

Nowadays, biogas and other renewable fuels play a significant role in the supply of transport fuels for Linköping. In 2009, a total of 9.5% of all transport fuels used in Linköping were from renewable sources, i.e. biogas (4.6%), ethanol and biodiesel. This puts the city well ahead of the European target of 5.75% renewable fuels by 2010.

Keywords: *Technological transitions, niche management, biogas, renewable energy, biofuels for transportation*

1. Introduction

Our purpose with this conference paper is to analyze the process of biogas development in Linköping using technological transition theory. We argue that the success story was an example of the interplay between three technological niche processes; social networking, learning processes and the articulation of expectations. Our focus is mainly local, but since national initiatives and plans also affected the process, some of these are included in the description. We suggest a local Swedish "style" of technological niche development as a topic for further research.

2. Methodology

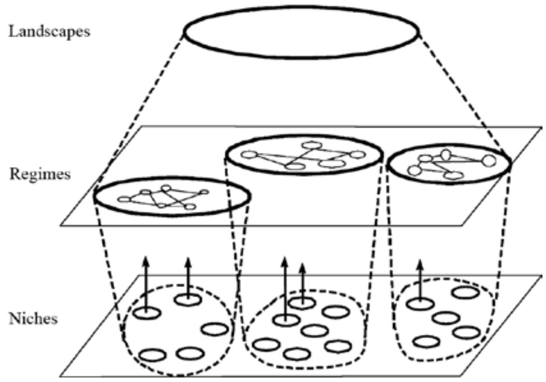
To create a deeper understanding of the development of biogas in Linköping, we assemble a new theoretical perspective to re-analyze two earlier studies on this topic. The theoretical perspective stem from two bodies of literature; the main framework come from technological transitions-theory [1], [2], to which we add key concepts from large technical systems theory developed by Thomas Hughes [3], as well as findings from Swedish scholars within this field

[4], [5]. No new empirical material has been collected and the analysis veers more towards theory building than generalizable conclusions.

3. Theory

The basic conception of the paper is that technical systems are embedded in a societal context; they are socio-technical, which means that technical systems and societal actors both affect and are affected by each other [2]. This reflexivity is particularly evident in the case of emerging socio-technical systems, whose meaning and performance are still under negotiation in the process to reach a concluded design solution [6].

If successfully spread, an emerging socio-technical system may be taken up and evolve into a socio-technical regime, consisting of prevailing institutions and rule-sets (formal laws and regulations), which provide stability [7]. In a regime, relationships are since long established between for example suppliers, user and producer groups, research networks, public authorities and societal groups [2]. Different kinds of socio-technical systems often share the same characteristics within the same country. A typical feature of the Swedish way of constructing socio-technical regimes is the ”development pair”-configuration; a close, long-term relationship between an industrial company and a state customer regarding development projects on new technical systems. An example of this is the cooperation between the Swedish Powerboard (Vattenfall) and ASEA (later ABB) [5].



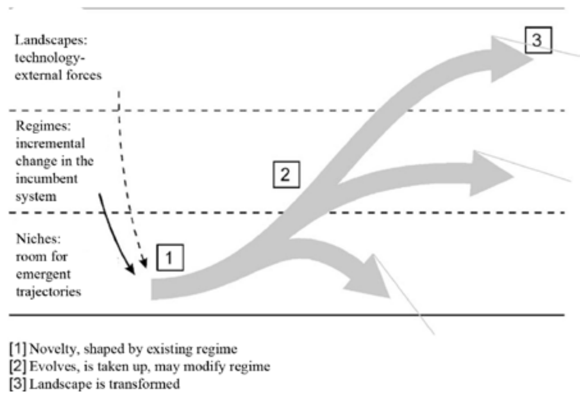


Fig 1. Multiple levels as a nested hierarchy[1] *fig 2. Describing the niche trajectory[1]*

Regimes are located at the meso-level in a heuristic model for socio-technical systems developed by Frank Geels, fig 1. Most changes in socio-technical regimes are of an incremental nature, so for major regime changes to occur, external pressure from outside of the regime level is needed [7]. An example of external pressure is when the oil crises during the 1970’s increased the transportation regime’s interest in renewable fuels.

The oil crises are examples of events in the socio-technical landscape. The landscape is located on a macro level in the model and is even more sturdy and hard to change than regimes. It contains technology-external factors such as financial fluctuations, diplomatic relations and international conflicts [2]. So while both the landscape and regime levels stabilize the incumbent practices of different socio-technical systems, they also create disincentives and barriers for disruptive technologies to develop [7].
The heuristic spaces for disruptive and/or emerging technical systems are the technological niches, found at the bottom of the socio-technical hierarchy. Here, change can still be radical, as uncertainties caused by socio-technical ”child diseases” must be overcome. It is important

to find an organizational form and agreements between the involved actors, for example through the formation of joint ventures. The technology must furthermore be trustworthy, the operational risks low, and subcontractors with the right components must exist on the market. [4]. Uncertainties at the niche level can be overcome by constructing a first and large enough secure market outlet to lower the economic risks involved in doing research on a yet immature technology. This is important as 'incubation room' where the nurturing can proceed without the pressures from mainstream market selection. The focus of this paper will be at the level of technological niches for which three crucial processes have been identified [2]:

1. The building of social networks with meaningful relational connections between involved actors. Such networks are the arena for users, decision-makers and other interest groups to give feedback about the technical system to firms, engineers and researchers, and vice versa.

2. The creation of learning processes is important, not only for technical aspects such as design and user preferences, but also from a societal point of view to understand for example regulation and infrastructure requirements.

3. Finally, the articulation of expectations and visions around a socio-technological system is important both to attract attention and resources from the social network, as well as to provide space for learning processes.

Achieving a successful interplay between the three processes is necessary to develop a development trajectory for a new radical socio-technical system [2]. If this is successful, the system can start to expand and require other systems and organizations to adapt. This is what Thomas Hughes calls 'momentum', a dynamic inertia that strives to enlarge the action space for and increase the number of activities in the socio-technical system. Momentum thrives on overcoming reverse salients, i.e. anomalies and/or uneven development that constrain the system from expanding. Reverse salients stimulate inventive activity and are thereby also important drivers for learning processes [3].

All socio-technical regimes have started out as niche trajectories. Regimes are the formalized results of social network activities, learning processes and achievements surrounding a technical system, which have gained enough momentum to overcome reverse salients and develop into a socio-technical regime in its own right, fig 2.

4. The biogas development in Linköping

4.1. Empirical data

The following description is in large parts collected from two reports. The first is a published paper by biogas researcher Magdalena Fallde [8], and the second is an unpublished report on the Linköping biogas development written by Undén [9], the former CEO of Svensk Biogas. We have taken into account that Undén have all the reasons to write a success story and have tried to stay away from bias in our description. The intention has been to re-frame these written accounts from a technological niche development perspective.

4.2. Context: biofuels in Sweden

Biofuels achieved attention on a national Swedish level after the oil crises of the 1970's. A large-scale methanol initiative characterized the first years of development without achieving much of a break-through. While methanol always remained a strictly top-bottom initiative, ethanol could to a larger extent be endorsed and played out locally [10]. The same was also true for biogas; which still can be seen in the fact that most of Sweden's biogas facilities and the achieved competences most often remain within municipally owned companies [11].

4.3. Initial incentives

It was in many respects lucky circumstances that made biogas the option as the fuel for sustainable transportation in Linköping. Following the oil crisis (a critical event in the socio-technical landscape), the Swedish socio-technical regime discussions on environmental issues intensified on a national as well as local level. In Linköping, the discussion focused around the city center and especially the central bus stop square which was characterized by the smell of diesel exhaust and soot particles. Since the inner city was banned for other transportation vehicles than buses, the environmental problems could only be referred to them. This led to a joint will among the local politicians to improve the local transportation regime and the environment of the inner city in an economically feasible way. The local bus authority at the time, LITA, had problems convincing the citizens to continue using their buses, which had been regarded as the most sustainable transportation system in the city. The question became even more delicate for LITA since it coincided with both the expiration of the local authority monopoly for bus transportation and the widespread implementation of new catalytic exhaust technique in petrol driven private cars. On a deregulated market and with this technical alternative at hand, why would people choose their buses for transportation? LITA had only one choice, to change fuel in their buses [8]. All of these events in the local socio-technical transportation regime were influential in the biogas development process.

Parallel to these local triggers, there were plans to build a national natural gas pipeline through the county where Linköping is situated; a great possibility for both import and export of methane. This national project in the socio-technical energy regime, was part of Linköping's provider of regional services', Tekniska Verken AB (TVAB), search for alternative burning fuels. At the time TVAB had permission problems with their waste incineration plant, which the local authority threatened to close down. When the plans for the natural gas pipeline were rejected due to economical reasons, the idea of gas driven vehicles had stuck in the minds of the managers at LITA. Gas to them appeared as a new and unproven fuel but also attractive and with existing techniques for operation [8]. This interplay between national and local changes in different kinds of socio-technical regimes provided the ground for further initiatives for biogas on the local scale.

4.4. Early signs of a niche trajectory

When the bio-methane by-product in TVAB's wastewater treatment plant turned into a possibility, fuel for transportation was not at all their business idea. This was instead triggered by the fact that LITA was searching for new fuel for their buses. Replacing the missing natural gas with this existing source of bio-methane seemed obvious, even though bio-methane was mostly produced for reserve electricity purposes in Sweden at the time [8].

The two municipality-owned companies got the permission to perform a pilot study on refining the bio-methane from the wastewater treatment plant. The idea was to convert five diesel buses into bio-methane ones and put them in operation within regular traffic. This pilot study established the social network around the development project and added more concrete ways of practice. Part of the money invested in the project was a grant from the Swedish state; the rest came from the municipality of Linköping, the county, the regional bus authority, LITA and TVAB. Setting up this network of actors around a created offset market of bio-methane buses, proved successful as the first five rolled out in regular traffic in 1992. The work conducted in the pilot study was characterized by a steep learning curve. Several technical issues concerning upgrading and distribution of bio-methane were solved and overcome during the scope of two years. The learning-by-doing process was considered fruitful to such an extent that the possibility of a full-scale operational project, from five to 20 buses, was discussed during the later part of the pilot study [9].

The wastewater treatment plant could not alone provide enough bio-methane for such an expansion, and had thus to be complemented by production from other substrates. Studies were carried out on different raw materials suitable for digestion at the same time as two other Swedish projects with bio-methane as fuel for transportation were about to start. This created a greater focus on the achievements done in Linköping and according to the CEO; a general wish of being pioneers was spread among both the personnel and politicians [9].

The calculations for the full-scale project of 20 buses showed that a switch to bio-methane would cost more than continued traffic with diesel buses. Nevertheless, the politicians made the decision to go ahead not only with 20 but the entire bus fleet of 65 buses, since economies of scale made the larger project less costly per driven kilometer. On the other hand, the capital risked in investments would also be bigger and with the implemented technology in the whole bus fleet of the inner city, a failure would be critical [9].

4.5. Technological momentum catching on

Around the same time, a new main supplier of raw material to the biogas digestion appeared in the form of the locally situated slaughterhouse Farmek. They had problems getting rid of their organic waste and biogas could be a way to secure their offset. Furthermore, the digested by-product from bio-methane production is a highly valuable fertilizer for farmland, so to secure the offset even further; LRF (the farmers association) was enrolled as an actor to take part in the social network surrounding the project as well. With this set-up, the bio-methane production system generated income at three times during the process: from receiving/treating the waste and the production of approved bio-fertilizer and bio-methane. Getting these actors to work together proved crucial, not the least since it at the same time confirmed the local authorities belief in the project. Successful enrollment of more actors proved that achievements and visions spread also outside of the established social network. This new setup of three stakeholders (TVAB, Farmek and LRF) started an associated company to TVAB with shared ownership, and a state grant was received to establish a first production facility for bio-methane in 1995. The plant was established during 1996 and provided a new space for further learning processes, so that the efforts made during the pilot study could be continued but on a larger scale [9].

In late December 1996, the first batch of substrate was loaded into the plant. During the first years of operation, experiences and breakthroughs were made about the operation of the whole system; from the controlling of digestion chambers, via the upgrading system and refilling stations to the everyday maintenance and operation of the bus fleet running in the inner city. Pioneering work became a part of the workforce's everyday and a strategy to allocate investments in personnel and to tie competence and not only technology to the project, was complemented with the sharing of experiences from other projects in Sweden [9].

Actors other than just the locally concerned thus shared the visions around the project, and the project gained a lot of attention both regionally and nationally. Between 1997 and 2008 the plant managed to manifold it's production of bio-methane due to conquests in process techniques and managed to keep the production steady by relocation during a period of difficulties in substrate deliverance. The plant also had to continuously increase the production of bio-methane in order to meet the launching of converted bio-methane buses [9]. That the project had been able to manage and overcome these hardships, can be seen a sign of the niche trajectory building up a momentum. This was going to be put to the test when the project was seriously questioned for the first time since the start in 1990.

4.6. Reverse salients

The problem stemmed from the odor from the production site and proved very hard as well as important to solve, not the least since its solution was important in relation to the inhabitants of Linköping. A costly process was initiated by boxing in the incidence and an odor panel of local citizens was assembled to derive the cause of the problems and thereby undertake necessary measures at the plant. It took several years with an odor-reducing program until better levels for the surroundings were achieved [9].

At the same time as this process went along, the top management was changed and a new CEO was installed. The bio-methane production was not profitable enough so a new business idea was badly needed. A face-lift into yet another expansion phase was figured out to get more economically beneficial through size advantage. The expansion required large investments in both technology and personnel, and a crucial decision was taken to expand regionally and into the private market. The new CEO pushed the expansion plans through, although the political opinion was not throughout positive. This was due to that TVAB at the moment generated much better profit to the municipality than their other business areas [9].

Already during 2001 and 2002, two large investments were done in new upgrading units and the first public filling station. The entrance to the private market was announced through a public statement that bio-methane should be a fuel you can rely on in Linköping also for your private car. LRF and Farmek was not interested in this expansion and sold their ownership to TVAB, which became full owner of the new company that was now formed [9].

In 2003 TVAB planned to establish filling stations for private cars in every regional city to create a demand for bio-methane as quick as possible with as little investments as possible. The change of the name to Svensk biogas (Swedish biogas) coupled with logotype change packaged their new business idea, and the expansion first aimed at building a new production facility in the neighboring city of Norrköping. At the same time, they had also showed the possibility to transport compressed bio-methane to newly established bio-methane markets without local production, which was a new business practice by then. During the period of 2003-2006 Svensk biogas established 14 public fuelling stations regionally and grew the public market from 300 000 to 3 100 000 Nm^3 [9]. During these later stages of niche trajectory development, signs of a stabilizing momentum can be seen as more and more reverse salients are conquered and the socio-technical system achieves an expansive dynamic.

5. Results

The Linköping biogas case provides insights of how the intertwined process of social networking, learning processes and the articulation of expectations and visions can be configured for a technological niche development. Two initially important factors can be highlighted: the initial pilot study and the creation of an offset market in the form of the local bus fleet. This constructed an “incubation room” or niche, which could act as a protected arena for interactions and a starting point from which a trajectory could be developed.

Characterized by a steep learning curve, the pilot study years was successful enough in creating expectations and visions to overcome the crucial moment to further expand into a second pilot study. At that point, the expectations created within the social network were strong enough to dare go into an even greater expansion than first planned for; 65 instead of 20 buses. Furthermore, the visions surrounding the project seemed hopeful enough to successfully enroll more actors to the network to provide a larger resource base of organic waste needed for the expansion.

The reconfigured social network and the larger second project provided yet another and extended arena for learning processes. New expectations and visions were in this process created around the project, which lead to the expansion into the private market. The dynamic expansion of the biogas project had begun to show signs of a technological momentum, as the enrolled actors had to adapt their processes to the biogas development. Furthermore, it conquered the first encounter with a reverse salient; the odor problems from the factory.

The biogas niche trajectory in Linköping was the combined result of the three processes. The relationship between the actors from different socio-technical regimes created a stabilized yet diverse local network. Although they had different incentives, they learned and developed the biogas technology and created a momentum through co-operation and a shared vision.

6. Discussion and Conclusions

An interesting feature in Linköping is the way that different socio-technical regimes affected the development of a biogas trajectory. Initially, pressure came from landscape change inflicted by the oil crises. Furthermore, the national gas pipeline project (the energy regime) had its implications as well as the earlier attempts and projects with other biofuels (the transportation regime) made in Sweden. These pressures, together with the local trigger event of bad air quality, opened up a window of opportunity for changes to occur locally. The biogas niche trajectory could develop as actors from different socio-technical regimes became enrolled and involved in the process: the wastewater treatment plant and agricultural sector found offsets for their by-products, while slaughterhouse waste became a resource provided by the food industry. Of course, the possibility of networking across regime borders stems from the fact that biogas (upgraded methane) is an energy source found as organic by-product in many different industrial processes. Still we believe it important, both for researchers and practitioners interested in socio-technical niche development, to look over the regime fences for possible exchanges as well as useful pressure mechanisms and offset markets.

The findings of this article furthermore suggest it reasonable for a slightly altered ”development pair”-concept to describe the development of biogas in Linköping. The co-operation between the municipally owned bus company customer on one side, and the municipally owned producer (TVAB) and the private actors they enroll to their network on the other, form the starting point for a niche trajectory. This cooperative pair-arrangement and their long-term collaboration form the basis of the development. It is important to stress that one observation alone is not enough to generalize any conclusions to be applicable also to other biogas cases in Sweden. Still, it is so that municipally owned companies run most biogas facilities and have the largest embodied competence on the subject in Sweden. We believe that it would be fruitful to conduct further research to seek out whether a local Swedish ”style” for technological niche development for biogas can be detected.

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Estimation of Renewable Energy Potential and Use- A Case Study of Hokkaido, Northern-Tohoku Area and Tokyo Metropolitan, Japan-

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Abstract: The present work is intended to evaluate renewable energy potential in Northern Japan area and Tokyo metropolis and to reveal possibility of supplying renewable energy from Northern Japan area to Tokyo metropolis. This evaluation method consists of three processes with GIS. The first process is simulation of the meteorological parameters such as river discharge and direct solar radiation. The second process is extraction of potential areas with restrictions such as meteorological conditions, geographical features and social environment. The third process is calculation of annual energy production. The application of the new method to Northern Japan area shows that the sum of renewable energy potential is 185,000 GWh/year, which contains 120,374 GWh/year of wind energy, 29,111 GWh/year of mini-micro hydropower, 986 GWh/year of solar power, 31,089 GWh/year of geothermal energy and 3,440 GWh/year of biomass energy. The geothermal and biomass energy potential were quoted from earlier study. The renewable energy potential in Northern Japan area is bigger than the 78,519 GWh/year of electricity demand in civilian sector in Tokyo. It is possible for the renewable energy potential in Northern Japan area to satisfy electricity demand not only in Northern Japan area but also in Tokyo metropolis.

Keywords: *Renewable Energy Potential Estimation, GIS, Wind Energy, Hydropower, Solar Energy*

Nomenclature

E_{pw}	*Wind energy potential*	$kWh \cdot year^{-1}$
V	*Wind velocity*	$m \cdot s^{-1}$
$f(V)$	*Weibull model*	-
$P(V)$	*Power curve*	kW
E_{ph}	*Mini-micro hydropower potential*	$kWh \cdot year^{-1}$
H	*Height*	m^{-1}
Q	*River discharge*	$kg \cdot s^{-1}$
μ_t	*Waterwheel efficiency*	-
μ_g	*Generation efficiency*	-
E_{ps}	*Solar energy potential*	kWh
N_h	*Number of household*	*family*
C_p	*Capacity*	$kW \cdot family^{-1}$
S_e	*System utilization*	-

1. Introduction

The present work is intended to evaluate extensively renewable energy resources potential in Northern Japan area and Tokyo metropolis and to analyze locally renewable energy potential in Akita prefecture in order to reveal possibility of supplying renewable energy from Northern Japan area. In Japan, Tokyo metropolitan government and Northern Japan area, such as Aomori, Akita, Iwate, Yamagata and Hokkaido, have agreed on interregional cooperation for renewable energy use. The purpose of the agreement is to realize reducing CO_2 emission in Tokyo metropolis and revitalization of the rural economy and expansion of job opportunities by supplying renewable energy from the rural area to the huge city. There are differences of circumstance between rural areas that have a huge renewable energy potential and a big city that has huge energy demand behind.

In order to efficiently construct renewable energy facilities the systematic and accurate evaluation of renewable energy potential is important. Voivontas et al., for example, developed a decision support system by using GIS (Geographical Information System) for the evaluation of renewable energy sources potential and conducted financial analysis of renewable energy investment in Crete, Greece [1]. The evaluation methods in earlier studies were designed locally for each specific area. In contrast, the authors intended to evaluate extensively renewable energy resources potential and to prove features in each area by comparison of evaluation results. Therefore the authors developed a new evaluation method by using GIS and publicly available digital spatial data in Japan [2].

2. Methodology

2.1. Study area

The study was carried out for Northern Japan area which includes Hokkaido and Tohoku area (Aomori, Akita, Iwate and Yamagata prefectures) and Tokyo metropolis in Japan. Fig. 1 shows that Hokkaido and Tohoku area lies in the northern part of Japan.

Fig. 1 Study area: Hokkaido, Tohoku area and Tokyo metropolis.

2.2. Software and data source

In the present work we used GRASS ver.5.3 and 6.2 as GIS software [3]. We also used GIS data from the database published by the Ministry of Land, Infrastructure, Transport and Tourism in Japan [4].We used 50 m grid elevation data, 1 km grid annual rainfall data, 100 m grid natural park data, 1 km grid number of family data, 100 m grid land use data and road vector data from the database.

2.3. Concept of estimation

In the renewable energy potential evaluation, we evaluate two kinds of potentials: "theoretical potential" and "practical potential." A theoretical potential is an amount that all energy potential theoretically exist, for example, all solar energy and wind power. A practical potential is an amount that potential is evaluated with restrictions such as climate conditions, geographical features and social environment. In the present work we evaluate the practical potential with a common small number of restrictions to prove features in each area.

2.4. Procedure

This new evaluation method consists of three processes. The first process is simulation of the meteorological parameters such as river discharge and direct solar radiation. The second process is extraction of potential areas with restrictions such as meteorological conditions, geographical features and social environment. The third process is calculation of annual energy production. In this process we develop a s cenario for calculation of the power generation facility, annual energy production and number of introducing facilities.

2.4.1. Wind energy

First, wind property was quoted from the 500 m grid simulation result by NEDO [5]. Second, potential areas for wind energy were extracted under the consideration of the following restrictions;

- A minimum allowable wind speed of 5 m/s (in altitude of 30m) ;
- A maximum distance from roads of 200 m;
- A maximum slope from the level of 20 degrees;
- A maximum elevation of 1000 m.

The following areas were not considered for the installation of wind turbine;

- Construction areas for houses;
- Natural parks and national parks.

Third, in order to calculate electrical output of wind power generation, we developed a scenario that wind electrical output was calculated with power curve. The power curve is in proportion to the cubic of wind velocity and approaches 1000kW with 13m/s of wind velocity. Additionally, wind speed distributions were assumed as the Weibull model for calculation of annual energy production [5]. The number of introducing wind turbines was calculated on condition that wind turbines are set at 700 m interval in a potential area. The calculation for wind energy potential is described in Eq. (1). Wind energy potentials tend to be estimated bigger where extracted potential area is larger with this evaluation method.

$$E_{pw} = \sum \left(f(V) \times p(V) \right) \times 8760 \qquad (1)$$

where E_{pw} is the wind energy potential, V is the wind velocity, $f(V)$ is weibull model, $P(V)$ is power curve and 8760 is hours in a year.

2.4.2. Mini-micro hydropower

First, the river discharge was simulated from elevation and amount of an annual rainfall data with GRASS r.watershed module [3]. Second, potential areas for mini-micro hydropower were extracted under the consideration of the restriction that a minimum allowable river discharge is 0.01 m^3/s. Third, in order to calculate electrical output of mini-micro hydro electric generation, we developed a scenario that facilities is small scale hydropower: conduit type and afflux type power generation. This evaluation also assumed that hydro electric generators were set at 50m interval in each river in the target area and that the heights of facilities were calculated from maximum slope data and 50 m grid digital elevation model data. Additionally, we assumed that outflow rate of water from rainfall to river discharge is 30 % and that utilization ratio of river discharge is 20 % for calculation of annual energy production. The calculation for mini-micro hydropower potential is described in Eq. (2). Mini-micro hydropower potentials tend to be estimated bigger where output per unit is huge with this evaluation method.

$$E_{ph} = 9.8 \times H \times Q \times 0.20 \times \mu_t \times \mu_g \times 8760 \div 1000 \qquad (2)$$

where E_{ph} is the mini-micro hydropower potential, 9.8 is the gravity acceleration, H is height, Q is river discharge and 0.20 is utilization ratio of river discharge μ_t is waterwheel efficiency, μ_g is generation efficiency, 8760 is hours in a year and 1000 is unit conversion from W to kW.

2.4.3. Solar enegy

First, the direct solar radiation was simulated from elevation data with GRASS r.sun module [3]. Second, potential areas for solar energy were extracted under the restriction that a minimum allowable direct solar radiation is 0.1 kWh/m^2 a day. This restriction extracts almost all inhabitable areas as potential areas. Third, in order to calculate photovoltaic output, we developed a scenario that we introduce 1 kW photovoltaic cell to each household. Additionally, we assumed that PV system utilization is 12 % for calculation of annual energy production. The number of introducing photovoltaic cell was calculated with number of household in each 1 km grid. The calculation for solar energy potential is described in Eq. (3). Solar power potentials tend to be estimated bigger where population is huge with this evaluation method.

$$E_{ps} = N_h \times C_p \times S_e \times 8760 \qquad (3)$$

where E_{ps} is the solar energy potential, N_h is Number of household, C_p is capacity, S_e is System utilization and 8760 is hours in a year.

3. Potential evaluation result

The results of renewable energy potential evaluation in Northern Japan area and Tokyo are summarized in Figs. 2 -4. These figures summarize each potential by each municipality and the municipalities in darker color have huge renewable energy potential.

3.1. Wind energy potential evaluation

Fig. 2 shows that each prefecture has several municipalities with huge wind power potential, which are over 1000 GWh/year, in Northern Japan area. These municipalities with huge wind potential mainly locate along the coastline and the mountains. In Tokyo metropolis, a few municipalities have wind energy potential, which are smaller than 30 G Wh/year. Municipalities with large wind energy potential locate along the coastline in Tokyo.

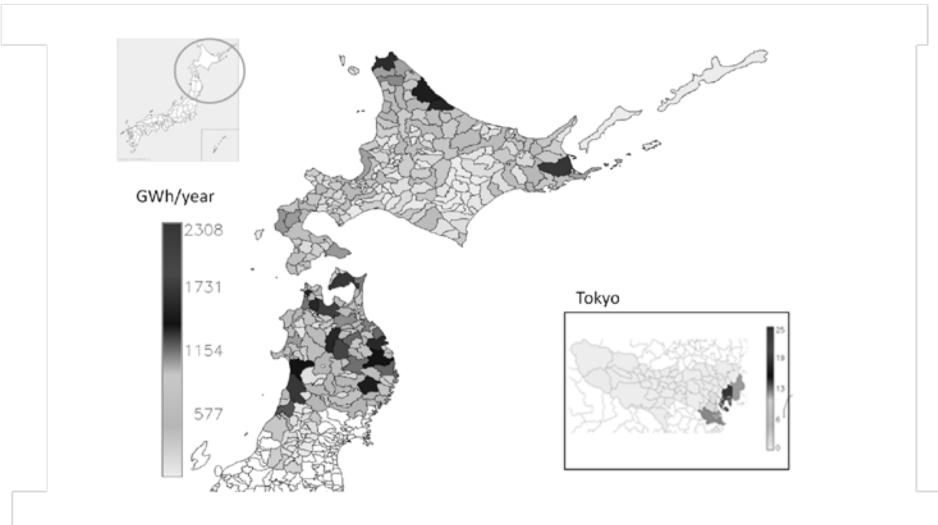


Fig. 2 Evaluation result of wind energy potential in Northern Japan area and Tokyo metropolis.

3.2. Mini-micro hydropower potential evaluation

Fig. 3 shows that a few municipalities with huge mini-micro hydropower potential locate in Hokkaido and Yamagata, which are over 800 GWh/year. Fig. 3 also indicates that many prefectures have large hydropower potentials, which are over 200 G Wh/year. These municipalities with large hydropower potential tend to be along the steep river with large river discharge and to have upper reach of a river. In Tokyo metropolis, municipalities with large mini-micro hydropower potential locate in western part of Tokyo. These municipalities have upper reach of a river and have mini-micro hydropower potential, which are around 100 GWh/year.

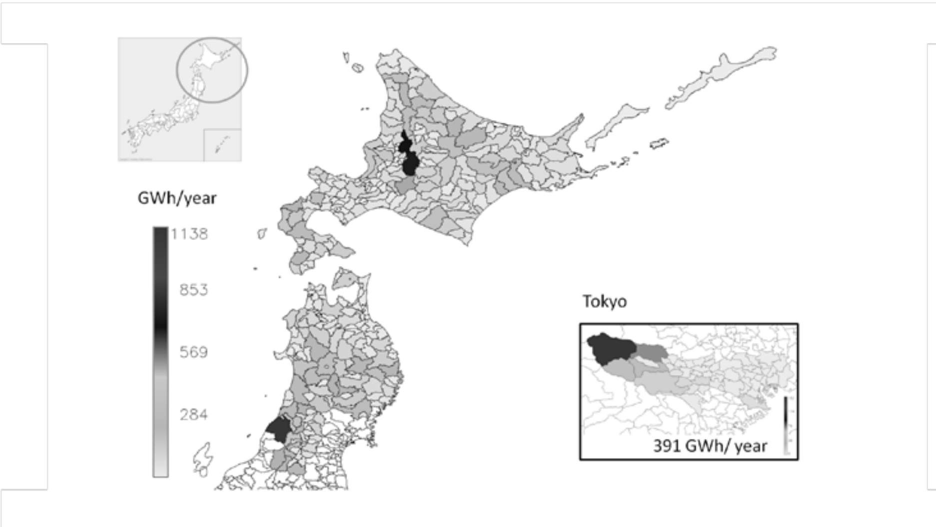


Fig. 3 Evaluation result of mini-micro hydropower potential in Northern Japan area and Tokyo metropolis.

3.3. Solar energy potential evaluation

Fig. 4 shows that a few municipalities with huge solar energy potential exist in Northern Japan areas, which are between 50 GWh/year and 120 GWh/year. These municipalities with large solar potential mainly locate along the coastline. In Tokyo metropolis, many municipalities have large solar energy potentials, which are over 50 GWh. Municipalities with large solar energy potentials locate in center area of Tokyo where populations are huge.

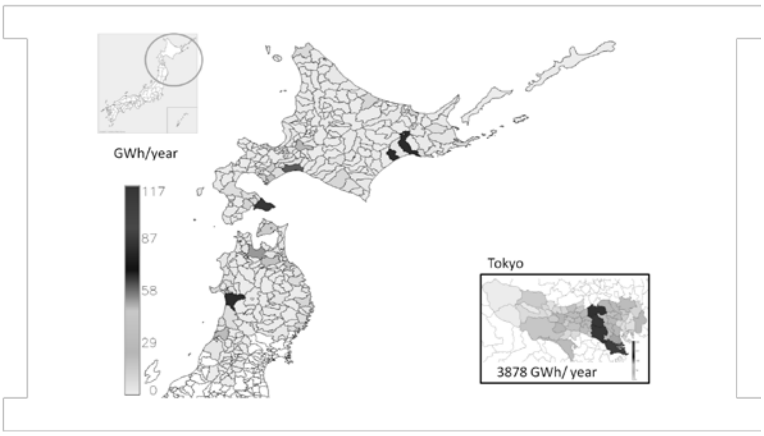


Fig. 4 Evaluation result of solar energy potential in Northern Japan area and Tokyo metropolis.

3.4. The sum of renewable energy potential

Table 1 shows the sums of wind, solar and hydropower potential with geothermal and biomass energy potential in Northern Japan area and Tokyo metropolis. The geothermal potential is quoted from Geothermal Potential Map in Japan [6]. The biomass potential is quoted from Biomass GIS Database [7]. The sum of renewable energy potential in Northern Japan area is 185,000 GWh/year, which contains 120,374 GWh/year of wind energy, 29,111 GWh/year of mini-micro hydropower, 986 GWh/year of solar power, 31,089 GWh/year of geothermal energy and 3,440 GWh/year of biomass energy. The sum of renewable energy potential in Tokyo metropolis is 8,168 GWh/year, which contains 52 GWh/year of wind energy, 391 GWh/year of mini-micro hydropower, 3,878 GWh/year of solar energy, 675 GWh/year of geothermal energy and 3,173 GWh/year of biomass energy. On the other hand, Tokyo metropolis needs 78,519 GWh/year of electricity demand in civilian sector [8]. The electricity demand of 78,519 GWh/year in Tokyo is almost equivalent to ten times of 8,168 GWh/year of the renewable energy potential. It is difficult to satisfy the electricity demand in Tokyo with renewable energy potential in Tokyo. However, the renewable energy potential of 185,000 GWh/year in Northern Japan area is enough to cover the electricity demand in civilian sector in Tokyo. It is important for Tokyo metropolis to make the most use of renewable energy potential in Northern Japan area in order to promote renewable energy use.

Table 1 Renewable energy potential evaluation result in Northern Japan area and Tokyo.

(GWh/year)	Hokkaido	Aomori	Iwate	Akita	Yamagata	Tokyo
Wind	56608	21589	23315	13752	5111	52
Mini-micro hydropower	13458	1778	5223	3398	5254	391
Solar	598	178	53	120	37	3878
Geothermal	20052	2330	3618	3005	2085	675
Biomass	1510	491	532	506	401	3173
Sum	92226	26366	32740	20780	12888	8168

3.5. Discussion on extensive renewable energy potential evaluation

The evaluation results show that extensive renewable energy practical potential evaluation with a common small number of restrictions proves features of each area and that renewable energy potential in Northern Japan area is important resource not only for Northern Japan area but also Tokyo metropolis. However, these evaluation results are not efficient to plan the specific project, because the evaluation method evaluates only one aspect of the renewable energy potential. Therefore, the authors conducted more detailed potential analysis for use in Akita prefecture in order to analyze features of the evaluated potential.

4. Wind energy potential analysis for use

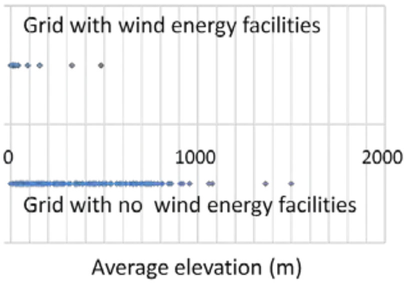
4.1. Study area

The extensive renewable energy evaluation result showed that there is huge wind energy potential in Northern Japan area and that the wind energy potential in Akita prefecture is one of most important renewable energy potential in Table 1. Therefore, we analyzed locally wind energy potential with potential classification in Akita prefecture. The study area is Akita prefecture in Northern Japan area in Fig. 1.

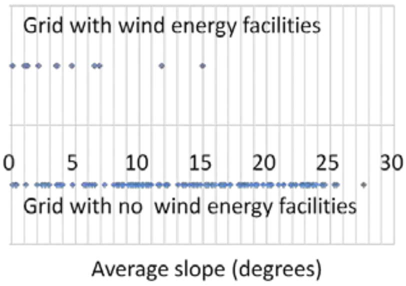
4.2. Classification methodology of wind energy potential

We classified wind energy potential in order to analyze how to make use of wind energy potential. In this study, we classified wind energy potential with mean annual wind speed of over 6.0 m /s in altitude of 70m. The criteria for classification were decided based on feasibility of introducing wind energy facilities. In order to analyze feasibility of introducing wind energy facilities, the study area is divided into 10km square grids. We compared properties of grids that have installed wind energy facilities with the other grids. We focused attention on pr operties of average elevation and average slope. The areas with higher elevation or slope value are concerned about the possibility of increasing construction costs.
Fig. 5 shows comparison of properties in grids with wind energy facilities between in grids with no wind energy facilities. Fig. 5 (a) is a comparison of average elevation and Fig. 5 (b) is a comparison of average slope in each grid. Fig. 5 (a) indicates that the grids with installed wind energy facilities have average elevation of lower than 500m. The relationship is consistent with tendency of lower elevation to be encouraged in planning introducing wind energy facilities. Figure 5 (b) indicates that the grids with installed wind energy facilities have average slope of lower than 15 degrees. The relationship is also consistent with tendency of lower slope to be encouraged in planning introducing wind energy facilities. Therefore, the areas with following properties are seen as a strong possibility of introducing wind energy facilities.

- Average elevation is lower than 500 m in the grid.
- Average slope is lower than 15 degrees in the grid.



(a) Relationship between average elevation and installed wind energy facilities.



(b) Relationship between average slope and installed wind energy facilities.

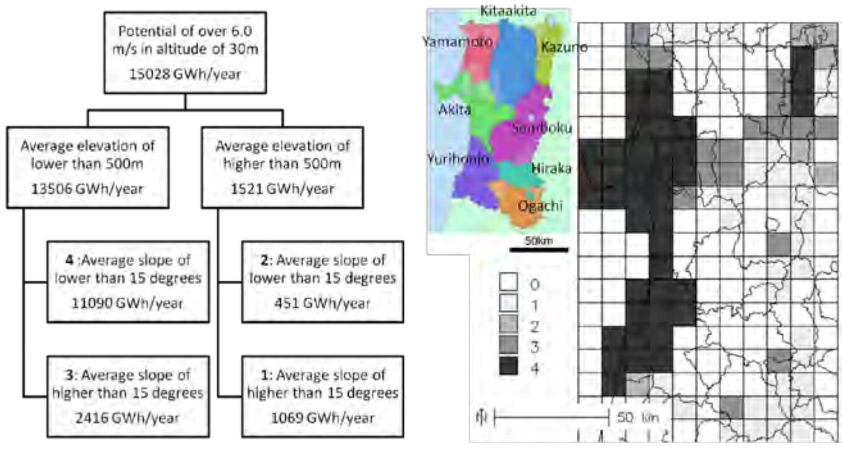
Fig. 5 Comparison of properties in grids with wind energy facilities between in grids with no wind energy facilities.

4.3. Classification result of wind energy potential

Fig. 6 shows classification result of wind energy potential in Akita prefecture. Fig. 6 (a) shows the potential classified according to average elevation and average slope in Akita prefecture. Fig. 6 (a) shows the potential is 15,028 GWh/year with a minimum allowable mean annual wind speed of 6.0 m/s in altitude of 70m in Akita prefecture. The wind energy potential of 15,028 GWh/year includes potential of 11,090 GWh/year with average elevation of lower than 500m and average slope of lower than 15 degrees in each grid. On the other hand, the wind energy potential of 15,028 GWh/year also includes potential of 1,069 GWh/year with average elevation of higher than 500m and average slope of higher than 15 degrees in each grid. Fig. 6 (b) shows that the distribution of classification results in Akita prefecture. In Fig. 6 (b) darker gray shows hopeful grid. The hopeful grids colored with darker gray exist in several parts of Yamamoto area, Akita area, Yurihonjo area and Kazuno area, which are with lower elevation and slope. In fact, a portion of the wind energy potential is used there. In addition the grids with light gray exist around Kazuno area. The southern part of Kazuno has potential with lower elevation and higher slope. On the other hand the northern part of Kazuno has potential with higher elevation and lower slope.

5. Conclusion

The sum of renewable energy potential in Northern Japan area is 185,000 GWh/year, which contains 120,374 GWh/year of wind energy, 29,111 GWh/year of mini-micro hydropower, 986 GWh/year of solar power, 31,089 GWh/year of geothermal energy and 3,440 GWh/year of biomass energy. Tokyo has 78,519 GWh/year of electricity demand, whereas only 8,168 GWh/year of total renewable energy potential. The renewable energy potential of 185,000 GWh/year in Northern Japan area is enough to cover the electricity demand in civilian sector in Tokyo. In Akita prefecture, wind energy potential of 11,090 GWh/year is with mean annual wind speed of over 6.0, with average elevation of lower than 500m and average slope of lower than 15 degrees in each grid. The hopeful wind energy potential exists in several parts of Yamamoto area, Akita area, Yurihonjo area and Kazuno area. It is possible for making use of the huge wind energy potential extensively there.



(a) potential classified according to elevation and slope (a) Distribution of classification results

Fig. 6 Classification result of wind energy potential in Akita prefecture.

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Evaluating the greenhouse gas impact from biomass gasification systems in industrial clusters – methodology and examples

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Abstract Biomass gasification is identified as one of the key technologies for producing biofuels for the transport sector and can also produce many other types of products. Biomass gasification systems are large-scale industrial systems and it is important to evaluate such systems from economic, environmental and synergetic perspectives before implementation. The objective of this study is to define a methodology for evaluating the greenhouse gas (GHG) impact of different biomass gasification systems and to exemplify the methodology. The ultimate purpose of the methodology is to evaluate the GHG performance of different biomass gasification systems integrated in industrial clusters. A life cycle perspective is applied.
Most biomass gasification systems are multiproduct systems, simultaneously producing biofuels, heat at different temperatures and pressures and electricity. The value, in economic terms and in terms of GHG emissions, is well defined for some products (e.g. biofuels), whereas for other products (such as heat and electricity) it is more uncertain and in some cases dependent on time and location.

Keywords: *Greenhouse gas impact assessment, Biomass gasification, System analysis*

List of abbreviations

DH	*district heating*	*MTO*	*methanol to olefins*
FT	*Fischer-Tropsch*	*PE*	*polyethylene*
GHG	*greenhouse gas*	*PP*	*polypropylene*
GWP	*Global Warming Potential*	*SNG*	*Synthetic natural gas*

1 Introduction/background

Biomass gasification is seen as an important technology for the future production of biofuels. This paper is part of the project "***Advantages of regional industrial cluster formations for the integration of biomass gasification systems***" which aims to evaluate the economic performance and greenhouse gas (GHG) impact of different biomass gasification systems. The study is performed as a case study in south-west Sweden, focusing on the technical systems and opportunities for integration with existing industries and infrastructure. This paper discusses the methodology for evaluating the GHG performance of the different gasification systems from a life cycle perspective.

Life cycle assessments of bioenergy systems available in literature were analysed by [1] concluding that the use of different input data, functional units, allocation methods, reference systems etc. contributes to a wide range of results for similar systems and complicates the comparison between studies. Wetterlund et al. [2] show the effects of applying system expansion in the well-to-wheel CO_2 evaluation of biofuels. Our approach is similar to the one taken by [2], but we apply it to systems with a wider range of products and include non-CO_2 GHG emissions from all parts of the chain, and soil emissions from biomass production. We also describe how products with a longer lifetime can be handled in the evaluation.

2 Objective

This paper outlines and exemplifies a methodology for evaluating the GHG impact of biomass gasification systems integrated with other industries and infrastructure. The methodology is suitable for comparing alternative configurations and could also be applied to other bioenergy systems. The outlined methodology has a life cycle perspective, addressing the potential climate impact in terms of GWP (global warming potential)-summarised emissions. The methodology does not predict absolute environmental impacts.

3 The scope of the evaluation

Depending on scope, a GHG evaluation could answer different questions. The methodology of this paper includes two different aspects:

i) How much do the biomass-based systems reduce emissions compared to the conventional (often fossil-based) systems?
ii) In which applications does the biomass-utilisation result in the largest emission reductions?

We take a consequential approach and marginal data should therefore be used [3] for the assessment, since possible changes in the production could affect the directly or indirectly related marginal suppliers and competing products. Further, we include global emissions of carbon dioxide, methane and nitrous oxide, using GWP factors 1, 25, and 298 respectively based on [4]. *Fig. 1* shows the two systems to be compared in order to answer the first question above. Comparing several biomass-based systems to their reference (as in Fig. 1) can help answering the second question.

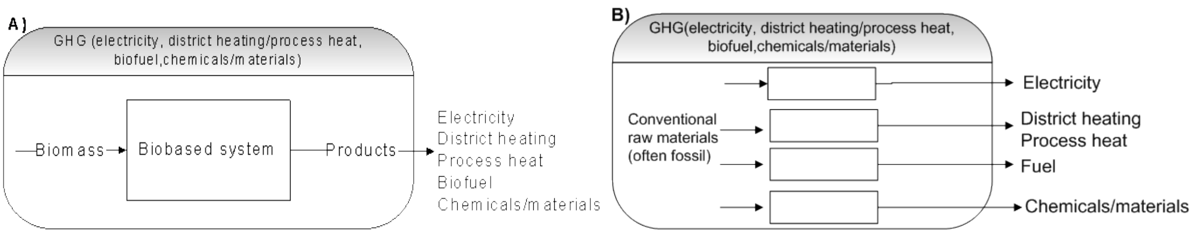

Fig. 1. Comparison between reference system (B) and biomass based system (A). The same amount of each product is produced in each system.

4 Methodological aspects

In this section we describe how important factors in the GHG evaluation process of the biomass gasification system should be treated, including; system boundaries, reference system and life cycle data from other studies. In the next section we exemplify our methodology.

4.1 System boundaries

Fig. 2 is a schematic view of the conceptual system and system boundaries of the biomass gasification system integrated with industry evaluated in this study. The geographical boundaries for the different parts of the system and the chosen time perspective should be taken into consideration [5]. The geographical boundaries could limit raw material supply, infrastructure for the transport and delivery of products and could also define the framework for the choices of reference systems. The time perspective can help to define the appropriate reference systems by giving a context for technology development. Even though focus is on the conversion system it is important to include both downstream and upstream systems.

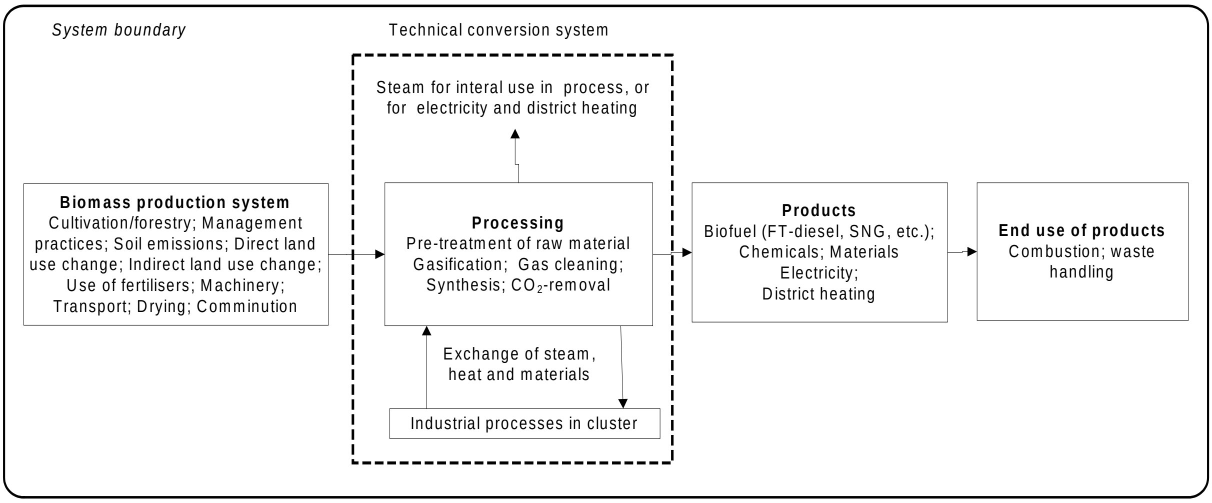

Fig. 2. Schematic view of conceptual system and system boundaries of the biomass gasification system evaluated in this study.

4.2 Functional unit

The functional unit is g $CO_{2eq.}MJ^{-1}$ biomass input. This unit was chosen since the evaluation focuses on the technical conversion system and the amount of input biomass is the same in all systems. For further discussion on the choice of functional unit, see [1,2].

4.3 Reference system

The reference system, *Fig.* ***1***B, is the conventional system to which the proposed biomass-based system, *Fig.* ***1***A, is compared. In the case of the biomass gasification system (and other multiproduct systems) the reference is not one single system but rather separate systems for each product. In most cases the reference is fossil fuel-based, but not necessarily. For future systems, such as in this study where different configurations of new installations are investigated, the definition of the reference system requires significant analysis.

4.3.1 Electricity

The reference for electricity should be the future marginal production technology determined by build margin [2]. Energy market scenarios with consistent assumptions for future prices and technologies could be used for determining the likely marginal production technology. Axelsson et al, [6], have developed a tool (ENPAC) for generating consistent energy market scenarios. The inputs to the tool are fossil fuel prices, levels of policy instruments (CO_2-charge, green electricity certificates) and available technologies and technology developments for electricity production. The output is scenarios that include future fuel prices, energy carrier prices and associated CO_2 emissions. The electricity price includes the cost for building new capacity and hence the marginal electricity production from the tool is the future build margin. This tool can be used in order to determine the appropriate marginal technologies for electricity production.

4.3.2 Heat

Prices from the ENPAC tool together with knowledge of local conditions for DH can be used to determine the appropriate reference for heat delivery. Infrastructure and possibilities for expansion are crucial for the performance (environmental and economic) of a bioenergy system with potentially large DH delivery [7]. Excess heat from a new biomass gasification unit running 8000 hours per year will constitute a base load to the DH system and the corresponding production technology for this load should be used as reference. The excess heat from a gasification unit can even result in significant reductions in emissions when it replaces biomass-based DH, since the excess heat will save biomass that can be used elsewhere. Excess heat can also be delivered to an adjacent industry, whereby emission reductions then correspond to fuel or other resource savings.

4.3.3 Biomass

GHG emissions from the biomass production system could constitute a significant part of the overall emissions from the bioenergy system [8,9] and should take all sources into account, including soil carbon losses due to management and land use change. Biomass gasification generally requires significant pre-treatment of the biomass and all these treatments should be included irrespective of where they are performed. Since the amount of biomass available for energy purposes is, and will continue to be, limited it is important to include an alternative use of the biomass in the reference system [10,2]. In a European perspective the marginal biomass user is identified as coal power plants with co-combustion possibilities or possibly (if strong policy instruments are applied) biofuel producers [6]. Other marginal users, such as biomass combined heat and power plants could also be feasible under certain circumstances.

4.3.4 Biofuels

The reference for biofuels could be conventional fuels: diesel, petrol or a combination of the two. These are appropriate references even for future scenarios with a time frame of 10-20 years, since it is likely that these fuels will constitute a significant part of the use even in the coming decades. In *Table 2* the chosen reference for biofuels used in this study is presented.

4.3.5 Materials and chemicals

Biosyngas can also be used for the production of chemicals and materials. The reference for these products should be similar products produced by the conventional route. The end use could be complex since there might be several uses of the product although it will be similar to the conventional product. In our approach we take into consideration the incineration at the end of life and that some products act as carbon storages due to long lifetime by applying the method outlined in [11,12]. The latter point means that we apply a factor that reduces the GWP-value. The reduction of the GWP-value will be larger the longer the lifetime of the product. In the calculations we have used the simplified approach as suggested by [11].

4.4 Life cycle data from other studies

Our focus is on t he technical conversion system (biomass gasification) and emission and energy consumption data for the other parts of the system and reference flows are taken from literature. However, these life cycle data need to be recalculated to ensure that assumptions are consistent for co-product allocation, marginal production of electricity etc.

5 Examples

In order to exemplify our methodology we show GHG emission reduction potential for three different types of biomass conversion systems; one biomass gasification unit producing FT-products [13], one biomass gasification unit producing bio-SNG (synthetic natural gas) [14] and one biomass gasification unit producing methanol [7] with a down-stream MTO-process (methanol to olefin) producing PE (polyethylene) and PP (polypropylene) [15]. The input and output to the installations are given in *Table 1* and the GHG emission reductions for different cases of assumptions for reference streams are shown in *Fig. 3*.The different cases are explained in *Table 2*. The plants have been scaled so as to have the same biomass input. In all cases, the input is wet (50 % wt.) forest residues that are dried using excess heat from the conversion process. Emission factors for the different fuels and materials are taken from literature [16-23]. The assumed annual operation time is 8000 hours for all plants.

Table 1. Capacity data for example installations.

Conversion Plant	**Input (MW)** Biomass	Electricity	**Output (MW)** FT-products	SNG	PE/PP (kton yr^{-1})	Heat[a]
FT	371	9.8	167			50
SNG	371	-15.3		265		89
MeOH/PE& PP	371	37			32.1/15.7	134

[a] In the base case the maximum amount of deliverable DH is 300 GWh yr^{-1} for all biorefineries. In the case of heat delivery to industrial process the delivered amount is 711 GWh

6 Results

The results (*Fig. 3*) show that there is a significant difference between total impacts depending on assumptions made for the reference streams. Only one reference use of electricity is displayed but it constitutes a significant part of all chains. Also the GHG savings due to DH delivery constitute a significant part of the savings in most cases. Hence, it is important to make calculations for scenarios using different possible references for these flows

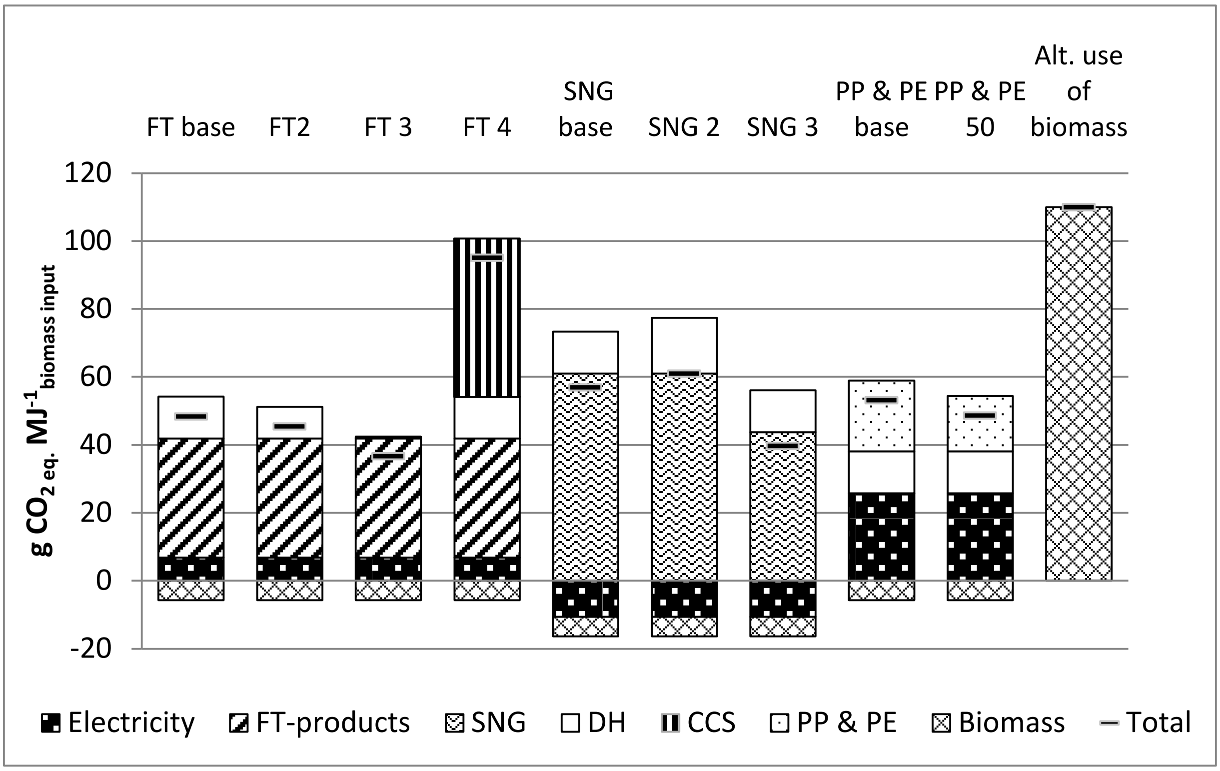

Fig. 3. GHG emissions savings for different reference systems for the different conversion systems. Positive values mean net savings of emissions compared to reference system. Alternative use of biomass is co-combustion in coal power plant.

In FT 3 we show the effect of not taking into consideration that biomass is a limited resource and thereby could save emissions by being used elsewhere. In FT 3 the emissions savings due to the DH delivery is reduced to the savings of not producing and utilising the biomass. The chosen reference systems of other products are of some importance e.g. case SNG 3, where the bio-SNG replaces natural gas in industry instead of petrol in cars. Case FT 4 shows that CCS at the biomass conversion plants is of significant importance. Our results also show that the conversion to plastics results in significant savings compared to the fossil route. The significant electricity production in the methanol plant is an important part of the savings in these cases and in addition the electricity production possible from the end use of the materials (incineration) is also an important part of the total savings from the material part. The delay of emissions due to the lifetime of products had little impact, mainly since the delay will also occur in the reference system and the crediting for the electricity produced at incineration is delayed. Further, all of the gasification systems showed lower potential for GHG reduction than using the biomass for co-combustion in a coal power plant. This means that even though the biomass gasification systems result in net savings compared to the fossil systems, they are not optimal solutions for GHG mitigation when biomass is a limited resource.

Table 2. Assumptions for the different cases presented in Fig. 3.

Case	Assumptions
FT, SNG and PE & PP base	Reference electricity is produced in coal power plant. SNG replaces petrol in private cars. 85% of FT-products replace diesel in heavy duty vehicles and 15% replace petrol in private cars (based on [13]). Bio-based PE and PP replace fossil PE and PP based on naphtha, the end use is assumed to be short lived products (< 1 yr.). DH replaces biomass boiler; 300 GWh heat can be delivered from each of the plants. The delivery of DH leads to a reduction in biomass demand corresponding to the amount needed in the biomass boiler, which instead can be used in coal power plant.
FT 2, SNG 2	DH replacing natural gas boiler in industry. Greater amount of DH can be delivered due to higher number of operational hours in industry.
SNG 3	SNG replaces natural gas in industry
FT 3	Biomass resource is not considered limited. The reduction in biomass utilisation due to DH delivery does not lead to increased use in coal power plant.
FT 4	CCS is applied. 50% of coal in biomass could be stored away (based on [24])[a] .
PE & PP 50	The lifetime of the end products is assumed to be 50 years, and the carbon storage in products is taken into account according to method by [11,12]
Alt. use of biomass	Alternative use of biomass. Includes emissions from the life cycle of biomass and reductions from the saving of coal utilisation in co-combusted power plant.

[a] Assumption on electricity consumption for capture, separation and storage is based on [25].

7 Discussion

Few studies include a reference use of the biomass [2, 26] but our examples show that the biomass reference impacts results significantly. It is important to include either a reference use of the biomass or a reference land use [1]. Even though our results show that using biomass for co-combustion in coal power plants has higher potential of reducing GHG emissions, there are several reasons to further investigate the gasification systems. Transportation biofuels constitute an alternative to the limited fossil sources, and are thereby not only a solution to GHG mitigation. Further, conversion and efficiency data for our examples were taken from literature. However, the availability of data on optimized and integrated processes is limited and needs further investigation. For example, SNG processes with reduced or no electricity demand do exist at smaller scale and FT-processes have good possibilities for carbon capture. According to our results, such systems show GHG emission reductions comparable to the savings in a co-combustion plant. Knowledge of the methanol production plant with the downstream MTO process is very limited and needs to be investigated further. Our results show that reference electricity and DH production are important parameters for sensitivity analysis. A scenario approach using the tool from [6] could be used for this. The LCAs of other reference products should also be adapted to the assumptions of the scenarios.

A LCA for a biorefinery concept, producing chemicals, based on switchgrass showed that the biomass production chain had a significant impact on the overall result [27]. However, in our case, using forest residues, both land use emissions and fertilisers are of little importance and hence the biomass production chain constitutes only a small part of total emissions. Since gasification units might use different biomass feedstock it is important to state which biomass has been used for a specific GHG evaluation.

8 Future work

Biomass gasification systems should be studied in more detail. Increased integration and optimal solutions could possibly increase emissions savings to levels comparable to those of using the biomass for coal co-combustion in power plants.

Acknowledgments

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Application of CHP Gas Engine Plant for a Detergent Factory: Energy and Environmental Aspects

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Abstract: In Middle East countries like Iran, energy intensity is higher than the other regions due to low energy prices. One of the good motives towards energy efficiency is energy prices and because of this fact Iranian government wants increase the energy prices. One of the best technologies in energy efficiency is combined production of heat and power (CHP). In this paper the feasibility study of utilizing a CHP unit in an Iranian detergent factory has been described. The thermal and electrical energy uses in the factory has been measured According to the energy consumptions. The CHP system has been selected based on reciprocating gas engines. The feasibility study for the CHP system has been performed with different energy prices and environmental effect like reduction in CO2 emission has been analyzed. The CHP system can save 6,500 tons of CO2 per annum. In the feasibility studies rate of return method has been utilized. According to the energy prices scenarios, the rate of return would vary between 13% and 33%.

Keywords: *CHP, Gas engine, Energy efficiency, Carbon dioxide emission, Feasibility study*

Nomenclature

AEL annual saving of electricity bill................ €
ANG annual fuel cost .... €
i rate of return
AO&M annual operation/maintenance cost..... €
ARH recoverable heat from intercooler/oil... kW
CHP combined heat and power
CI capital investment..................................... €
ASNG annual saving of natural gas bill........... €
EUF energy utilization factor........................... €
E30 30,000th hour maintenance cost.................€
E60 60,000th hour overhaul cost.......................€
ELEC present worth of saving electricity production ....€
NGC natural gas consumption.................. $m^3 \cdot h^{-1}$
MRH recoverable heat from water jacket..... kW
L percent of electrical full load

1. Introduction

After the first energy crisis in 1970s, OECD Countries decided to change their energy policies in order to reduce their dependence on imported energy from the Middle East. They utilized energy efficiency as an effective way to reach that goal. The best way to comprehend the presence of energy efficiency in a country or a region is to take a short look at its energy intensity curve. By utilizing energy efficiency in energy programming, the energy intensity will decrease every year (Fig.1).

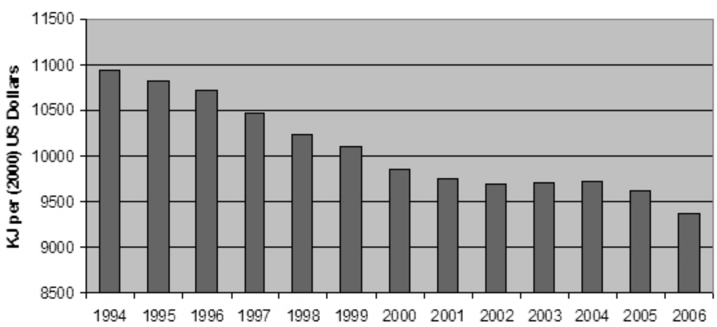

Fig. 1. World energy intensity [1].

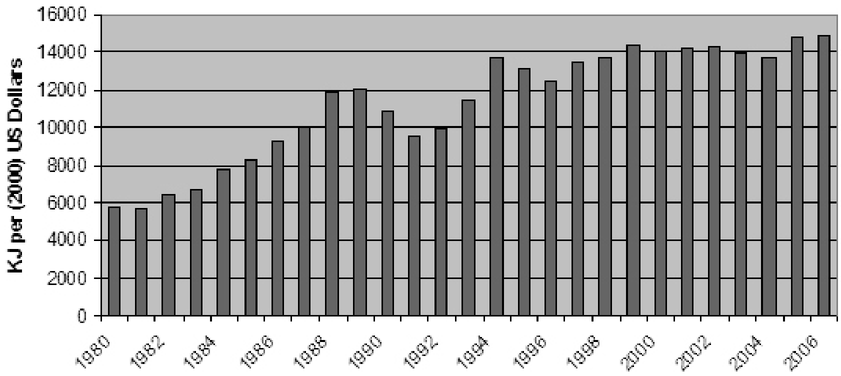

Fig. 2. Iran energy intensity [1].

On the other hand, Middle East Countries like Iran, which have rich energy resources, delayed utilizing the energy efficiency (Fig.2). In such countries, there is a huge obstacle on the path to reach an ideal energy efficiency, which is obviously the “low energy price”. Low energy price always turns a profitable energy efficiency project to a lowly-lucrative one. In order to remove this obstruction, the Iranian government has planned policies to increase energy price in the near future. This project has sparked so many controversies amongst politicians because of its influential effect on the rate of inflation. However, because of the above-mentioned debates, it has not been enacted yet. Such an increase in energy prices is a nightmare for Iranian industries who are accustomed to low energy prices. The only way the industries may be able to come up with is by changing this threat to an opportunity through energy efficiency programs. One of the good practices in energy efficiency, which has been achieved since 1970s, is combined production of heat and power (CHP). In addition, distributed CHP systems in industries will result in reduction of electrical grid losses. The average thermal efficiency of thermal power plants in Iran is 36% and the loss in high and medium voltage electrical network is 4% [2]. Most of factories in Iran receive their electrical power by medium voltage network. Therefore, if the industries produce their own electrical demand by a CHP system, the grid losses, the fuel consumption and carbon dioxide emission will be lower. In this paper, application of a CHP system in a detergent factory in Iran is studied and discussed about the ratio between natural gas (as a fuel) and electricity prices and feasibility of the project. This factory is one of the largest detergent producers in the Middle East and produces over 132,500 tons of detergents per annum. The process of this factory requires electrical and thermal energy simultaneously. Therefore, CHP system is a perfect way to utilize energy efficiency in the factory, reducing energy bills and carbon dioxide emission.

2. Methodology

In the following section the energy demands of the factory, utilization of gas engines CHP system and economical analysis are described.

2.1. *Energy demands of the factory*

By installing a power logger in the main electrical feeder of the factory, electrical demand of the factory was measured. The electrical power demand of the factory is 3600 kilowatts and the annual consumption of electrical energy is 28,400,000 kilowatt-hours.

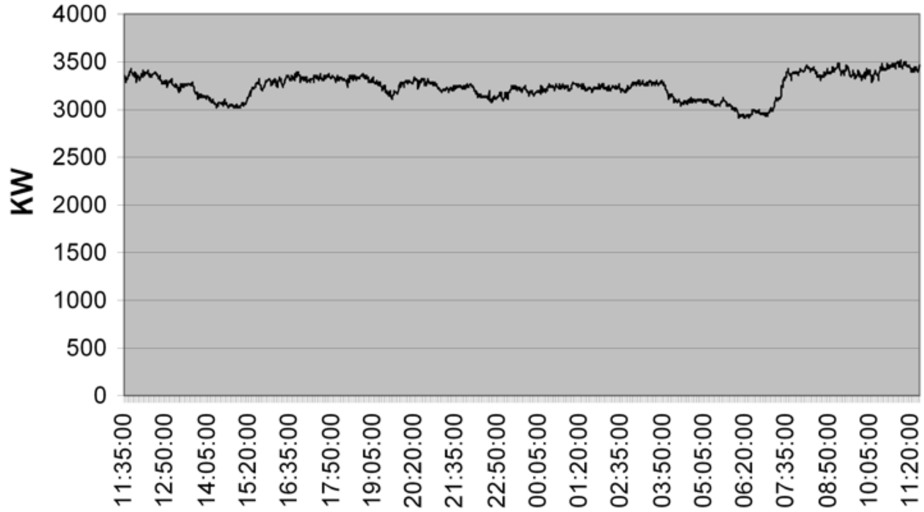

Fig. 3. Electrical demand of the detergent factory in a typical day.

The factory process consumes 244,931,438 kWh of thermal energy annually. Thermal energy source of the factory process is 45 tons per hour saturated steam at 1 MPa by 5 fire tube steam generator. The boiler's fuel is natural gas. The feed water enters the steam plant at $15^{\circ}C$ and it is heated by pegging steam in heat exchangers to $60^{\circ}C$. It enters the dearator to be heated to $95^{\circ}C$ in order to remove incondensable gases from feed water. For preheating the feed water in the steam plant, the factory needs 4.6 tons of steam per hour. All the produced steam is consumed within the process and there is no pipeline to return the condensate and recycle it as boiler feed water.

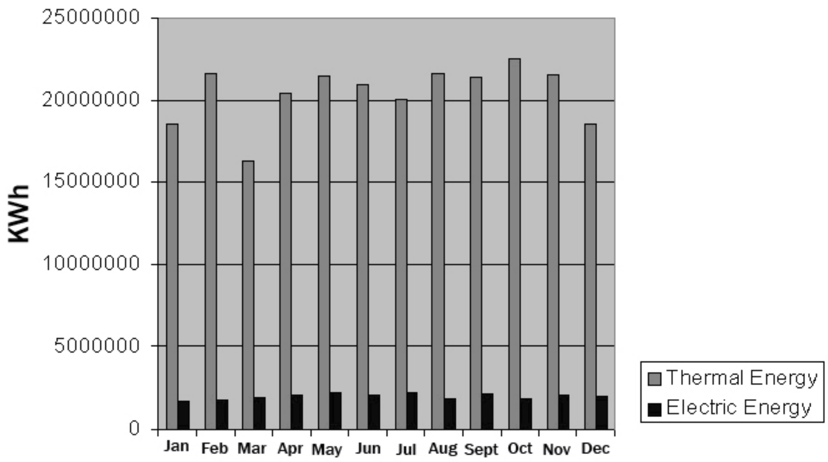

Fig. 4. Electrical and thermal energy usage in the detergent factory.

2.2. The choice of gas engine CHP system

In this case study, the authors selected a CHP system with 4 gas engine generating sets to cover the electrical demand. The nominal power of each gas engine is 952 kW therefore the overall nominal power of the plant is 3808 kW. The plant altitude is 1100 meters above the see level and in this site conditions the gas engines derate and actual power would be 4% and 3655 kW respectively [3]. For heat recovery of the system 2 plate heat exchangers are allocated for each gas engine. One of the plate heat exchangers recovers the waste heat from intercooler and engine oil and the other dedicates for waste heat of engine water jacket. The temperature of the intercooler/oil and water jacket are $60^{\circ}C$ and $95^{\circ}C$ respectively. The waste heat of intercooler/oil is 844 kW (4 gas engines) and it can heat the feed water from $15^\circ C$ to $31^\circ C$ [3]. After preheating in intercooler/oil heat exchanger, the feed water enters the water jacket heat exchanger and gains 2520 kW thermal power and reaches to $80^\circ C$. Utilizing the waste heat of the gas engines will saves up to 3.8 tons per hour of steam in heat exchangers and dearator in steam plant. The electrical and thermal efficiency in full power at actual site conditions are 38% and 35%. Therefore the EUF of the plant is 73% at full power. However, the EUF, thermal and electrical efficiencies would vary with different electrical power output.

2.3. Energy analysis

According to Fig.3 the hourly electrical demand of the factory is fluctuating and the gas engines have to follow these fluctuations. With changing the electrical load of a gas engine, its waste heat will be different. Less electrical output of a gas engine means less amount of heat to be recovered. However, the variation in amount of recoverable heat is not linear with electrical output power. The electrical demand of the factory has been measured with the sampling time of 1 minute for 24 hours. To calculate the amount of recoverable heat from intercooler/oil and water jacket, the demand is divided between 4 gas engine generators. In Table 1 the thermal data sheet of the gas engine is mentioned. By interpolation between columns of Table 1, the correlations between the amount of recoverable heat from intercooler/oil and water jacket versus electrical output power have been developed. To reach this goal authors fitted a polynomial order 3 curves between the electrical output power versus the amount of recoverable heat from main and auxiliary water circuits.

$$MRH = 5 + 1216 \times L - 1112 \times L^2 + 520 \times L^3 \quad (1)$$

$$ARH = 76 - 81 \times L + 300 \times L^2 - 84 \times L^3 \quad (2)$$

$$NGC = 12 + 302.5 \times L - 125 \times L^2 + 62.5 \times L^3 \quad (3)$$

$$EUF = \frac{Electrical \quad Power + Heat \quad Power}{Inputed \quad Heat \quad by \quad Fuel} \quad (4)$$

Where L is the ratio between electrical load on each generator and maximum net actual power on the given site conditions for one gas engine generator. Using Eqs. (1) and (2), the amount of recoverable heat from intercooler/oil and water jacket is calculated every minute for 24 hours. In order to estimate the consumption of natural gas of the gas engines versus load, a correlation has been developed (Equation 3). Table 1 shows fuel consumption of the engines. In this table, fuel consumption is mentioned as heat power in kilo Watt. To transfer the heat power to flow rate of natural gas, the net heating value of natural gas is needed [4]. Energy utilization factor (EUF) for a CHP system is the amount of electrical power plus useful recovered heat from the system divided by the amount of heat input from the fuel (natural gas) to the system. Table 2 shows the amount of recovered heat from auxiliary and main circuits, natural gas consumption for 24 hours period of a typical day and a year. Table 2 reveals that the total recovered heat per year is 26,760,340 kWh, which is equivalent to 2,804,554 m^3 of natural gas per year. In addition, the total heat input to the CHP system per year is 76,428,645 kWh. Therefore, the EUF of the CHP system is 72.14%.

Table 1. The gas engine thermal datasheet [3].

Power rating		Full	Partial load		
load	%	100	80	60	40
Electrical power	KW	952	761	571	380
Fuel consumption	KW	2386	1952	1538	1105
Water jacket waste heat	KW	630	533	447	347
Intercooler/oil waste heat	KW	211	160	117	86
Heat in exhaust gases (120 C)	KW	388	328	268	194

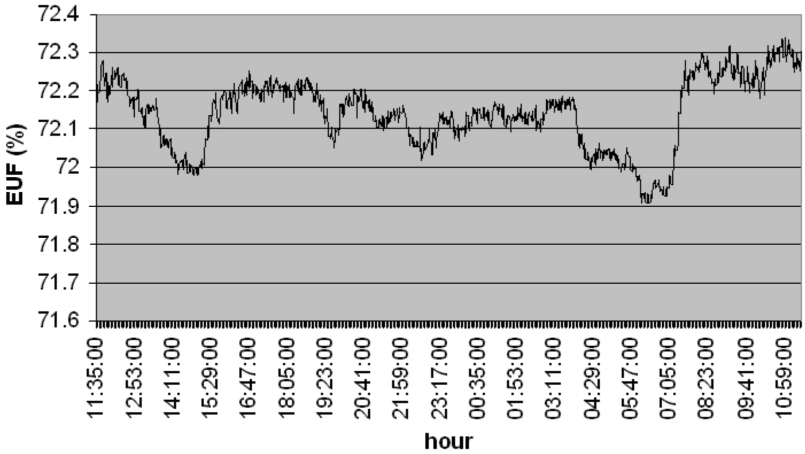

Fig. 5. Energy utilization factor of CHP System in a typical day.

Table 2. Energy parameters of CHP system.

	Unit	Per day	Per year
Natural gas consumption	m^3	21,945	8,009,925
Electrical energy production	kWh	77,754	28,380,210
Auxiliary circuit	kWh	17,743	6,476,195
Main circuit	kWh	55,573	20,284,145
Total heat recovery	kWh	73,316	26,760,340

2.4. Economical analysis

First step towards the economical analysis of a combined production of heat and power in the detergent factory is to determine the costs and benefits of the project. The costs of the project include the capital investment (which is 1.440.000 Euro), annual fuel cost, annual operation and maintenance (O&M) cost, and the 30,000th-hour maintenance and 60,000th-hour overhaul costs. The maintenance period of the selected gas engine is 60,000 hours, which includes 30,000th-hour maintenance and 60,000th-hour overhaul and the same periodic maintenance will be carried out quite regularly. The benefits of the project include saving the electricity bill and saving the natural gas bill as the result of recovering heat from the engines for preheating the boilers feed water instead of using pegging steam. The lifetime of the gas engine for continuous operation assumed to be 20 years. As it is discussed, the current energy price in Iran is low (natural gas: 0.011 Euro/m^3, Electricity: 0.014 Euro/kWh) and Iranian government is planning to increase it rapidly (natural gas: 0.0695 Euro/m^3, electricity: 0.0348 Euro/kWh) in the near future. Therefore, the benefits of the project need to be calculated with two different energy price references accordingly. Economical analysis carried out with rate of return method. Rate of return method is based on time value of money. In this method, the net present worth of costs including capital investments, are placed to be equal to net present worth of benefits with a variable rate of interest (Equation 5). This variable rate of interest is called the rate of return.

$$AEL \times \left(\frac{(1+i)^{20} - 1}{i \cdot (1+i)^{20}} \right) + ASNG \times \left(\frac{(1+i)^{20} - 1}{i \cdot (1+i)^{20}} \right) = CI + ANG. \times \left(\frac{(1+i)^{20} - 1}{i \cdot (1+i)^{20}} \right)$$
$$+ AO\,\&\,M \times \left(\frac{(1+i)^{20} - 1}{i \cdot (1+i)^{20}} \right) + E30 \times \left[\frac{1}{(1+i)^{4}} + \frac{1}{(1+i)^{12}} \right] + E60 \times \left[\frac{1}{(1+i)^{8}} + \frac{1}{(1+i)^{16}} \right] \quad (5)$$

3. Results

In this section reduction in carbon dioxide emission, costs and benefits of project, economical analysis based on rate of return method are discussed.

3.1. Environmental analysis

As mentioned before, the average efficiency of Iranian national thermal power plants are 36% and energy losses in high and medium voltage grid is 4%. Currently the factory receives 28,380,210 KWh of electrical energy per annum from medium voltage grid, which means that the national power plants have to generate 29,562,935 kWh annually to overcome the energy losses. For generation of 29,562,935 kWh of electrical energy, a typical Iranian thermal power plant consumes 8,606,316 m^3 of natural gas. On the other hand for producing the same amount of electrical energy in the factory, the specified CHP unit consumes 8,009,925 m^3 of natural gas with 26,760,340 kWh of useful recovered heat energy, which is equivalent to 2,804,554 m^3 of natural gas. Therefore, CHP unit saves 596,391 m^3 of natural gas as the result of reducing grid losses and improving the electrical energy efficiency and 2,804,554 m^3 of natural gas as the result of recovering the wasted heat from the engines, which are totally 3,400,945 m^3. Burning each cubic meter of natural gas produces 1.91407 Kg of carbon dioxide [4]. Therefore, an annual saving of 3,400,945 cubic meters of natural gas means saving 6,509 tons of carbon dioxide emission per annum.

3.2. Economical analysis

By solving the Equation 5, rate of return of the project is revealed. In table 3, the feasibility study result of the project for two different energy prices has been discussed.

Table.3. Annual costs and benefits of the CHP system

Item	Amount	Current price (€)	Price in near future (€)
Natural gas	8,009,925 m^3	88,999	556,244
O&M	-	77,250 [5]	
Maintenance at 30,000 hour	-	140,000 [5]	
Overhaul at 60,000 hour	-	160,000 [5]	
Saving the electricity bill	28,380,210 kWh	394,169	985,423
Saving the natural gas bill	2,804,554 m^3	31,161	194,760
Rate of return	-	12.6 %	33.3 %

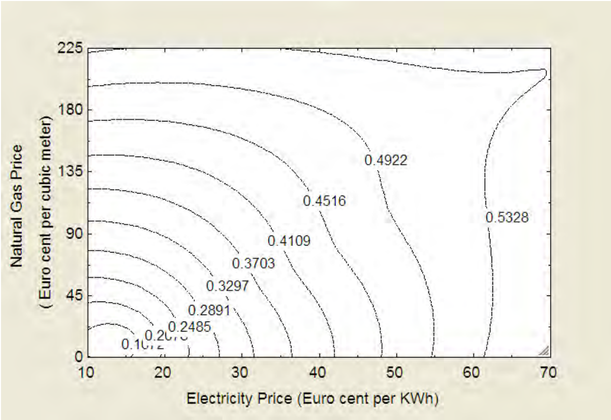

Fig.6. The sensitivity of energy prices versus rate of return.

Feasibility of the project is highly dependant to the energy prices. In the Fig.6, the effect of natural gas and electricity prices on the rate of return has been shown.

4. Conclusion

Application of a CHP system in the detergent factory was discussed from technical, economical and environmental point of views. Such a system can save 2,804,554 m^3 of natural gas and 6,509 tons of carbon dioxide annually without interrupting in the factory processes. The factory needs steam for its processes and the only way for direct steam generation with gas engines is utilizing heat from exhaust gases. The exhaust gases can produce only 2 ton of steam per hour but by utilizing low temperature heat from intercooler/oil and water jacket in order to preheat the feed water of boilers, 3.8 tons of steam per hour will be saved. This method of heat recovery is more efficient, simple and cheap. The feasibility of the project strongly depends on the fuel and electricity prices. Government should increase the energy prices in a conducted way to encourage the industries to utilize CHP system. Finally this study encouraged the owners of the detergent factory to install gas engines CHP plant and now the system is under operation.

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Combined Optimal Placement of Solar, Wind and Fuel cell Based DGs Using AHP

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Abstract: The integration of distributed generations (DGs) into grid has a great importance in improving system reliability. Many methods were proposed in the literature for finding best locations for DG placement considering various criteria. Sometime, it becomes difficult for combined placement of different kinds of renewable based DGs, such as solar, wind and fuel cell. The criterion of minimizing total system cost was used previously by many researchers for locating the optimal sites for DGs using OPF formulations. In this case, three different cost functions are formulated for different kinds of renewable energy sources (RESs). By taking combined cost function of all the RESs in the OPF to identify location for each different kind of sources becomes very cumbersome task. It would be difficult to find the exact locations for various kinds of RESs that is where to place which type of RESs. In order to solve this difficulty, three different objectives have been considered separately for determining the optimal locations for each kind of RESs using mixed integer nonlinear programming (MINLP) method. Having many alternatives with these three objectives, analytic hierarchy process (AHP) has been used to make a decision over getting the optimal locations for these different kinds of RESs. The proposed method for finding the optimal locations of solar, wind and fuel cell based DG placement has been demonstrated on 15 node distribution systems.

Keywords: *Analytic hierarchical process, Distributed generation, Mixed-integer non-linear programming, Optimal power flow, Renewable energy sources*

1. Introduction

The electric energy requirement has been rapidly increasing day by day throughout the global, Hydro and fossil fuel plants will continue to be the chief sources of electric supply for a few years. Electric supply authorities are likely to pay more attention to improve the generation technologies. Before the innovation of large generating units, small DGs were in use to supply electricity. But, due to economy of scale large generating systems were developed and the electricity is supplied at a cheaper price. However, there has been revival of interest in connecting DG to the distribution network. DG is often used to illustrate a small-scale electricity generator which can be owned and operated generally by customer to achieve sufficient volume of energy maintain the quality and reliability in electricity supply. It can be RESs, based on wind, photo-voltaic, biomass, fuel cell or hydroelectric power. RES may be either connected to the local electric power grid or isolated from the grid in stand-alone applications. RES plays an important role in providing clean energy along side reducing carbon foot prints, and hence a crucial constituent of future developments. The penetration of DGs in the network helps in achieving voltage control, reduction of power losses and improvement of system reliability.

Optimal location for the placement of DGs with minimization of losses using gradient and second order methods is presented in [1]. In [2], a linear programming approach to determine optimal allocation of embedded generation on distribution networks is proposed. Optimal location and sizing of distributed generation in a distribution networks using Genetic Algorithm (GA) is discussed in [3]. The allocation and sizing of DGs for social welfare maximization and profit maximization using Locational marginal price (LMP) is proposed in [4]. Optimal placement of distributed generation for profit maximization, reduction of losses and improvement in voltage regulation at various load buses in the distribution network is shown in [5]. In [6], a GA based methodology for optimal DG allocation and sizing in distribution systems, in order to minimize network losses, and guarantee high level of reliability and voltage improvement was proposed. A method to allocate and determine the size of DG for minimization of the active losses of the feeders using tabu search algorithm is presented in [7]. In [8], Analytical Hierarchical Process (AHP) is used to decide the hierarchy of the planning process and members constituting the hierarchy are allowed to rate each other and relative grading of weights is discussed. AHP method is used to solve the DG planning with uncertainties and a different objective in a DG planning problem is discussed in [9]. The application of solid oxide fuel cell (SOFC) systems to generate electric power and thermal energy required for residential use is discussed in [12].

In this work, the planning of RESs has been carried out by using a hybrid method consisting of both optimization and analytic hierarchy process. Three different optimal power flow (OPF) problems have been formulated and solved using the mixed- integer non-linear programming (MINLP) method, which provides optimal bus locations for RES at various load serving nodes and ranking of each of the optimal bus location for the system. With numbers of alternative bus locations and rankings obtained from three OPF formulations, the overall priority indices have been obtained by using Expert Choice based on an analytic hierarchy process algorithm. The results of AHP clearly indicate the ranking of optimal location for various kinds of RESs. The effectiveness of the proposed approach has been tested on 15 node distribution systems [15].

2. Problem Formulation

For the planning of various kinds of RESs, three different OPF formulations have been used. The different objectives used in these formulations consider the minimization of cost of fuel cell, photo-voltaic system and wind turbine generation. With each of these objectives, the ranking of RES source locations has been obtained. Optimal placement of RES can provide both economical and operational advantages. The OPF formulations are given below.

2.1. Objective function

The three objective functions can be mathematically expressed as follows.

Case A: Minimizing fuel cell cost:

$$C_{fuel} = C_c + C_f + C_m \tag{1}$$

Case B: Minimizing solar system cost:

$$C_{solar} = C_{O\&M} * LF + (C_{CC} * FCR)/8760 * CF \tag{2}$$

Case C*: Minimizing wind energy system cost:*

$$C_{wind} = (FCR * ICC)/AEP_{net} + AOE \tag{3}$$

where $C_c = C_{fc} * (i_r(1+i_r)^n)/((1+i_r)^n - 1)$ (4)

$$C_f = (\gamma_{ng} * P_{dgi})/\eta \tag{5}$$

$$AOE = LLC + (O\,\&\,M + LRC)\,/\,AEP_{net} \tag{6}$$

2.2. Equality Constraints

The network for the transmission of electric energy is modeled using the power balance equation at each node in the network. These include the usual load flow equations at each node and the power balance equation as given below.

$$P_{gi} - P_{di} = P_i \tag{7}$$

$$Q_{gi} - Q_{di} = Q_i \tag{8}$$

$$PLT = \sum_j P_{Lj} \tag{9}$$

$$QLT = \sum_j Q_{Lj} \tag{10}$$

2.3. Inequality Constraints

These constraints have considered the following.

Real and reactive power generation limits:

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max} \tag{11}$$

$$Q_{gi}^{\min} \le Q_{gi} \le Q_{gi}^{\max} \tag{12}$$

Voltage and angle limits:

$$V_i^{\min} \le V_i \le V_i^{\max} \tag{13}$$

$$\delta_i^{\min} \le \delta_i \le \delta_i^{\max} \tag{14}$$

Distribution generation limits:

$$u.*P_{dg}^{\min} \le P_{dg} \le u.*P_{dg}^{\max} \tag{15}$$

where C_{fuel} is fuel cell cost function, C_{solar} is solar system cost function, C_{wind} is wind energycost function, C_c is annual investment cost, C_{fc} is total purchasing cost, γ_{ng} is the price of natural gas, η is the electrical efficiency, C_m is maintenance cost expressed as 4–10% of the purchasing cost, P_{dgi} represent DG generated power at bus i, $C_{O\&M}$ is the operating and maintenance cost, LF represent levelizing factor, C_{CC} shows the capital cost, FCR is fixed charge rate, CF is capacity factor, ICC represents initial capital cost, AEP_{net} is net annual energy production, AOE represents annual operating expenses, LLC and LRC are land lease cost and levelized replacement cost, i_r represents annual interest rate, n represents lifespan in years, P_i and Q_i represents active and reactive power injection at bus i, P_{Lj} and PLT represent individual real line loss and total real system loss, Q_{Lj} and QLT represent individual reactive line loss and total reactive system loss, P_{gi}, Q_{gi}, P_{di} and Q_{di} are real and reactive power generation and demand respectively, P_g^{min}, P_g^{max}, Q_g^{min} and Q_g^{max} represent limits on real and reactive power generations, V_i and δ_i are the voltage magnitude and angle at the i th bus, V_i^{max}, V_i^{min}, δ_i^{max} and δ_i^{min} are the maximum and minimum limits on voltage magnitude and angle at bus i, u is the binary vector {0,1} that represent the absence and presence of DGs sources at a bus and P_{dg}^{max} and P_{dg}^{min} are limits of generated power from DG.

3. Analytic Hierarchy Process (AHP)

AHP is introduced by Saaty in [10]. AHP is a decision-making tool, which helps in finding goals or objectives among alternative courses of action. It is a systematic method for comparing a list of objectives and the alternative solutions satisfying respective objectives. First, pair wise comparisons are made between the objectives and, then, between alternative solutions with respect to each objective. For pair wise comparison, some weights are also assigned according to the importance, or preference of the objectives or the alternatives. A comparison of objectives/alternatives i and j utilizes a value b_{ij} , defined in Table 1.

Table 1. Relative importance, preference, or likelihood (b_{ij}).

1	Objective i and j are of equally importance
3	Objective i is weakly more important than j
5	Objective i is strongly more important than j
7	Objective i is very strongly more important than j
9	Objective i is extremely more important than j
2,4,6,8	Intermediate values

Further, if $b_{ij}=k$, then $b_{ji}=1/k$
Considering a decision-making problem to prioritize m alternatives with n objectives, the AHP algorithm has been shown in Table 2.

Table 2. Pairwise comparison matrix of objectives.

	*obj*1	*obj*2	…	*obj*n	Priority
ob_{j1}	b_{11}	b_{12}	…	b_{1n}	p_1
ob_{j2}	b_{21}	b_{22}	…	b_{2n}	p_2
.	.	.	.	.	.
.	.	.	.	.	.
ob_{jn}	b_{n1}	b_{n2}	…	b_{nn}	p_n

The relative weights of objectives can be computed as normalized geometric means of the rows (which are very close to the eigenvector corresponding to the largest eigenvalue of the matrix). The geometric means are computed as

$$h_i = \sqrt[n]{\prod_{j=1}^{n} b_{ij}} \qquad (16)$$

The relative weight (priority) of the i th objective is obtained as

$$p_i = \frac{h_i}{\sum_{i=1}^{n} h_i} \qquad (17)$$

Similarly, the pairwise comparison matrix can be defined for alternatives with respect to each objective. Therefore, with *m* alternatives for the *k*th objective, the priority of the *i*th alternative is obtained as

$$h_{ki} = \sqrt[m]{\prod_{j=1}^{m} b_{kij}} \qquad (18)$$

$$p_{ki} = \frac{h_{ki}}{\sum_{i=1}^{m} h_{ki}} \qquad (19)$$

The overall priority of the *m*th alternative is obtained as

$$p_m = \sum_{i=1}^{n} \sum_{k=1}^{n} p_i \, p_{km} \qquad (20)$$

4. Case Study

The proposed hybrid method for RESs planning has been demonstrated and analyzed on 15 node distribution system [15]. The MINLP method has been used to obtain the optimal locations of DGs for each case separately. For ranking of optimal DG locations, all of the available DGs are taken simultaneously. In case A, which minimizes fuel cell generation cost with five numbers of DGs, the optimal locations are found at buses 13, 15, 12, 11, and 10. Reducing the maximum available source to four, buses 13, 15, 12, and 11 are found as the optimal locations. Hence, it can be concluded that bus 10 was ranked last, i.e., fifth. Again, by reducing the available sources to three, buses 13, 15, and 12 are found as the optimal locations, and, hence, bus 11 is ranked as fourth. Similarly, by reducing the available DGs, the ranking of optimal locations are obtained.

Table 3. Ranking of RESs locations based on different objective and overall locations.

Rank	Case A	Case B	Case C	Overall locations
1	13	12	15	15
2	15	11	14	13
3	12	10	13	14
4	11	9	12	12
5	10	13	11	11

Considering case B, which minimizes photo-voltaic generation cost, with five numbers of DGs, the optimal locations are found at buses 12, 11, 10, 9, and 13. While considering case C, which minimizes wind turbine generation cost, with five numbers of DGs, the optimal locations are found to be bus 15, 14, 13, 12, and 11. Table 3 shows the ranking of DG locations with different objectives (cases A, B, and C) are found and overall ranking for these three cases obtained by using the AHP. The scheme for obtaining the optimal locations of DGs is given in Figure 1. It can be observed from Table 3 that, with each objective, different rankings of optimal locations are obtained with a few common bus locations. Thereafter, as

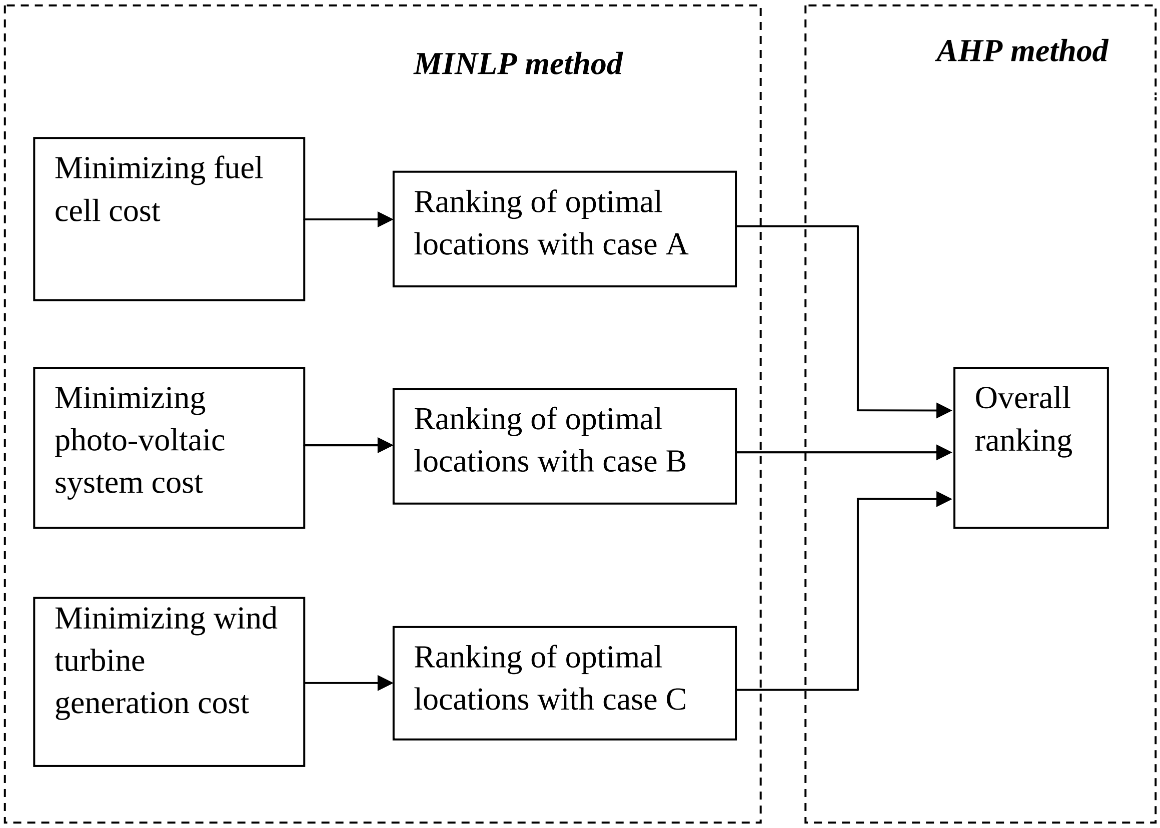

Fig. 1. Flow diagram of the hybrid method used for RESs planning.

given in the flow diagram in Figure 1, AHP algorithm is used to compute the overall ranking of optimal bus locations for RESs placement. The ratings considered for various types of RESs are 5 kW, 20 kW and 50 kW for fuel cell, photo-voltaic system and wind turbine generation system, respectively. Figure 2 shows the performance sensitivity graph with respect to criteria and goal. The objectives and alternatives are represented by the vertical and horizontal bars, respectively. The intersection of the alternative line graphs with the vertical criterion lines shows the priority of the alternative for the given objective, as read from the right axis labeled Alt%. The objective priority is represented by the height of its bar as read from the left axis labeled Obj%. The overall priority of each alternative is represented on the OVERALL line, as read from the right axis. It is observed from the graph that the suitable locations for wind, solar and fuel cell are 15, 13, 14, 12, 11, 10 and 9. The highest priority has been given to wind energy system whereas the solar system has got the lowest priority as shown in Figure 2. Finally we can conclude that wind energy system is the best for bus 15, fuel cell system is best suited for bus 13, wind energy system is best suited for bus 14 and solar energy system is best suited for bus 12, 11, 10 and bus 9, respectively.

Figure 3 shows the dynamic sensitivity of the different optimal bus locations, which indicates the priority in percentage for a particular bus. As per the Figure 3 the priority of bus 15, 14, 13, 12, 11, 10 and 9 is 28.4% (highest), 16%, 20.5%, 15.5%, 11.3%, 5.3% and 3% (lowest), respectively. Figure 4 shows the percentage of location for various types of RESs in the system. From this figure, it can be observed that 63.7% of the location is supplied by wind energy sources, 10.5% by solar energy and remaining 25.8% by fuel cell energy system.

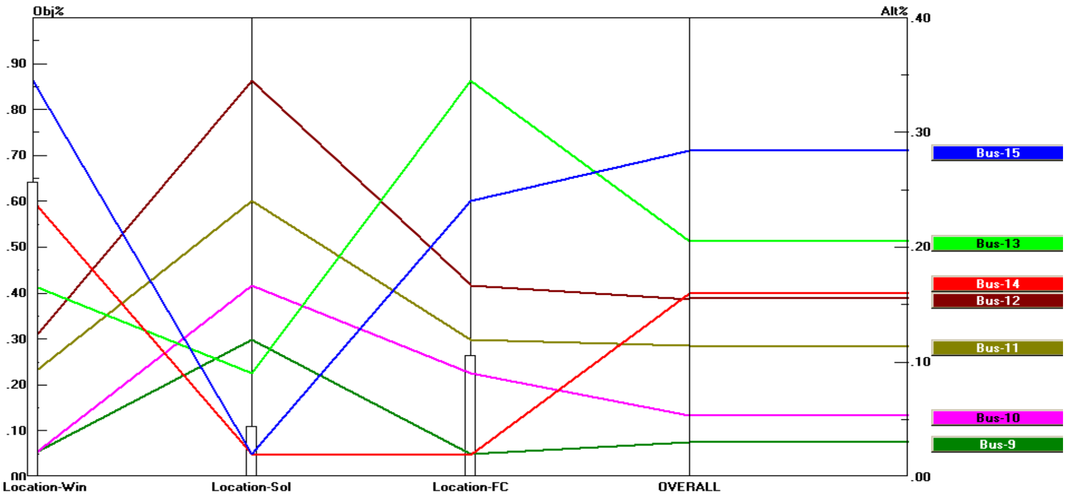

Fig. 2. Performance sensitivity graph with respect to criteria and goal.

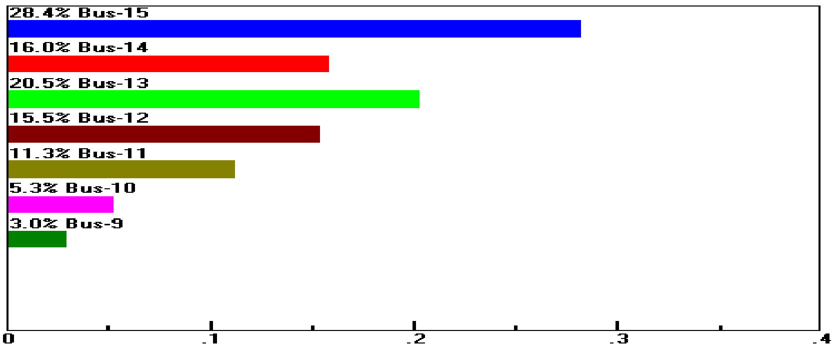

Fig. 3. Dynamic Sensitivity of the nodes.

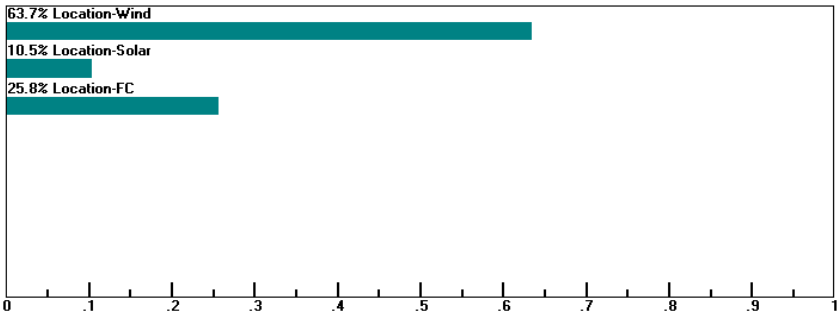

Fig.4. Distribution of RES locations based on different objective.

5. Conclusion

This paper proposes a hybrid method for DG planning taking various kinds of RESs simultaneously into account. This approach consists of two steps. In first step, the ranking of optimal locations are obtained by using MINLP method with an objective of minimizing the cost of respective RES. It has been observed that some of the optimal locations found to be same for different kinds of RESs, and which creates confusion over the placement of various types of RESs. Then, in second step AHP is used to distinguish the locations for various kinds of RESs by identifying the exact optimal location for a particular type of RES. These locations also indicate the placement and type of RESs. The results clearly indicate the overall ranking of bus locations and the type of energy sources to be placed there. In this planning work, wind, solar and fuel-cell energy has been used in the ratio of 63.7%, 10.5% and 25.8%, respectively. If this sharing of various RESs changes then, the locations for different kinds of RESs also changes.

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Exploring the sustainability of industrial production and energy generation with a model system

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Abstract: The importance and complexity of sustainability has been well recognized and a formal study of sustainability based on system theory approaches is imperative as many of the relationships between the various components of the system could be non-linear, intertwined, and non-intuitive. A mathematical model capable of yielding qualitative inferences can serve as an important tool for policy makers to: (1) explore various simulated important scenarios, and (2) evaluate different strategies and technologies. In this article, we consider a simplified ecological food web with an integrated macro-economic system, industrial production sector, an energy generation sector, and elements of a human society along with a rudimentary legal system. The energy sector is designed to supply energy to the other components of the system either by using a finite, non-renewable energy source or by a combination of a non-renewable source and biomass. Many of the components of the system depend directly or indirectly on the biomass used for energy production. Subsequently, this model is used to study the impact of using biomass for the production of energy on the sustainability of other components of the system under different scenarios such as population increases and per capita consumption increase.

Keywords: *Sustainability, Energy, Ecological Model, Scenario, Ecosystem*

1. Introduction

Sustainability or sustainable development has been generally defined (1) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." From this definition, it can be noted that sustainable development can be achieved (and sustained) only by addressing various diverse issues making the study of sustainability an inherently complex and highly multi-disciplinary concept. The sustained effort of the scientific community has led to the realization that continued exploitation of the Earth's resources cannot be infinitely sustained and can severely endanger the existence of many of the biological species (2). This has led to a vast mobilization of efforts spanning all strata of human society including the scientific, political, and social. A growing body of research has been reported in literature (3-8). It has tried to comprehend the causes of various naturally occurring phenomena and attempted to predict some future consequences, along with suggesting remedial actions that need to be implemented over a period of time to avoid catastrophic events. It should be noted that sustainability is not a goal but a path or corridor through time, which has to be continuously followed and monitored. Sustainability is dependent on the interactions between the various dimensions of the system such as ecology, human society, economics, technology, and other aspects. Often, these interactions are nonlinear, intertwined, and non-intuitive in nature (7, 8). Additionally, the effects of many current actions manifest over a long period of time making the study of sustainability quite complex, requiring a systematic approach.

Stable mathematical models featuring the critical components of a real system can aid in the formal study of sustainability. Models capable of yielding qualitative inferences about sustainability under various simulated scenarios can assist policymakers when evaluating various strategies and technologies. A comprehensive review of some of these models can be obtained from Whitmore et al. (5). The model proposed by Whitmore et al. (5, 6) integrated an economy under imperfect competition with a twelve-cell ecological model. Despite the unique features of the model, it had a limiting assumption as it presumed that an infinite amount of energy was available without any cost to the various components of the integrated system. This assumption warrants a cautious approach when extending the qualitative results of the model to any real world system, where it has been seen that factors related to energy not only have geo-political ramifications but also cause enormous stress on certain components of the system that could jeopardize sustainability.

An enhanced model, which considers various aspects, related to the production and utilization of energy from various types of energy sources in an integrated system has been presented in this article (8). This model can be used to simulate the production of energy based on a finite, non-renewable energy source or a combination of both a non-renewable energy source and biomass. The model is subsequently used to study the sustainability of different components of the integrated system due to the diversion of a part of biomass for the production of energy. Finally, we have used the model to study the sustainability of the integrated system under various plausible scenarios such as a population increases and an increase in the per capita material consumption levels of humans.

2. Integrated Ecological-Economic Model

The model consists of 14 compartments and represents a simplified ecological food web set in a macro-economic framework with farming, livestock raising, industrial production, energy generation, and a rudimentary legal system. The model shown in Fig. 1 consists of three primary producers (P1, P2 and P3), three herbivores (H1, H2 and H3), and two carnivores (C1 and C2) along with human households (HH). The Resource Pool (RP) represents a generic finite nutrient source while the Inaccessible Resource Pool (IRP) represents mass that is not biologically accessible to the rest of the system. The primary producers feed on RP and use energy from the Sun to make this mass available to the rest of the integrated system. A small amount of mass from IRP is recycled back into the system by P2 and P3, which symbolizes degradation by the actions of microorganisms. All nine biological compartments recycle mass back to RP through death. The Energy source (ES) represents a finite non-renewable energy source. The Energy Producer (EP) is an industry that uses labor to transform the energy source into a usable form of energy. This energy is supplied to HH and IS. EP is also capable of producing energy using P1, and this would represent the production of energy using biomass. The IS produces products valuable to HH using P1 and RP. The use of the IS products does not increase the mass of HH, but it instead passes through as this is used to increase the mass of IRP. Similarly, the use of mass by the EP to produce energy results in the increase of the mass of the IRP and a corresponding decrease in the mass of ES. The biological compartments of the system can be aggregated as shown in Fig. 1 into domesticated species that have economic value and wild species that have no economic value. A legal system assigns property rights to domesticated biological species, the product of the industrial sector, and the non-renewable energy source. Grazing rights are given to H1 to access P2, while the access of C1 to H1 is limited. Moreover, C1 is a protected species and cannot be hunted or consumed by other components of the integrated system. Similarly, the access of P1 by H2 is limited by using capital and labor, i.e. erecting barriers or “fences.”

The human workforce can choose to work in any of the four industries (P1, H1, IS or EP) and the wages are set by IS depending on the demand supply gap of the IS product along with the population, i.e. IS dominates the labor market. The demand for any product (P1, H1, and IS) by HH also depends on the price and demand for various other products. The demand for a particular product (say P1) decreases with an increase in the price of that product (P1) and the demand increases (for P1) with an increase in the price of other products (like H1 and IS). The prices of the products depend on the wages paid for labor and the demand supply gap of that particular product. An increase in the wage levels or demand supply gap increases the price of the product. The price of energy depends on the labor and the amount of fuel that is available at the given point of time. An increase in labor cost increases the price of energy whereas a decrease in the amount of energy source would lead to an increase in the price of energy. The growth of the human population depends on the per capita human mass, the birth rate, and the mortality. The human birthrate in turn is assumed to be a negative function of the real wage as it represents the opportunity cost of opting to remain outside the labor force for the purpose of rearing children. The complete system is closed to mass so that it abstractly represents a planet. The food web is modeled by Locka-Volterra type expressions whereas the economy is represented by a price-setting model wherein firms and HH attempt to maximize their well-being. The aim of this model is to represent the critical elements of a real world system while keeping it simple enough for tractable mathematical analysis. Some of the salient features of the model include an organization based on trophic levels with fewer species and lower total mass for higher trophic levels, species specific preferences for food, cyclic variation in the growth of the primary producers, discharge fee on the industrial sectors and the ability to accommodate both non renewable mass and biomass to produce usable energy. Also, the model is flexible enough to allow for variation of the amount of energy produced from biomass. For this article, it was assumed that 30% of the total energy demand by the integrated system is being provided by the biomass. If sufficient amount of biomass is not available, the maximum available biomass is used for the production of energy and the remaining energy is produced from the non-renewable energy source. Moreover, it was assumed that there is no surplus or deficit in the energy levels as the EP produces as much energy as required by HH and IS. The dashed lines in Fig. 1 indicate mass flows that occur under anthropogenic influence. The dotted lines indicate the flow of energy from EP to HH and IS. The square dotted line between P2, P3, and IRP indicate slow transfers of mass as a result of microbial activity. For the sake of brevity, the complete mathematical model is not presented here and details including the base case results can be found in Kotecha *et. al.* (8)

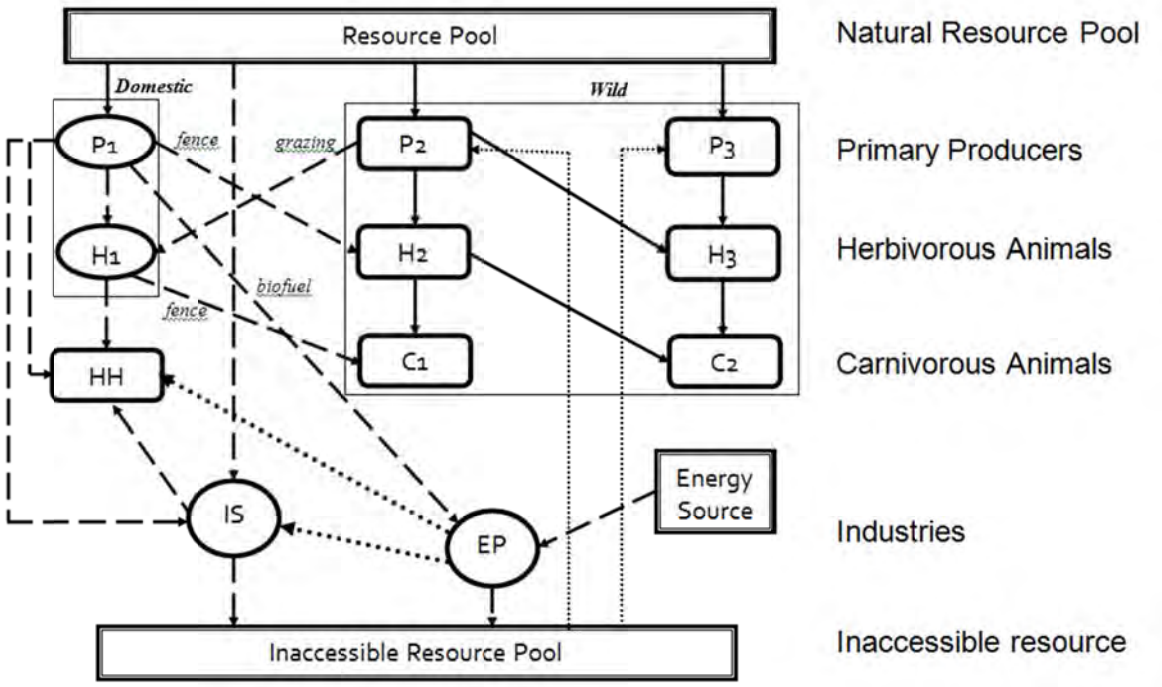

Fig. 1. Integrated Ecological Model

3. Scenario Analysis

Model based scenario analyses are an integral part of systems theory and help in understanding the dynamics of systems under various simulated scenarios without disturbing any actual system. Such analyses have been credited with helping make informed and rational decisions by their ability to offer insights into ramifications of current and possible future actions. However, the results of the scenario analysis should not be mistaken for actual forecasts, projections or predictions of the future as the future need not necessarily evolve based on the assumptions underlying the scenario analysis. At times, the actual future may involve a combination of different scenarios or even witness happenings not envisioned as possible scenarios. There have been a number of studies, which are based on scenario analysis and have been discussed in the literature (7, 8). We will consider here the two scenarios of an increase in human population and an increase in the per capita human consumption levels. For the sake of brevity, profiles of only the most important compartments have been provided.

3.1. Population Increase

Rapid population increase is one of the scenarios commonly envisaged by many environmentalists. The enormous growth of the human population has already placed severe stress on many finite resources of the Earth and may pose serious concerns on the sustainability of its ecosystem. It is widely believed that the human population will double from its current level and peak in the next 50-100 years (9, 10). This premise is largely based on the fact that mortality rates will be dropping due to better health care facilities whereas the birth rate will also get lowered due to better education of women and increased awareness of birth control techniques, particularly in the under developed countries. This period will be followed by a steady decline in the human population due to aging and a decrease in fertility rates (7, 8). As in previous published studies based on this model (7), the human mortality rate drop is modeled in a piecewise linear manner before settling at a final value while the coefficients in the birth rate function are nonlinearly varied. The issue of population is included here to provide a complete description of the system, but addressing it is well outside the purview of the U.S. EPA. This work should, therefore, not be construed as providing any guidance on population issues. The following discussion describes the dynamics of the various compartments of the integrated system.

From Fig. 2, it can be seen that the amount of P1 decreases faster initially when energy is produced using biomass. The price of P1 is initially higher for the scenario where bioenergy is used. Although, P1 is used for bioenergy, it does not decrease beyond a certain point because of market equilibrium. Due to an increased amount of resource pool mass, the amount of P3 increases with time whereas the amount of P2 declines due to an increase in the growth of H3. The increase in the growth of H3 is essentially due to an increased level of P3. From Fig. 2, it can be seen that there is a sudden decrease in the level of H1, and H1 never recovers. This sudden decrease occurs at the point where population growth is highest. At this stage, the resources for H1 to consume became limited due to consumption of P1 by humans as well as for its use for bioenergy. However, the level of H2 increases because the decrease in H1 leads to a decrease in the levels of C1, which in turn decreases the consumption of H2, and hence increases the compartmental mass of H2. From the figure, it can be seen that there is a drop in the level of C1 if a portion of the P1 is used for producing energy. This can be attributed to a drop in the amount of H1 that is being transferred to the C1 compartment due to a decreased level of H1, because of the production of energy using biomass. The amount of C1 drops due to the usage of P1 for producing energy even though C1 does not directly consume P1. Another important thing to notice is that though C1 is a protected species, its mass drops significantly because of the economics of P1. Similar observations also hold for C2. However, it was observed that the species C1 or C2 do not become extinct due to the production of energy using biomass.

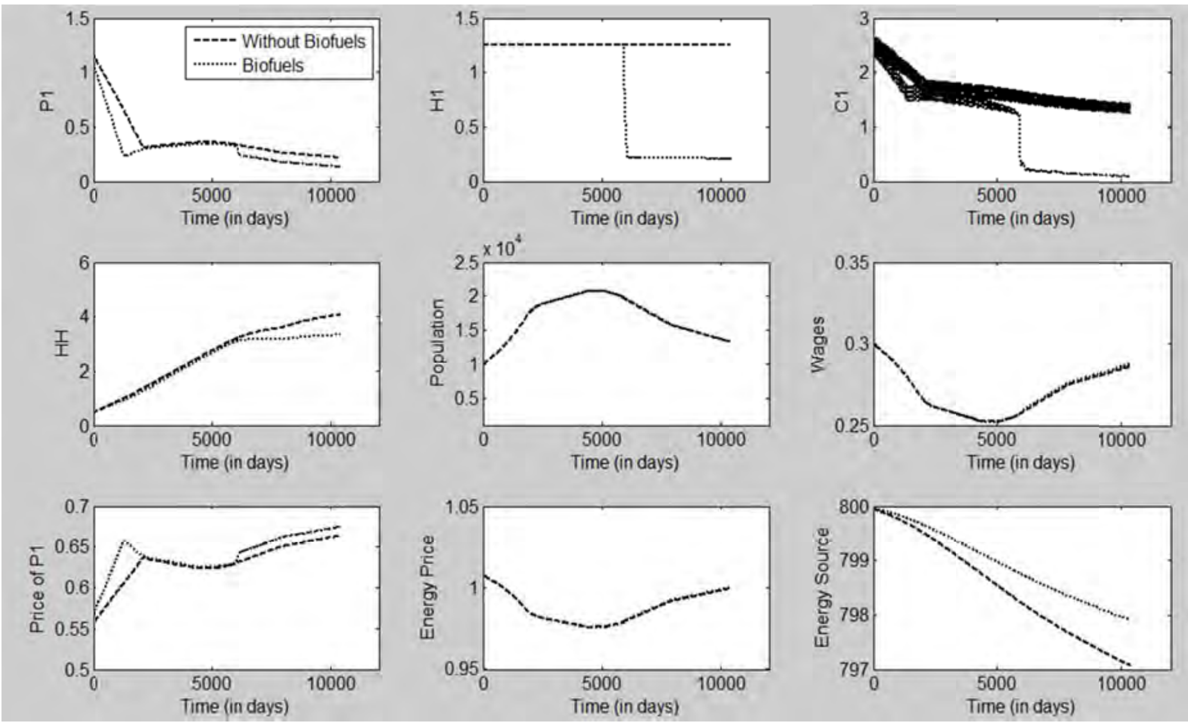

Fig. 2. Profiles of compartmental mass and price (population increase)

Figure 2 shows that the amount of human mass has slightly decreased due to the production of energy using biomass. The amount of human mass is directly dependent on the amount of P1 transferred to the HH compartment. Due to the production of energy using biomass, the amount of P1 decreases and hence the availability of P1 to feed HH decreases thereby causing the drop in human mass. Figure 2 also shows no change in the level of human population because of the production of energy using biomass. It can also be seen that the drop in the compartmental mass of human households is not translated into a reduction of the human population. This invariably indicates that the per capita mass of humans has decreased thereby corroborating both the decrease in human mass at similar levels of human population. Figure 2 shows that the production of energy using biomass does not lead to an increase in wages. Wages paid to human households is inversely proportional to the human population i.e., an increase in the human population decreases the wages of the human households. Thus, the wages are low when the population is high and increase with a decrease in the population.

Figure 2 shows that the decrease for ES is less if a portion of the energy is produced from biomass. This is because in the production of energy using biomass, P1 is used for producing energy and hence the non-renewable energy source is not used for that portion of energy thereby leading to a slower decrease in the amount of ES. The price of energy is similar in both cases. The price of energy initially decreases because the human population is increasing and leads to lower wages. Subsequently, the human population starts to decrease and wages start increasing as this gets reflected in the price of energy. This completes the discussion of the population scenario analysis, and we will now discuss the scenario of increase in the consumption levels of the humans.

3.2. Consumption Increase

Many of the resources that humans consume are non renewable and are finite in nature, and the resources which are renewable are often consumed at a rate much faster than the rate of replacement. Such abnormal high consumption levels could severely affect the current composition of the ecosystem (11, 12). Moreover, with an increase in per capita income, the quality of life and disposable income have increased often leading to an increase in per capita consumption of both mass and energy. This continuous increase in consumption levels could not only exceed the capacity of the ecosystem to provide services, but endanger the longer-term sustainability of the system. For the model under study in this article, the increase in the consumption level of humans is modeled by linearly varying the constant coefficients involved in the estimation of per capita demand for resources. This strategy of modeling consumption increase is similar to the previous published work on a similar model by Shastri et al. (13). We will now present the discussion on the dynamics of various compartments present in the integrated system under increased levels of per capita consumption.

Figure 3 shows that increase in the consumption levels of humans leads to a decrease in the levels of P1, H1, and C1. The magnitude of decrease is more prominent when energy is produced using biomass. This is because a part of P1 is being used for the production of energy, and, thereby, is not available to the rest of the system. The increase in the price of P1 leads to a lower consumption of P1 by the H1 compartment. The level of P2 was also seen to decrease whereas the level of P3 increased due to increased levels of the resource pool. These changes in the primary producers have cascading effects on the other components of the integrated system. The herbivore H1 preys on P1 and a rapid decline in the levels of P1 leads to a rapid decline in the levels of H1. Similarly, the level of H2 falls rapidly when P1 is used for producing energy, since the levels of P1 and P2 are lower. However, the level of H3 remains the same in both the cases as it depends on the level of P3. The level of C1 and C2 in both cases decreases to significantly lower levels due to a decrease in the levels of H1 and H2. However, their decline is more rapid when P1 is used for the production of energy. For the case of population increase, the amount of C1 and H1 had also decreased but in the case of consumption increase, the mass of these two compartments not only decreases, but they become extinct. It should be noted that the extinction of C1 occurs despite the fact that it is a protected species. This is an example of the complex interaction between the various dimensions of sustainability, and how one or more dimensions can dominate the others. In this case, the economic dimension dominated the legal dimension, and this resulted in the extinction of the C1 species. It can be seen that the use of P1 to produce energy in an increasing consumption level scenario could accelerate the extinction of some species.

From Figure 3, it can be seen that the amount of human mass has increased substantially due to an increase in the consumption of P1 and H1. However, the use of P1 to produce energy leads to a lower increase in the mass of the human compartments. The figure shows that there is a drop in human population towards the end of the simulation horizon. The level of human population is slightly less when P1 is used as a source of energy for producing energy. This can be attributed to the fact that the non-availability of P1 leads to a decrease in the compartmental mass of the human households and subsequently manifests into a decreased population. The figure shows the prevailing wages as decided by the Industrial Sector (IS). The difference in the wage levels is a reflection of the difference in the population level for the two cases. Since the population is slightly lower when P1 is used for producing energy, the wage rates for this case are higher. The wage rates are constant for a considerable period of time and start to increase towards the end due to a decrease in the human population. This is consistent with the assumptions of the model wherein the wage rate remains constant with a constant population level and increases with a drop in the population.

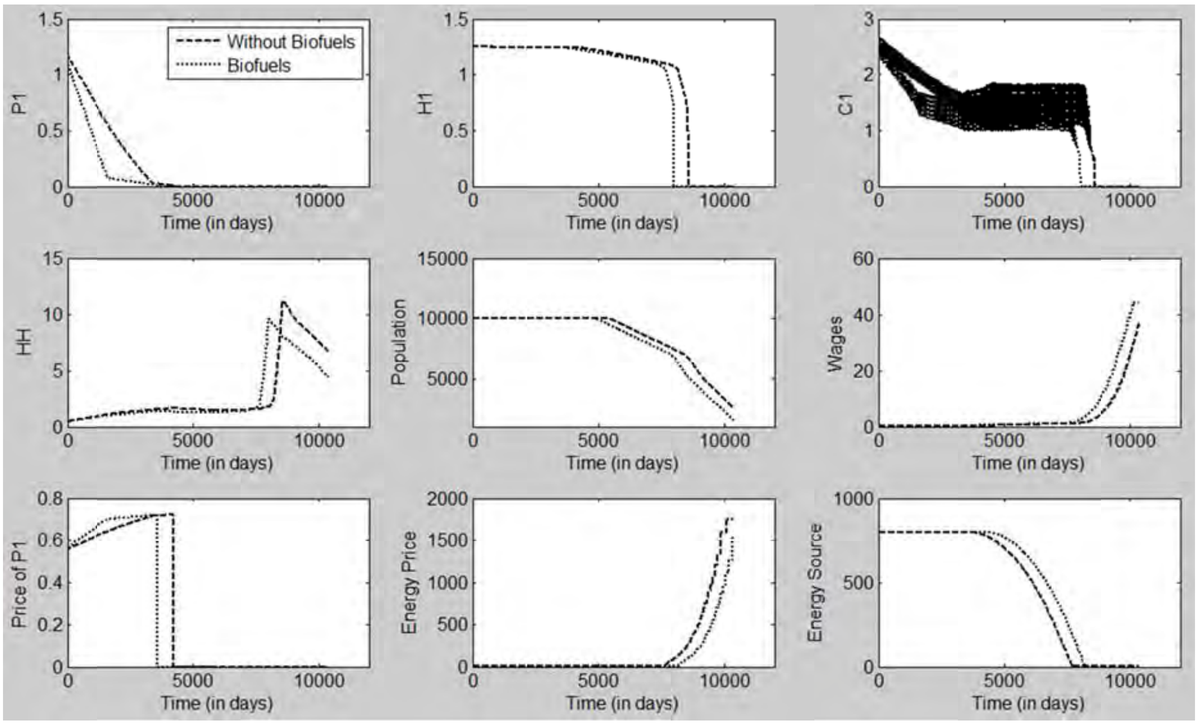

Fig. 3. Profiles of compartmental mass and price (consumption increase)

Figure 3 shows the price of P1 and energy along with the amount of non-renewable energy source available in the integrated system. As with the base case and the population increase scenario, the decrease for ES is less if a portion of the energy is produced from biomass. The use of P1 for producing a part of the energy decreases the utilization of the non-renewable energy source and hence the decline in it is moderated. However, in both the cases, the energy source faces decline, and the use of biomass for producing energy merely delays the exhaustion of the non-renewable energy source. The price of energy is a function of wages and the amount of energy source available in the system. Irrespective of the use of biomass to produce energy, the energy prices keep increasing. However, the use of biomass for producing a portion of the energy seems to lower the cost of the energy for this particular scenario of increasing consumption. This is because of the fact that the use of biomass helps in maintaining a higher level of the non-renewable energy source longer, and this, thereby, leads to a relatively lower cost of energy. It can be seen that the price of energy is significantly higher in the scenario of consumption increase than either the base case or population increase scenario. This is because the human population has decreased to very low levels thereby increasing the wage levels. Moreover, the scarcity of the energy source contributes to the increase in the price of energy.

4. Conclusions

An enhanced 14 compartmental model for an integrated system incorporating the generation and utilization of energy has been developed to aid in the formal study of sustainability and to derive qualitative inferences for various scenarios. Under the scenario of population increase, the use of biomass does not decrease the human population, but leads to a decreased per capita human mass, which may be inferred as an indicator for the quality of life. Moreover, the use of biomass for producing energy only delays the inevitable exhaustion of the non-renewable energy source and does not significantly impact the energy prices. For the scenario of per capita consumption increase, it was observed that the integrated system could not sustain high levels of human consumption. It was observed that the use of biomass for the production of energy delays the exhaustion of the non-renewable source, but can expedite some of the catastrophic events such as the extinction of protected species and human well-being. The proposed model can be used to explore strategies, policies, and to evaluate the impact of alternate generic technologies on the long-term sustainability of the system. The inherent assumptions of the model have to be borne in mind, and a cautious and conservative approach should be practiced while extending these model inferences to reality.

Acknowledgments

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Natural Ionizing System of Electrical Protection against Atmospheric Discharges (Lightning)

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Abstract: This is the New Highest Technology, 100% Venezuelan and Unique in the World, Technological Innovation, World Patent for Maximum Protection, Security and Zero Risk (0) to all Electrical and Power Generation Systems: Hydroelectric and Thermoelectric Power Plants; Wind, Nuclear and Solar Power Plants; others. It's the only technology around the world that has the potential to disperse and propagate to land mass the enormous energies associated to the Atmospheric Discharges (Lightning), which are in the order: 200,000 to 500,000 Amperes; 1,000 million Kilowatts and High-Level Transient Voltage of 100 million Volts. This New High Technology is the solution to the paradigm of Benjamin Franklin and it's the mechanism to end the "Blackouts" that produces so many damages and losses of billions of dollars to both: generators and users of electrical service, throughout the world.

Keywords: *Atmospheric Discharges, Lightning, Electrical Substations, Grounding Protection.*

1. Introduction

The Electrical Faults, Interruptions and "Blackouts" generated by Atmospheric Discharges (lightning) in Transmission Lines, Electrical Substations (High Voltage), Power Equipment and Electronic Equipment of High Sensitivity are the main problem in today's Electrical Engineering in the world.

The calculation and design of Protection Systems for Transmission Lines and Electrical Substations (Reticular Mesh of Grounding, Bars and others) that are currently used in Electrical Engineering are inefficient, because those calculations for Reticular Mesh of Grounding are made by taking into account only the electrophysical characteristics of Power Transformers and other items such as: transformers capacity, reactance, capacitance, inductance, secondary current, short circuit current symmetrical and asymmetrical, land resistivity, mesh geometry and others. In other words, Reticular Mesh of Grounding aren't designed or calculated to counteract the destructive effects of lightning.

The dispersion capacity of a Reticular Mesh of Grounding would be in the order of 10,000; 20,000 or 30,000 Amperes. In that sense, the energy values associated to lightning are in the order of: 500,000 Amperes, 1,000 millions of Kilowatts and High-Level Transient Voltage of 100 millions Volts that no Reticular Mesh of Grounding would be able to disperse.

The only existing device to disperse and propagate this huge energy is the Natural Ionizing System of Electrical Protection conformed by: Lightning Rod Ionizing Natural Ionca and Ionic Electrode Active Trimetallic Triac of Grounding, both High Technologies, 100% Venezuelan. (Cabareda, 2006. Science, Technology and Innovation Award, FUNDACITE, Science and Technology Ministry of the Bolivarian Republic of Venezuela). Finally, the only definitive and total solution to avoid Interruptions and Electrical Faults in Electrical Substations, Power Equipment and Electronic Equipment of High Sensitivity generated by Atmospheric Discharges (lightning) and to end "Blackouts" is by installing these devices on existing Towers and Transmission Lines, Electrical Substations and for those to construct.

2. The New Highest Technology, 100% Venezuelan,

2.1. Natural Ionizing Lightning Rod Ionca

It bases its operation on its electrophysical structure and the enormous differences of existing potential and the electrical field in the atmosphere in conditions of storm that allow to generate “crown effect” or “ionizing effect” that produce billions of high ion conductivity, because it has electrodes to atmospheric potential (atmospheric excitatory) and electrodes to grounding potential isolated to each other. This “ionizing effect” is increased by “hit effect” between air molecules and particles (ion) accelerated by the enormous existing electric fields during the storm. This natural ionization generates a “grounding direct discharge” which is the precursory current of lightning and that jointly with the stepped currents that derive from the interaction of the microparticles in the clouds, indicates the way and the trajectory for the Atmospheric Discharge (lightning), which will be lead through Lightning Rod Ionizing Natural Ionca and the Ionic Electrode Active Trimetallic Triac of Grounding to the land mass, scattering and spreading the enormous energies associated to this phenomenon, without causing damages. Electrophysical Characteristics: Height: 620mm. Diameter: 470mm. Weight: 6.4Kg. Material: Stainless Steel 304, Polytetrafluoroethylene (400°C). Vertical Penetration: 50 y 100m. Warranty: 20 years.

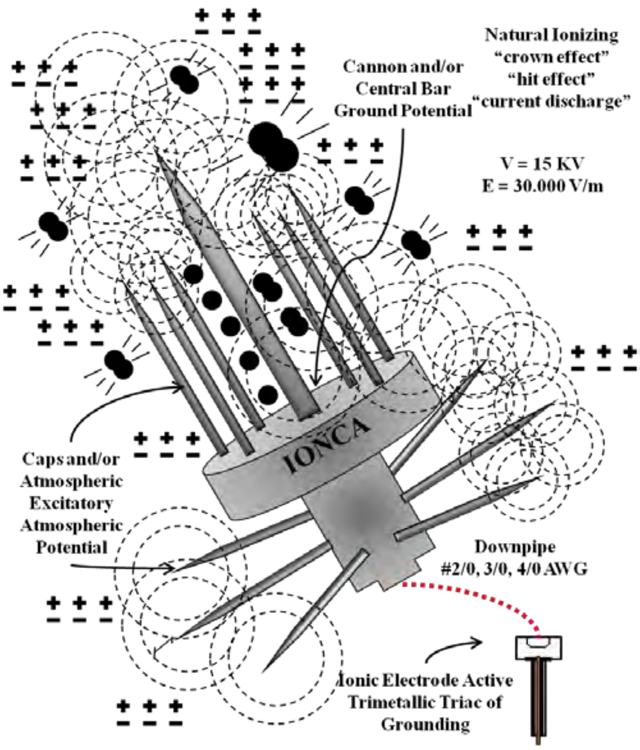
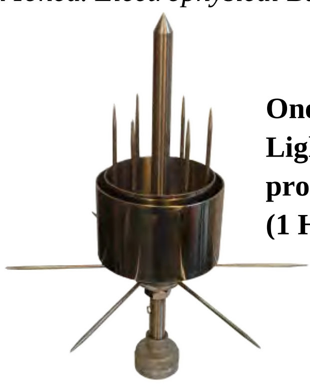


Fig. 1. Natural Ionizing Ligthning Rod Ionca. Electrophysical Basis.



One Natural Ionizing Lightning Rod Ionca can protect an area of 10,000m^2 (1 Hectare)

Fig. 2. Natural Ionizing Lightning Rod Ionca.

2.2. Active Trimetallic Ionic Electrode Triac of Grounding

It bases its operation and highest efficiency on its electrophysical characteristics that allow the total and complete adhesion to the land mass, whose land has been dealt chemically with high-electrical conductivity electrolytes that decrease the enormous resistivity and allows: water saturation and humidity retention, total adhesion to the land mass and high indices of alkalinity. The volume of the treated ground is from $18m^3$ to $27m^3$ approximately and is united to the land mass by the electrolytic and not mechanic adhesion, facilitating the way of dispersion and propagation of the enormous energies associated to the atmospheric discharges (lightning) and electrical faults, generally. Energy Dispersal Capacity to Land Mass: 500,000 Amperes, 1,000 million Kilowatts, Lowest Electrical Resistance R = 0.86 to 3 Ω (ohm). Land Characteristics: Lowest Land Resistivity, Porosity and Compaction, Maximum Humidity, Temperature, Station of the Year, Electrolytes, PH.

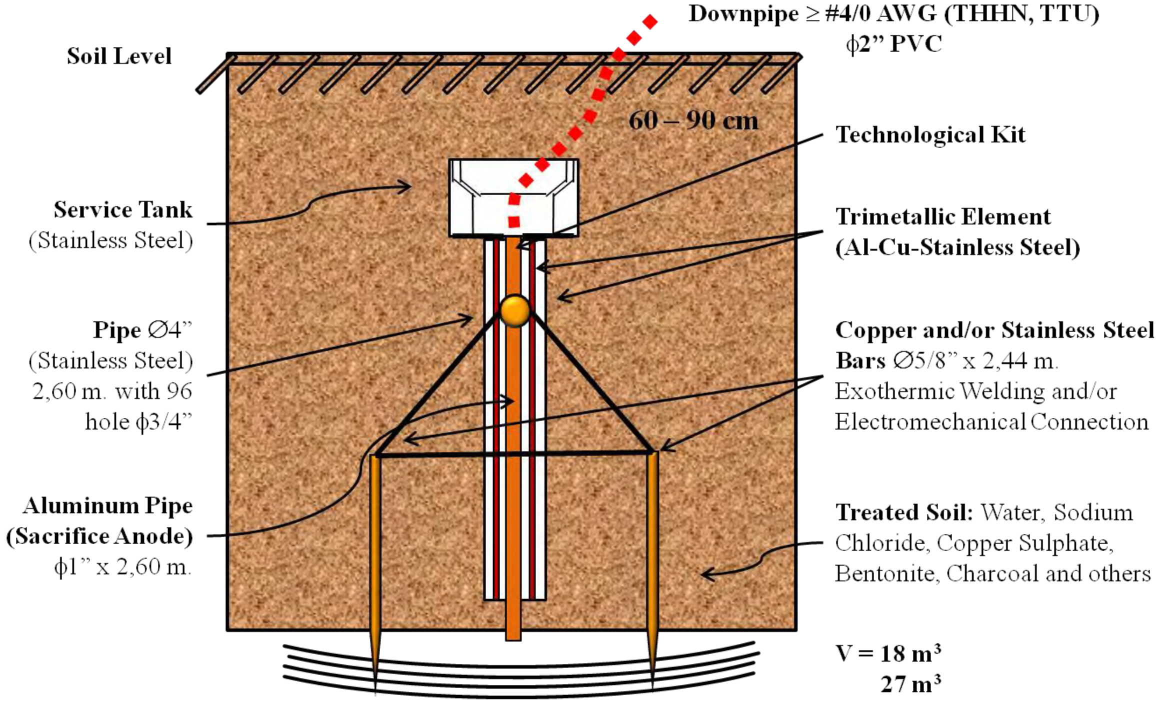


Fig. 3. Active Trimetallic Ionic Electrode Triac of Grounding. Cross Section.

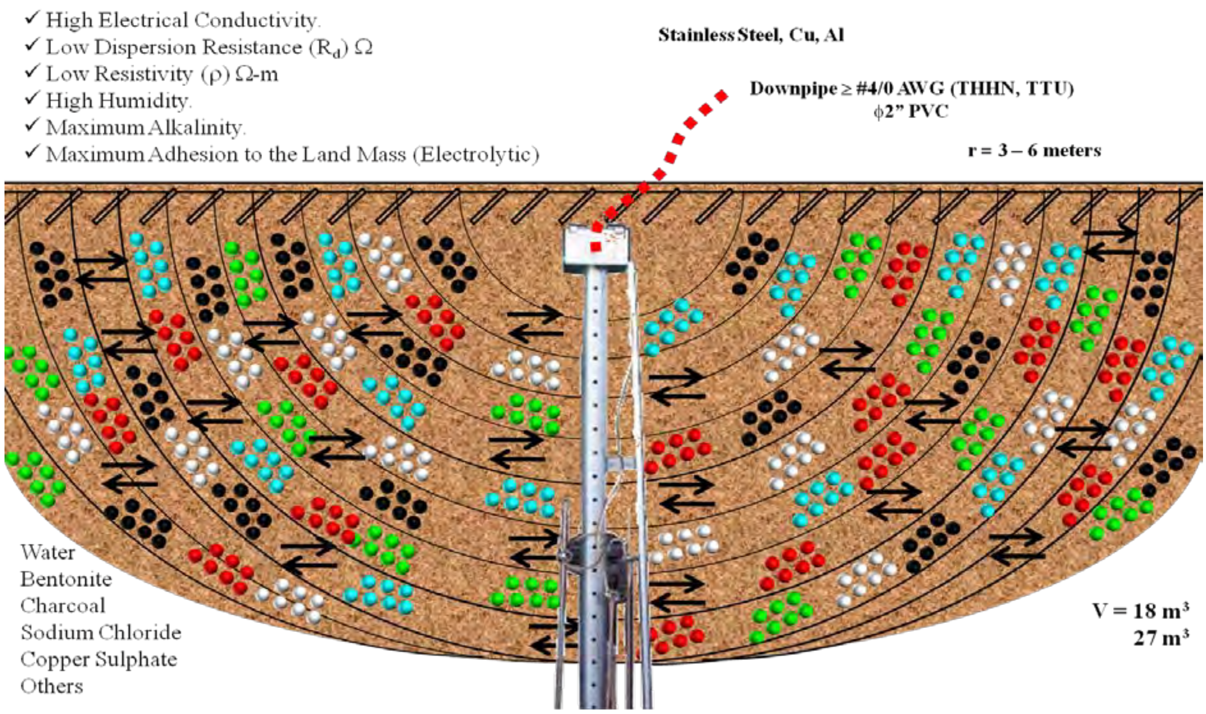
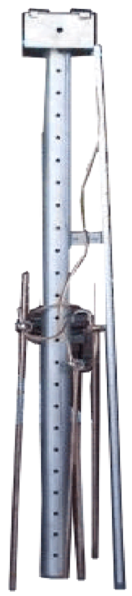


Fig. 4. Active Trimetallic Ionic Electrode Triac of Grounding. Electrophysical Basis.



HIGH CAPACITY OF DISPERSION OF THE ENERGY to the land mass:

-600,000 Amperes.

-1,000 million of Kilowatts.

-100 million of Volts.

-R = 0.86 a 3 Ω (ohmios)

Fig. 5. Active Trimetallic Ionic Electrode Triac of Grounding.

2.3. *Energy of Lightning*

Lightning, it's an interaction and transmission of elevated electrical charges between the atmosphere and the earth in conditions of storm or Atmospheric Disturbances. On Earth happens: 4,000 storms daily. 9,000,000 lightning daily. The Energy of Lightning is in this order: 200,000 to 500,000 Amperes; 1,000 million KW; 1 millions MW = 1.000.000 MW; 100 millions Volts.

The Energy generated for the biggest Hydroelectric's Dams around the world would only reach 10% of the Energy of a single Lightning: Hydro Québec (Canada) 36.810MW, Guri (Venezuela) 10.000MW, Macagua (Venezuela) 3.140MW, Caruachi (Venezuela) 2.160MW, Tocoma (Venezuela) 2.160MW, Itaipu (Brazil-Paraguay) 14.000MW, Three Georges (China) 22.500MW, Hoover (USA) 2.080MW, Tehri (India) 2.400MW, Aswan (Egypt) 2.100MW, Inguri (Georgia) 1.300MW, Grand Dixence (Switzerland) 2.000MW, Nurek (Tajikistan) 4.000MW.

2.4. Consequences of Atmospheric Discharges (Lightning)

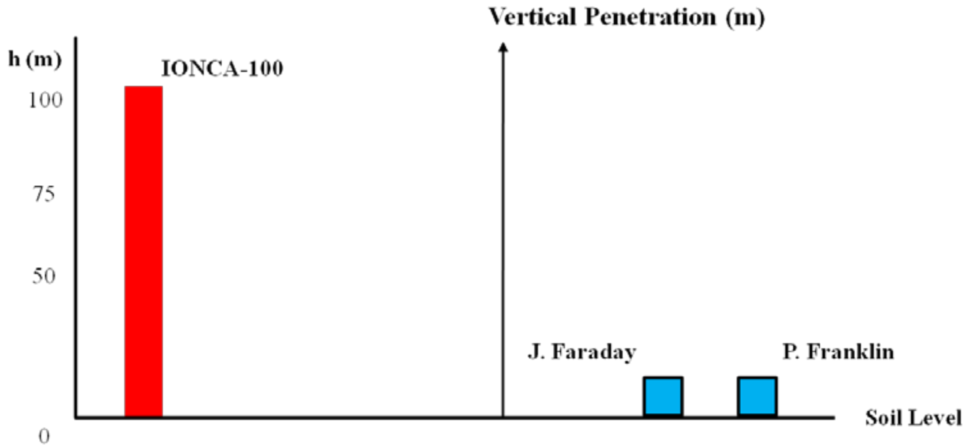
Damages to Constructions and Electricals Equipment, Electronic, Communications, Computation and Cybernetic, generally: Inductive and Conductive Effects that produce High Levels of Transitory Overvoltages (100 millions Volts). Damages to People: Cardiac and Respiratory arrest, Cerebral Injuries, Burns, Plow of the Eardrum, Pulmonary and Bony Injuries, Post-traumatic Stress. Losses of billions of dollars to both, generators and users of electrical service around the world.

2.5. Characteristics of Atmospheric Discharges (Lightning)

30 - 100 million Volts. 200,000 – 500,000 Amperes. 100 - 1.000 million Kilowatts. Electric Field: 30 Volt/m. Potential Gradient: 15KV. Air Impedance: 5KΩ. Atmospheric Pressure: 100 Atmosphere. Duration Time: 10 – 30 μseg. Energy: 3×10^9 J/m. Temperature: 15,000 to 30,000°C. Acustic Energy: 25% (thunder) Caloric Energy: 75% (electrical discharged)

2.6. The Lightning Rod

The Lightning Rod is a device conformed by one or several metallic bars with certain geometric disposition united to an grounding electrode by a downpipe conductor, that facilitates the way of the lightning from the cloud to the Earth, allowing the dispersion and propagation of the enormous energies associated, without causing damages to people and/or equipment.



Maximum Security (∅=30°)	Protection Area (m²)
IONCA-100	10.466 (1 Hectare)
Faraday Cage	300
Franklin Lightning Rod	100

Fig. 7. Traditional Lightning Rods and Natural Ionizing Lightning Rod Ionca comparison.

2.7. Grounding Systems

It's a set of metallic elements directly buried that allow and facilitate the dispersion and propagation of energy associated to a lightning and electrical faults, without causing damage. The adhesion to land mass of Traditional Systems of Grounding like Bars and Reticular Mesh of Grounding is mechanical. The adhesion to land mass of the Active Trimetallic Ionic Electrode Triac of Grounding is Electrolytic.

- It protects people and/or equipment (electrical, electronic, communication, computation).

- It protects against: Lightning, Transitory Overvoltages of Discharge and Low Level, Accidental Contact with Lines of High Tension (HT) and Low Tension (LW).
- It stabilizes the voltage of normal operation.
- It facilitates the switch operations.
- Equipotentiality: Touch Voltage and Step Voltage.
- It allows the dispersion and propagation to land of the associated energy (lightning) to electrical faults, leakage currents and Atmospheric Discharges.

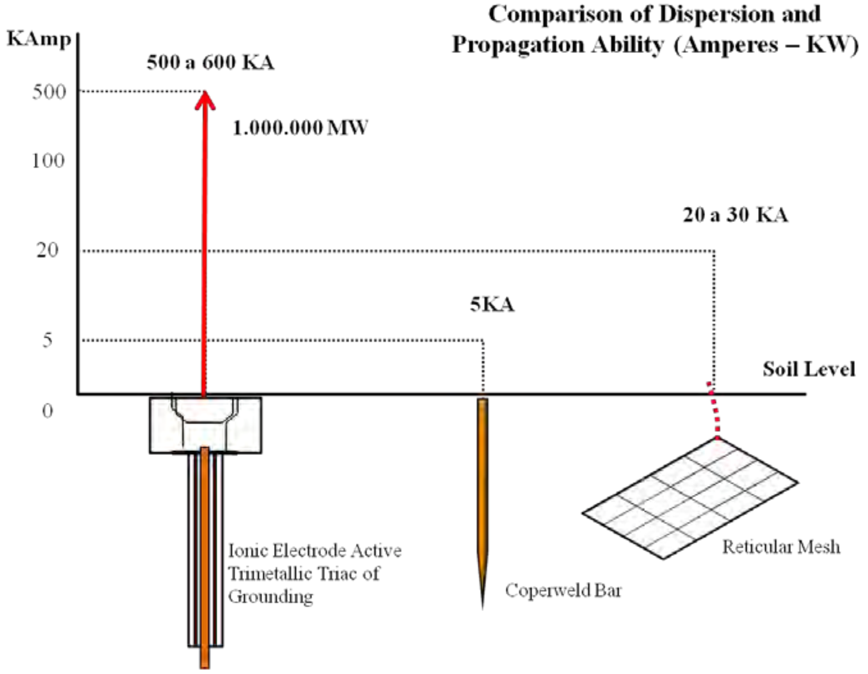


Fig. 8. Comparison of Traditionals Systems of Grounding with the Active Trimetallic Ionic Electrode Triac of Grounding.

2.8. Actual Electrical Substation

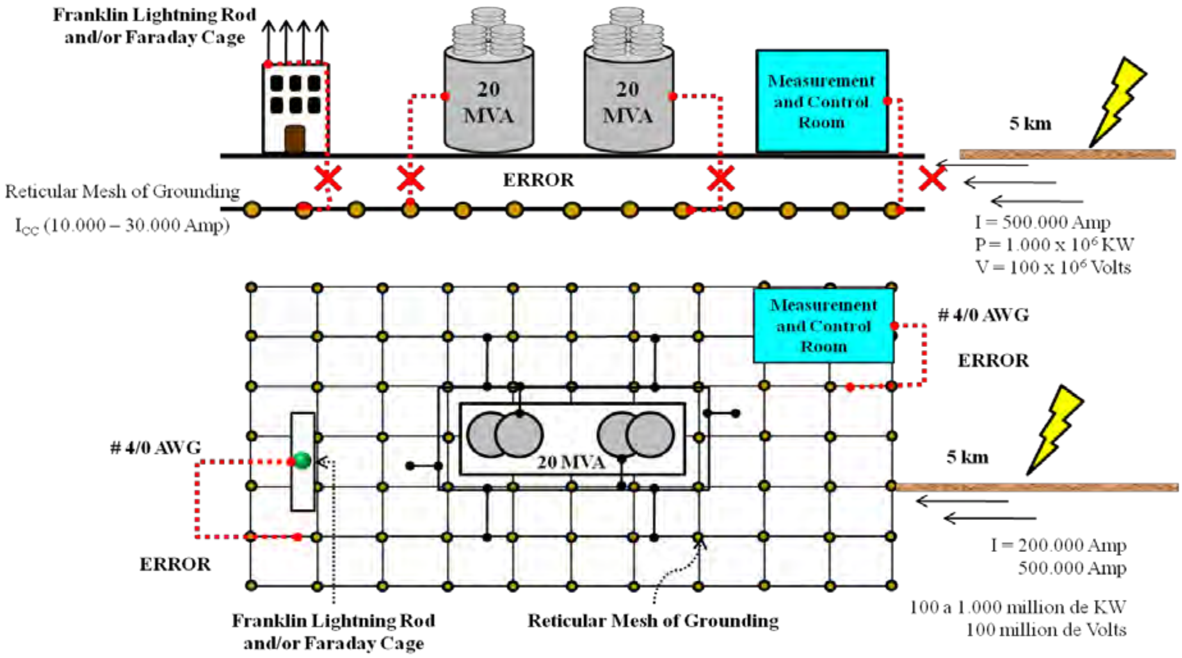


Fig.9. Actual and Traditional Systems of Grounding (ERROR)

2.9. Electrical Substation: The New Highest Technology

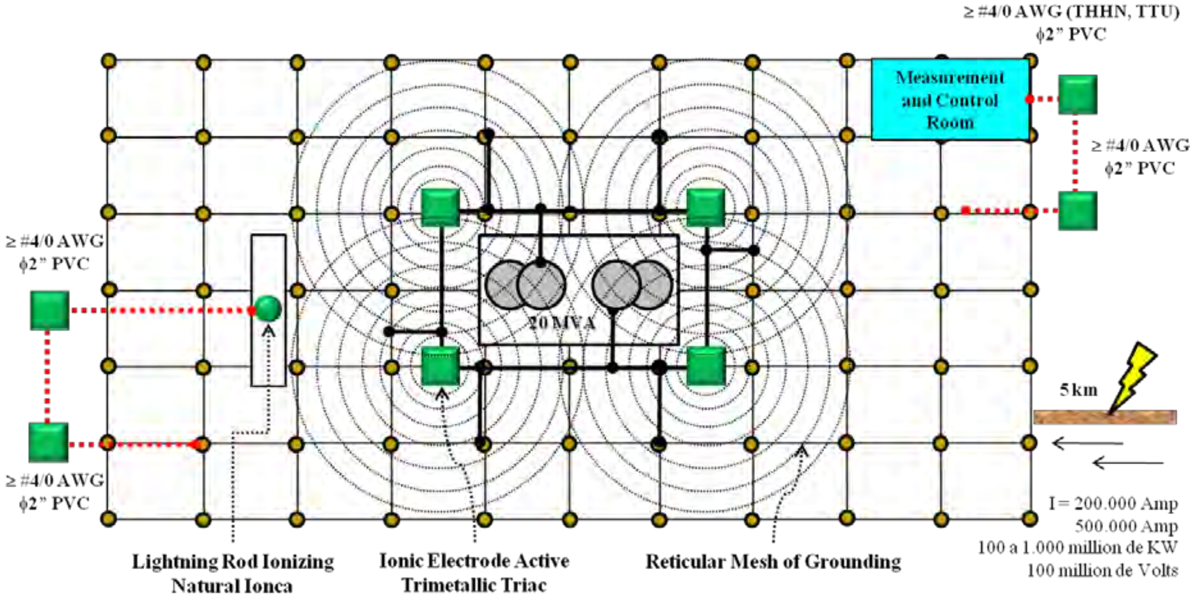


Fig. 10. Natural Ionizing System of Electrical Protection. New Concept, Design and Calculation of Engineering in Electrical Substations. (CORRECT)

3. Results/Conclusion

Power generation is vital and very important, but provide protection and security to the energy generated is perhaps even more important. We must avoid the energy losses with an efficient and effective protection. The 85% of major “Blackouts” and Electrical Faults in power generation, Power Equipment and Electronic Equipment of High Sensitivity in the world are produced by the destructive effects of Atmospheric Discharges (Lightning). This results in loss of lives and billions of dollars each year.

The New Highest Technology, 100% Venezuelan, Unique in the World, Natural Ionizing System of Electrical Protection conformed by the Lightning Rod Ionizing Natural Ionca and the Ionic Electrode Active Trimetallic Triac of Grounding of world-wide standard whose operation and electrophysical basis are based on phenomenon and events scientifically verified like: Atmospheric Discharges (lightning), “crown effect”, “hit effect”, “grounding direct discharge”, metallic and atmospheric ionization, electromagnetic and electric fields, ionizing potential and electronic affinity, electrical potential presented in the atmosphere in conditions of electrical storm, resistance and atmospheric pressure, tripole in the cloud, cosmic rays, physical state of the water (liquid, solid and gaseous), electrolytes, resistivity of the ground and resistance of dispersion, effects to improve the ground resistivity to give high degree of alkalinity), principle water humidity and retention (properties of the charcoal, copper sulphate, sodium chloride and the bentonite), substances, equipotential lines and equipotentiality of a system (properties of the steel, receives and aluminum like good electrical conductors), exothermic weld.

This New High Technology, 100% Venezuelan is the definitive and total solution against Electrical Faults and Interruptions generated by Atmospheric Discharges (lightning) and affect Electrical Substations, Power Equipment and Electronic Equipment of High Sensitivity, Oil Exploration, Drills, Tanks and Stations of Fuel Provision. At the same time, avoiding “the burning” of Electronics Cards in Electronics Equipment of High Sensitivity (Rx, CT, MRI). It’s the mechanism to end the "blackouts" that produces so many damages and losses of billions of dollars around the world. It´s scientifically proved and globally accepted that the existing Electrical Systems of Protection at the moment like: Reticular Mesh of Grounding and Coperweld Bars don´t have capacity to disperse and propagate to land mass the enormous energies associated to the Atmospheric Discharges (lightning), which are in the order: 500,000 Amperes, 1,000 million Kilowatts and High-Level Transient Voltage of 100 million Volts, enormous energies that cannot be dispersed by Reticular Mesh of Grounding, which it has a maximum capacity between 20,000 and 30,000 Amperes. This is the principal cause of major Blackouts and Electrical Faults around the world.

Finally remarks

The Lightning Rod Ionizing Natural Ionca and the Ionic Electrode Active Trimetallic Triac of Grounding are Ecological, Natural, Don't Contaminate the Environment and fulfill all Electrical Codes and Norms International and National such as: IEEE, NFPA, ANSI, BSCP, WMO, NFC, NEC, CODELECTRA, COVENIN; and it has received the Certification and Recognition by: IEEE, The Institute of Electrical and Electronics Engineers, Latin America and The Caribbean Region. XXI World Energy Congress, WEC 2010, Canada, Author, Presenter, Venezuela Delegate. The New Highest Technology Paper: The International Energy Technology Data Exchange (www.etde.org); US Department of Energy Office of Scientific and Technical Information, OSTI, Library and Archives Canada and Scientific Libraries Worldwide. IEEE, XV International Congress of Electrical, Electronic and Systems Engineer, INTERCON 2008, Peru, Author, Presenter, Venezuela Delegate. Polytechnic Experimental National University "Antonio Jose de Sucre" (UNEXPO), Arbitrated University, Venezuela. Antenor Orrego Private University (UPAO), Peru. Science, Technology and Innovation Award granted by Foundation for the Development of Science and Technology (FUNDACITE), Ministry of Science, Technology and Intermediate Industries, 2006, Venezuela. General Department of Science and Technology Research, Ministry of Science, Technology and Intermediate Industries, Venezuela. National Center of Technological Innovation. CVG MINERVEN. National and Internationals Publics and Private Companies. Projects and Construction built: Church La Chiquinquira. CVG MINERVEN (Gold Mining). Promotora Minera Guayana (PMG), AGAPOV Group (Rusian) – Gold Mining. Corporación 80.000, C.A., AGAPOV Group (Rusian) – Gold Mining. CVG ALCASA (Aluminum). CVG VENALUM (Aluminum). Clinics: Medical Specialty Center, La Floresta, Chilemex, Maracay Medical Center. FIOR Venezuela (Iron Briquettes). CVG CARBONORCA (Anodes). Project: Toyota Venezuela (Toyomaya). Engineering Projects: Petróleos de Venezuela (PDVSA), PDVSA Boquerón, ENELBAR (Electrical Substations: Bárbula, Morón, Valle Seco, Chivacoa, Nirgüa, Yaritagüa), CADAFE (Electrical Substations: Tucupita, Temblador).

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Implementing bioenergy villages – a promising strategy for decarbonizing rural areas?

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Abstract: An increasing number of rural municipalities want to meet their entire energy demand with biomass. This article gives a system analytic view on these "bioenergy villages" by balancing pros (GHG reduction potential) and cons (costs) using the example of a model municipality in Germany. The results indicate that a 100 % energy supply based on biomass potentials within the boundaries of a rural municipality is technically possible but less reasonable with respect to land-use competition and costs of energy supply. Whereas heat and power demand in bioenergy villages can be covered WITH RELATIVELY LITTLE LAND and to relatively low costs, the production of transport fuels based on energy crops (rape seed) leads to significant negative impacts. For a cost-efficient decarbonization of rural areas it can therefore be recommended to particularly expand the utilization of biomass for heat and power production.

Keywords: *rural supply concepts, sustainable energy, life cycle assessment*

1. Concept and status of bioenergy villages

Numerous bioenergy villages have been realized in rural areas of Central Europe over the last decade, for instance in Güssing (Austria), Jühnde (northern Germany) or Mauenheim (southern Germany). In Germany alone, planning and implementation of 55 additional bioenergy villages[1] is in progress or already completed [1]. These villages aim to maximize coverage of energy demand with biomass and to operate the bioenergy infrastructure independently. The German Agency for Renewable Resources (FNR) emphasizes that using fossil technologies for covering peak load demand can be compatible with the concept of bioenergy villages and specifies that – while balancing economic and environmental impacts – at least 50 % of heating demand and 100 % of electricity demand[2] should be met with biomass [2]. To fulfill the requirements of the concept, energy autarky (within the territory of a municipality) can be aimed but is not a mandatory goal [3]. It is rather emphasized that biomass provision should be „regional" or „decentral".

Table 1 highlights some pros and cons of bioenergy villages. Looking at the realized villages, it is interesting to see that they do not restrict themselves to biomass utilization and some even underline the implementation of additional renewable energy such as solar or geothermal energy. Moreover, it is noticeable that despite a relatively low energy demand density all bioenergy villages trust in district heating systems instead of using separate technologies for each building (such as split log boilers). This is because district heating systems offer the opportunity to gain economies of scale, to switch over to renewable energy fast and collectively as well as to keep the added value completely within the region (by using regional energy sources and operating the plant by local stakeholders). Besides, the rollout of district heating systems in rural areas often benefits from the lack of competing grid bound systems (e.g. pipelines distributing natural gas) [4].

[1] Moreover, more than 100 regions in Germany intend to cover 100 % of their future energy demand with renewable energy [11].
[2] the latter with regards to a yearly balance

And in fact, using renewable energy in rural areas seems to have advantages compared to urban areas. They have a good resource base, a case study of Baden-Württemberg for instance points out that in rural areas seven times more biomass (per capita) is available compared to large cities [5]. Moreover, market penetration is much higher, 60 % of Germany's installed bioenergy capacity is located in rural areas [6].

Table 1. Pros and Cons of bioenergy villages

pros	cons
Low fuel costs	High up front costs (Investments)
Stimulation of regional and rural economy	Transport of biomass (Traffic)
Reduction of energy related greenhouse gas emissions	Increase of „local“ emissions (particulate emissions)
Shifting away from finite resources	
Reaching (to a large extent) independency from price development of fossil energy carriers	Increase of land use competition
Image building and strengthening of tourism	Acceptance of residents is an important pre-condition for economic feasibility

2. Research design

Against the background of the rapid development of bioenergy villages, this survey investigates the prospects of a range of bioenergy technologies such as fermentation biogas plants, district heating-plants and CHP[3]-plants (combustion and gasification), biodiesel plants and BTL[4] plants. The complete list of technologies is given in Table 2. The typology of bioenergy technologies is deduced from those technologies which are implemented in the cases of Güssing, Jühnde and Mauenheim. Alternative renewable energy sources such as solar and geothermal are not considered.
This article draws on a previous work [7]. It presents updated information, more detailled data on technologies and new evaluations and illustrations.

The analysis is carried out using the example of a rural "model municipality" representing an average German village and provides a system analysis focusing on costs and CO_2-reduction. The methodology is inspired by the pioneer of urban ecology Abel Wolman, who applied a similar approach in the 1960s to analyze the material flows of an US-American City [8]. The demand characteristics of the village result from a comprehensive evaluation of statistics and a literature review [5], [9], [10]. The analyzed model village has 1,050 hectares of agricultural land, 400 hectares of permanent grassland and 900 hectares of forest land. The number of inhabitants accounts for 3,000.

In a first step, a technology analysis is carried out to define the specific CO_2-emissions (g/kWh) and specific energy generation costs (EUR-cent/kWh) of biomass technologies as well as fossil reference technologies for the provision of heat, electricity and transport fuel. The analysis follows the principle of life cycle assessments (LCA) and – as illustrated in Fig. 1 – includes direct and indirect emissions (up- and downstream processes,

[3] CHP = Combined Heat and Power
[4] BTL = Biomass to Liquid

such as transport-diesel, fertilizer or deconstruction of facilities) as well as generating costs [11].

Table 2. Analyzed technologies for the provision of heat, electricity and transport fuel

Technology	Capacity	Fuel	End energy	Abbreviation
Fermentation biogas plant	150 kW_{el}/200 kW_{th}	Manure	heat/power	BG 150 M
	150 kW_{el}/200 kW_{th}	Corn	heat/power	BG 150 C
	600 kW_{el}/700 kW_{th}	Manure	heat/power	BG 600 M
	600 kW_{el}/700 kW_{th}	Corn	heat/power	BG 600 C
District heating plant	2.5 MW_{th}	Wood chips	heat	HP 2.5
	5 MW_{th}	Wood chips	heat	HP 5
	10 MW_{th}	Wood chips	heat	HP 10
	12.5 MW_{th}	Heating oil	heat	HP 12.5 HO
CHP plant (extraction condensing steam turbine)	max. 1.7 MW_{el} max. 3.5 MW_{th}	Wood chips	heat/power	CHP ST
CHP plant (gasification+gas engine)	2.0 MW_{el}/4.5 MW_{th}	Wood chips	heat/power	CHP gas
Biodiesel plant	3.6 MW/2.9 Mio. l/a	Rape seed	Biodiesel	RME
BTL plant	3.6 MW/2.8 Mio. l/a	Wood chips	BIODIESEL AND GASOLINE	BTL

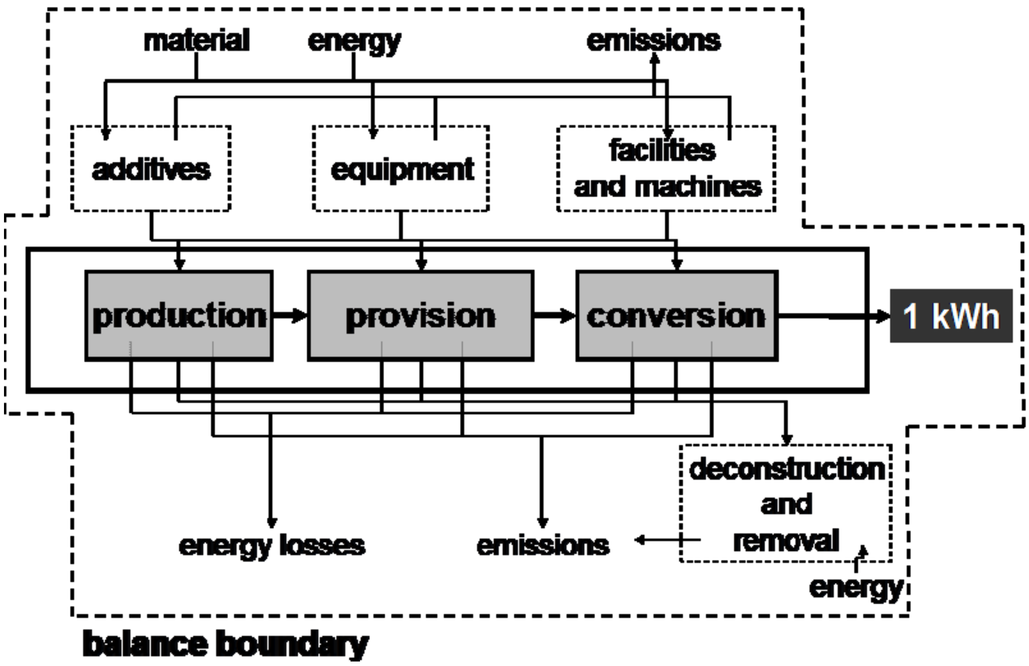

Fig. 1. Balance boundaries and elements of the life cycle assessment (LCA)

In a second step, six different combinations (BF1, BF2, BB1, BB2, BBB1 and BBB2) of the selected technologies are assessed. They are designed to cover the energy demand (heat, electricity, transport fuels) of the model village. The energy demand is considered as the cumulative energy demand during the period of one year. The actual coverage of the fluctuating energy demand during the period of a day or the four seasons is (with the exception of heat supply) not considered. The six technology combinations are shown in table 3 and represent different cases for the substitution of fossil fuels:

- In BF1 and BF2 (Bio + Fossil) more than 100 % of electricity demand is provided by biomass technologies. At the same time, 30 % of heat demand is covered by fossil fuels[5] (peak load). Biofuels are not produced at all.
- In BB1 und BB2 (Bio + Bio) 100 % of heat demand and more than 100 % of electricity demand are covered by biomass-technologies. Biofuels are not regarded.
- In BBB1 and BBB2 (Bio + Bio + Bio fuel) 100 % of heat and fuel demand are covered by biomass technologies and surplus electricty is generated.

For every export and import of electricity (surplus production), an economic and environmental value is credited: The credits for emissions equate the electricity mix in Germany (576 g/kWh). The credits for costs are calculated in two ways: One credit (FIT) is based on the feed-in tariff of the German renewable energy law depending on the kind and capacity of the technology used (8.0 to 14.7 EUR-cent/kWh). The alternative credit (AVEL) is based on the average costs of the German electricity production (5.5 EUR-cent/kWh).

Finally, the results of the biomass utilization options are compared to a fossil reference supply system which is defined as follows: 60 % of heating demand are covered by individual boilers with fuel oil (371 g CO_2/kWh; 10.5 EUR-cent/kWh), 30 % by natural gas condensing boilers (226 g CO_2/kWh; 10.4 EUR-cent/kWh) and 10 % by boilers with split logs (12 g CO_2/kWh; 8.0 EUR-cent/kWh). Moreover, the electricity mix in Germany (576 g CO_2/kWh; 5.5 EUR-cent/kWh) as well as the shares of conventional diesel and gasoline in Germany's fuel mix (210 g CO_2/kWh; 3.7 EUR-cent/kWh) are taken into account for the reference supply system.

Table 3. Analyzed supply systems and technology combinations

Supply system	Abbr.	Combination of technologies	Coverage rate biomass [% of demand] heat	elect.	fuel
Bio + Fossil	BF1	BG 150 M + 3x BG 600 C + HP 5 + HP 12.5 HO	70	133	0
	BF2	BG 150 M + 3x BG 600 C + CHP ST + HP 2.5 + HP 12.5 HO	70	272	0
Bio + Bio	BB1	BG 150 M + 3x BG 600 C + HP 2.5 + HP 5 + HP 10	100	133	0
	BB2	CHP ST + HP 2.5 + HP 5 + HP 10	100	116	0
Bio + Bio +	BBB1	BG 150 M + 3x BG 600 C + HP 2.5+ HP 5 + HP 10 + RME	100	133	100
Bio fuel	BBB2	HP 5 + HP 10+ CHP gas + BTL	100	131	100

3. Performance of technologies and technology combinations

Fig. 2 shows the results of the technology assessment. It contains the bioenergy technologies for heat, electricity and fuels without credits as well as the associated CO_2-emissions. There is quite a huge bandwidth of results, from 10 g/kWh (BG 600 M) to 116 g/kWh (RME) or (looking at costs with credits) 3.2 EUR-cent/kWh (BG 150 M) to 19.4 EUR-cent/kWh (BG 150 C).

[5] In these two cases the oil heating plant covers 63 % of the total capacity demand of 19.5 MW_{th}.

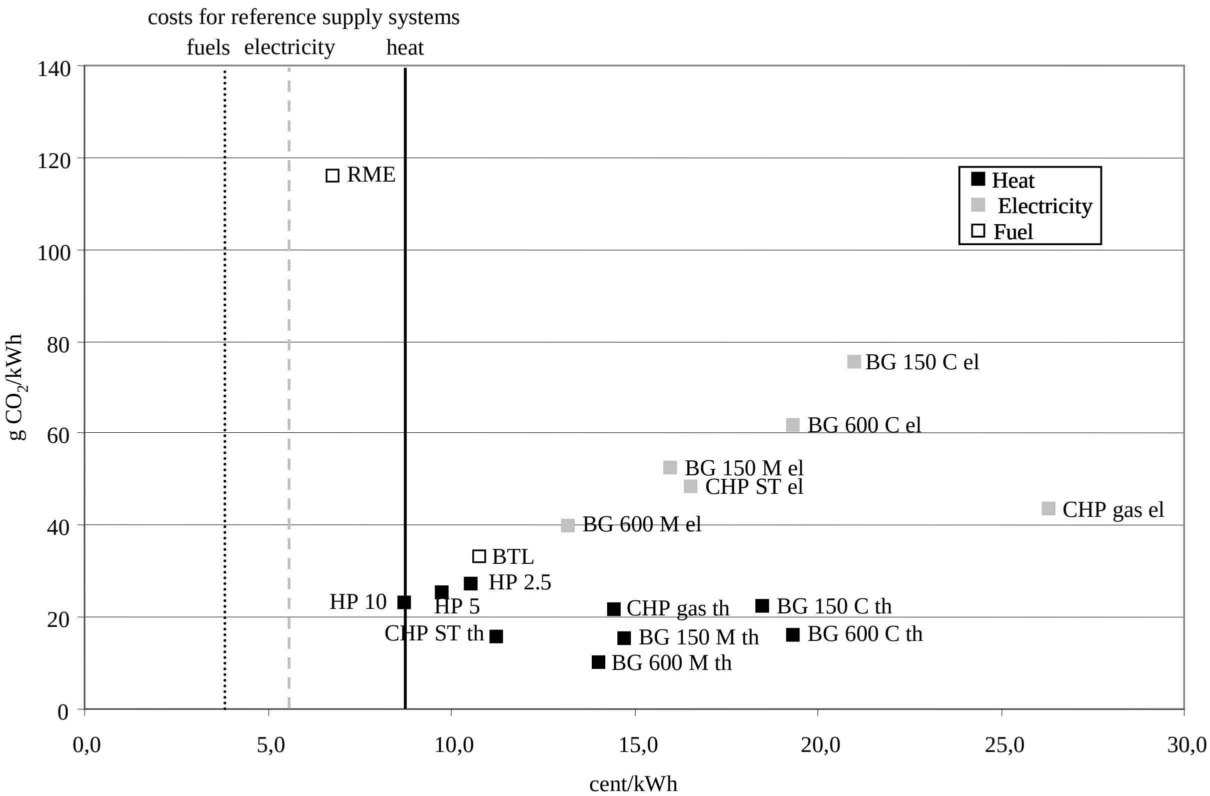

Fig. 2. Costs and CO_2 emissions of 11 bioenergy technologies[6] without credits (exergy allocation[7])

The results clearly indicate that:

- all bioenergy technologies come along with less CO_2 compared to the fossil reference technologies and (without feed-in tariffs) hardly achieve lower costs.
- heat provision is the most economic form of bioenergy and the provision of transport fuels comes along with the highest CO_2 emissions.
- using residues (manure) is much more favorable than energy crops. This is true for both, environmental and economic balances.

When looking at the six technology combinations in Fig. 3, the analysis furthermore proves that massive contributions to decarbonization of the rural energy supply can be achieved by implementing bioenergy villages. Even the least ambitious supply system (BF1) cuts emissions by 56 %, whereas the most ambitious approach (BBB2) reduces CO_2 emissions by even 97 %. Supply systems using biomass for peak load have considerably better results than systems with fossil peak load.

[6] The CO_2 emissions of the fossil reference technologies amount to 292 g/kWh (heating), 576 g/kWh (electricty) and 201 g/kWh (fuels).
[7] Exergy allocation attributes costs and emissions with respect to the share of energy that can be converted into any other from of energy (“available work”). Thus, the weight of useful heat depends on its temperature: the higher the temperature, the higher its weight. Due to thermodynamics, however, heat is always lower than 1. In turn, electricty always equals 1 per definition.

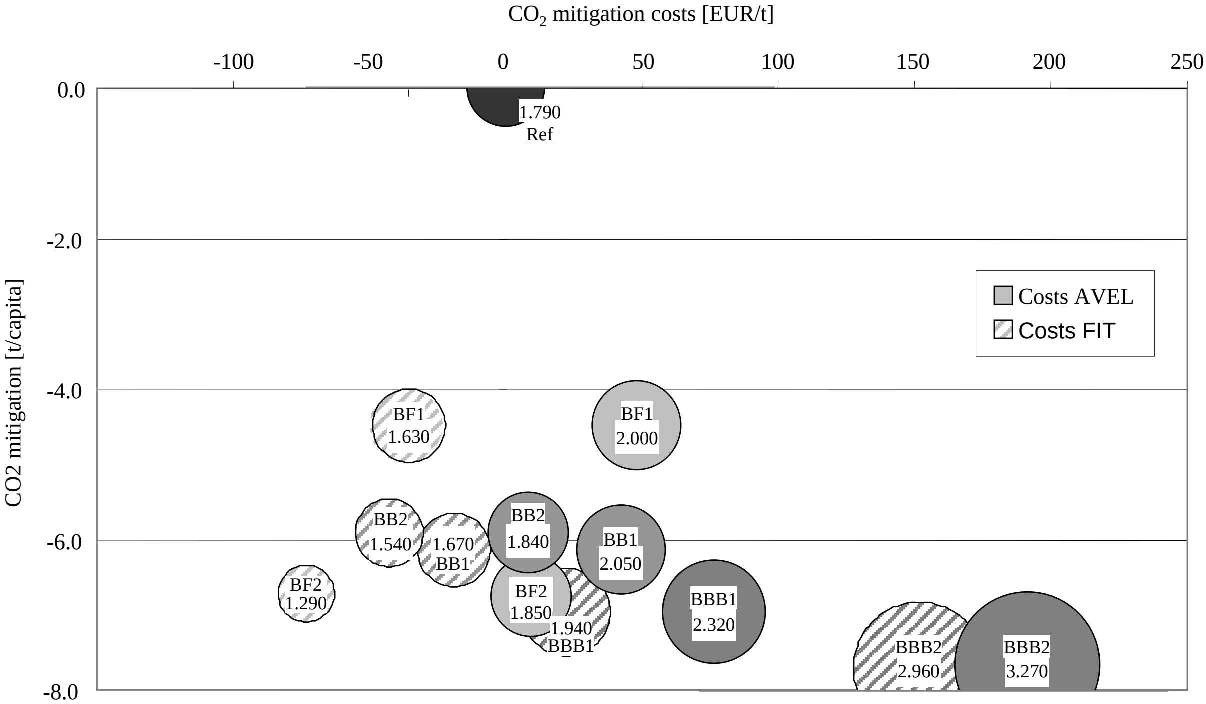

Fig. 3. CO_2 mitigation (compared to the reference supply system[8]), CO_2 mitigation costs and yearly costs per capita (bubble size, EUR/capita/a)

In contrast, under current prices for energy carriers, bioenergy villages hardly reach conventional supply systems without considering feed-in tariffs: the four cases BF1 (1,630 - 2,000 EUR/capita/a), BF2 (1,290 - 1,850 EUR/capita/a), BB1 (1,670 - 2,050 EUR/capita/a) and BB2 (1,540 - 1,840 EUR/capita/a) show higher costs (with regards to AVEL-costs) than the fossil reference system. In turn, costs based on credits for feed-in tariff certainly (FIT) are lower in BF1, BF2, BB1 and BB2 than the reference supply system.

In BB2 for instance costs are considerably lower compared to BB1 due to the utilization of less expensive woody biomass instead of energy crops. Comparing BB1 and BF1, only a small increase of costs (+2.5 %) can be seen. Therefore, it can be concluded that replacing a heating oil plant (peak load) with the wood chip heating plant can achieve moderate CO_2-mitigation costs. In turn, including transport fuels (BBB1 and BBB2) leads to a considerable increase of costs (up to 3,270 EUR/capita/a in BBB2).

Fig. 4 highlights that limits for the mass role out of bioenergy villages can appear with regards to resource base. In rural areas a 100 % supply with biomass – even though it is technically possible – can only be reached with unreasonably high competition to the food, fodder production, goods of the pulp and paper industry, and derived timber products. From this point of view, the combination with other renewable energy carriers (“renewable energy villages”) should have good potentials to reducing the problems of spatial limits.

[8] 8.0 t/capita

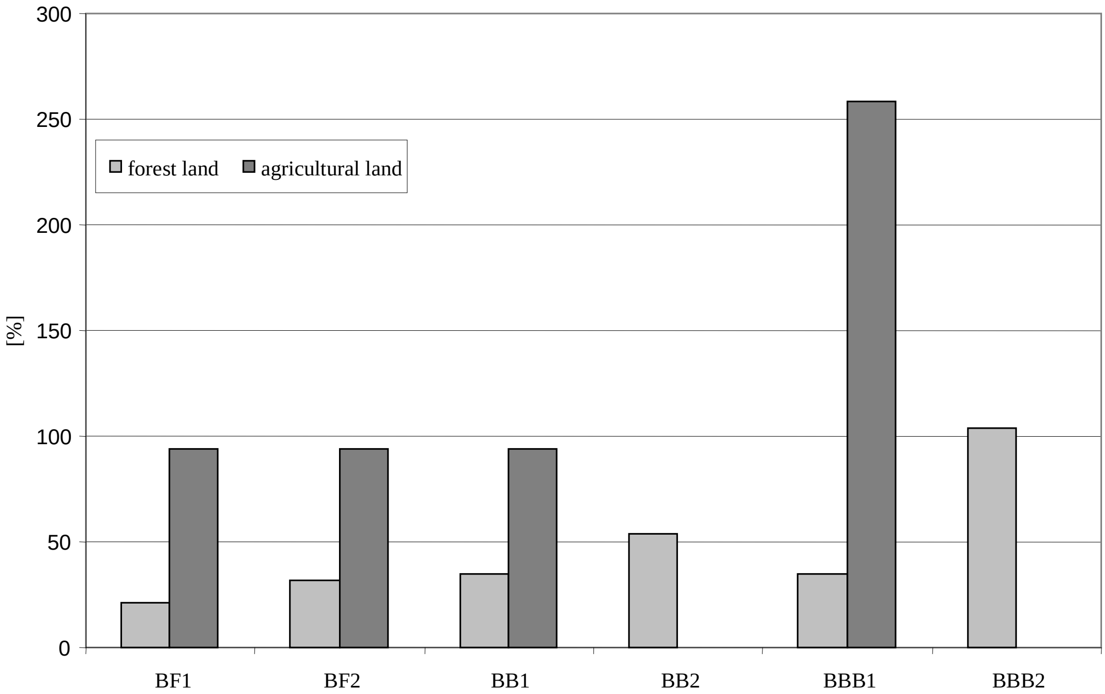

Fig. 4. Consumption of existing resource base (the share of all forest- and agricultural land is shown without considering non-energy use of forestry or agricultural products)[9]

4. Prospects for low carbon rural areas

The survey clearly proves that bioenergy villages offer good opportunities for achieving low carbon rural areas. In addition, most supply concepts – at least under current feed-in tariffs in Germany (FIT) – stood the economic test and (except the ambitious supply system BBB1 and BBB2) show negative CO_2 mitigation costs. Moreover, it demonstrates that a 100 % supply with heat, electricity and mobility is 'technically feasible' within the territory of an average German village. But such status can only be achieved if second generation biofuels are employed, which currently come along with significantly higher costs. Generally, energy autarky can only be reached with high competition to food- and fodder-production (conflict of aims). But it is possible to cover heating and electricity demand without causing significant land competitions.

Especially those municipalities which have large forest areas within their territory offer excellent prospects to become a bioenergy village. This is due to the circumstance that wood combustion technologies are the most developed and low-cost bioenergy technologies (see Fig. 2). In contrast, biogas technologies are competitive only due to the feed-in tariffs even when residues (manure) are used. The most expensive way of CO_2-mitigation is the production of biofuels. Therefore, the current strategy of most bioenergy villages (first providing heat and/or combined heat and power, then electricity and then fuels) is a wise approach.

Whereas a large resource base is given in rural areas, implementation of renewable concepts is facing serious drawbacks as low settlement densities lead to higher specific costs and losses

[9] Values < 100 % indicate that less biomass is used than can be provided within the boundaries of an average German rural municipality. In turn, values > 100 % imply that imports of biomass are mandatory to implement the respective bioenergy concept.

for heat distribution. Therefore, the implementation of individual technologies without heat distribution (e.g. pellet boilers) and the combination with other renewable energy carriers have good potentials to add to the concept of bioenergy villages.

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Sustainable regional development through the use of photovoltaic (PV) systems. The case of the Thessaly region

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Abstract: The purpose of this study is the contribution of photovoltaic systems to the Sustainable Development of the region of Thessaly in Greece. The aim is to explore both the potential for further installation of PV systems in the region and to record the opinions, knowledge and attitudes of residents about them. To document the theoretical data was carried out fieldwork using questionnaires given to a sample of 200 residents of the region of Thessaly. The work attempts to clarify the term "Sustainable Development" and what are the factors that contribute to it. The advantages and disadvantages of PV systems and the European policy that is followed in Greece for them, are recorded. The work focuses on solar rooftops and special attention is given to the advantages and disadvantages of solar roofs. The search area is studied and the general characteristics are given. The research, the results of statistical analysis and the X^2 test for independence are described. In this way, we are given the possibility to approach the degree to which citizens are informed and sensitized on the issues of photovoltaics. In the last part of the study the results of statistical analysis are commented, the conclusions are recorded and proposals are formulated to improve the current situation and further spread and use of photovoltaic parks and solar roofs in the region of Thessaly.

Keywords: *Sustainable Regional Development, Photovoltaic Systems Renewable energy.*

1. Introduction

Nowadays, it has become acceptable that sustainable development is directly linked to energy development. The use and evolution of renewable energy can contribute to the sustainable development of a place, because this will mean environmental protection, and security for the financial resources for this place. (Mitoula, 2006)

Regarding photovoltaic systems, the photovoltaic parks made today at a regional level, produce electricity channeled through the Public Power Corporation (PPC) for the electrification of areas. (www.photovoltaicscom.gr) The same occurs with the installation of PV on the roofs of houses (so-called solar roofs). The advantages of such a practice are many, since firstly, the citizen produces his own electricity for the home and secondly, a profit because it is connected to the electricity network and the "excess" power is sold to it. In this way achieve faster depreciation of the cost of installation. (www.atlantisresearch.gr) (www.helapco.gr), (www.pv-home.gr)

The purpose of this study is the contribution of photovoltaic systems to the Sustainable Development of the region of Thessaly in Greece. The aim of this study is to explore both the potential for further installation of PV systems in the region and to record the opinions, knowledge and attitudes of residents about them. To document the theoretical data was carried out fieldwork using questionnaires given to a sample of 200 residents of the region of Thessaly. The work focus on solar rooftops.

In the last part of the study the results of statistical analysis are commented, the conclusions are recorded and proposals are formulated to improve the current situation and further spread and use of photovoltaic parks and solar roofs in the region of Thessaly.

2. Case Study: The region of Thessaly

The region of Thessaly is the central - eastern part of mainland Greece. It consists of the prefectures of Karditsa, Larissa, Magnesia and Trikala and occupies a total area of 14,036 km^2 (10.6% of the total area of the country). (www.thessalia.gov.gr) (Sivignon, 1992) (www.el.wikipedia.org)

In the region of Thessaly operates 19% of photovoltaic power plants in Greece. The greatest contribution of Thessaly in energy through photovoltaic systems for large power stations, from 150 to 2000 KWp, sector which occupies 31% of national production. 9% contribute to a small group to 20 K Wp and 14% in average power of 150 K Wp. Then data on t he 4 prefectures of Thessaly are recorded.

In the prefecture of Magnesia, power stations are located, of which 14% of Thessaly contribution to the national average production of energy is produced. (www.anaptixiaki-anamth.gr)

The first photovoltaic park double-axis, power 94,5 Kw, (6 acres) was created in Stefanovikio of Magnesia in 2009 a nd its operation involves several elements of originality, since the construction is based on a tracking system of the sun (tracker double -axis), thanks to moving rather than stable panels follow the sun, ensuring maximum efficiency. (www.wordpress.com, www.qualitynet.gr). At the same time, authorized another photovoltaic power station same power (2MWp), adjacent to the operating station Industrial Area of Volos.

In the field of solar roofs, the Social Law Center South Pagason of Municipal Agency for Health and Social Affairs of the Municipality of Volos equipped with an integrated system for producing electricity from the sun. The PV panels are composed, produced more than 2.600 KWH per year, offsetting 2.3 t onnes of CO2 emissions in the same period. The PV system that was installed in front of this building is the first building unit of a municipal building in Greece and the PV modules are specially designed for buildings. (www.aleo-solar.gr) This system is innovative and the aim of Volos is the progressive intervention on e xisting buildings, contributing to environmental protection and energy security for the city. Having such a slogan “Volos-Green Town”, the Municipal Authority has been gradually implementing an ambitious program to become the capital of Magnesia benchmark and a model “Green City”.

The prefecture of Karditsa, has large areas of high sunshine, a favorable ground for development of this technology, which supports local development. As priority areas for siting installation of exploitation of solar energy are the areas that are barren or are not high productivity and preferably invisible from crowded places, and with opportunities of connectivity to the Network or System. (www.minenv.gr)

Example of installation of PV parks in the prefecture of Karditsa is in the municipality of Campos, where 5 P V parks were constructed, which produce 20 K W / h e ach. The funding was made by the Operational Programme "Competitiveness" of the Ministry of Development (45% subsidy from Ministry of Development and 55% own contribution). (www.oikosocial.gr) The project makes the municipality electrician producer. The benefits from the operation of this park are numerous and significant for the local community and the wider region. In 2008 e stablished the "Energy Company of municipality of Campos”. The local company that took over the project, pledged that 50% of profits will invested in environmental projects and the remaining or rest of 50% in activities of cultural, sporting and environmental sector, namely development projects for the benefit of the municipality. (www.karditsanews.gr) Also, 2.5 acres used for the installation of PV is like to have created 200 acres of forest. This is because many would be needed to absorb 280 tones of CO2, the release of which prevent the PV. (www.oikosocial.gr)

Also in Artesiano of Karditsa two units of 100 KWp are built in neighboring areas of PV panels of high efficiency, with rated power 100 KWp each. (Www.aleo-solar.gr)

Under construction is PV station in the Industrial Area of Karditsa with power 1MW.

In addition has given a license installation of a power station by PV power systems 0,84 MW, in place of the industrial area of Karditsa, Palama Municipality of Karditsa (www.thessalia-espa.gr/Files/espa_episimi.pdf)

Regarding the prefecture of Larissa, in recent years contributes significantly to generating/producing electricity using not only PV parks and solar roofs.

In the municipality Kranona installed PV park, thanks to the special bases of support, following the sun in two directions (two-axles trackers). This provides 40% more power than conventional – stable installations. Already by 2/4/2009 have been saved 1.616,54 kg CO_2 emissions from the PV station rated power of 19.80 kW, which came into full production mode on 13/3/2008. The project was funded under the CSF by the "Competitiveness" of the Ministry of Development, at 55%. (www.greenproject.gr)

Also, in the municipality Polydamanta was authorized in 2009 by the Ministry of Development and the Region of Thessaly, the transmission of energy production license and, installation license of PV station, power 9,99 MW.

In February 2010, in place Kritiri of the municipality Farsala of Larissa, was issued permit installation of PV power station, power 1.998 MWp.

Finally, based on the same article, was issued another permit installation of PV power station, power 4.996 MWp, in the municipality Narthakiou of Larissa. (www.photovoltaics.com.gr/solar-panel-pv-3.html)

As for the prefecture of Trikala, there is a rapid increase in installed PV systems.
Specifically, the Energy Regulatory Authority (RAE) approved the installation of PV systems with total power 95,04 KWp on the roof of the Technical Vocational High School of the city. This project covers not only the electricity needs of the school but the excess is sold to ΔEH. The choice of school was for learning and energy purposes. (www.news.trikki.gr)

Also, in 2008 completed the installation of PV power system with power 99.30 KWp in Vasiliki of Trikala. Using the single-axis moving bases, frames are always oriented to the sun by increasing production by 32%. The whole system is supported by a metal circular track of 12 meters in diameter, and thus the suncarrier oriented to the sun every 10 minutes.

The first photovoltaic station in Trikala of "small class" (up to 20 kWp), built in 2008 in the municipality Paleokastro. (www.aleo-solar.gr)

In Pigi of Trikala a new photovoltaic park of 19,98 kW rated power is installed and the connection to the electricity network was held on August 12, 2009.

Also, in the prefecture of Trikala installed PV park on a flat roof of industrial building crafts an extent of 1500 square meters, rated power 19,80 kW. This is the first PV system in Greece installed in the roof using sun tracking system (tracker). Due to the limited installation space and to avoid shadows, preferred to use single-axis tracker, which delivers increased production compared to systems of stable bases (approximately 30-35%).

In 2009, completed another PV park rated power 19,98 kW in Faneromeni of Trikala. The project was funded under the third CSF by the program "Competitiveness" of the Ministry of Development, at 55%. (www.greenproject.gr)

The Municipality Ichalias of Trikala converted in solar center, where completed the installation of two more PV parks of 19,80 kW each, reaching a total of 4 parks in the area.

In 2010, another permit to construct plants producing electricity from PV systems was issued, with a power of 1,006 MW, in the municipality of Paliokastrou in Trikala.

3. Research

In the investigation of these issues, in region of Thessaly, a fieldwork was carried out during the period between February and April 2010. 280 completed questionnaires shared, while 200 of those were returned, of which 60 relate to people of Volos, 40 of Karditsa, 60 of Larissa, and 40 of Trikala (total population = 317105 residents). The number of questionnaires was proportional to the population of each district. Completion of the questionnaire was anonymous, while the sample was selected using the simple random sampling and attempted to cover all the scales of ages and educational levels. After the completion of questionnaires, were processed, followed by checking their validity, the coding of variables and their introduction in the statistical program Statgraphics. Using the statistical program Statgraphics found the percentages. The Excel has the ability to make charts of the percentages of the respective responses of the respondents. Of the 200 people, 46% are men and 54% are women. The majority of respondents are aged 20-29, the rest ranging from 30-59 years old and only 3% are aged 60 or over, which consists of pensioners. The education level of respondents varied, with 52% ranging from 15.000 € to 30.000 €, 12.5 % have an annual household income <15.000 €, 31% from 30.000 € to 45.000 €, and 4.5% of respondents with more than 45.000 €. One very important factor that could influence the views of respondents are professional jobs where just over half the respondents, 51.5% appears to be private and civil servants, 11.5% self-employed, the 20.5% students, 9% are employed in households, 4.5% were unemployed and 3% retired.

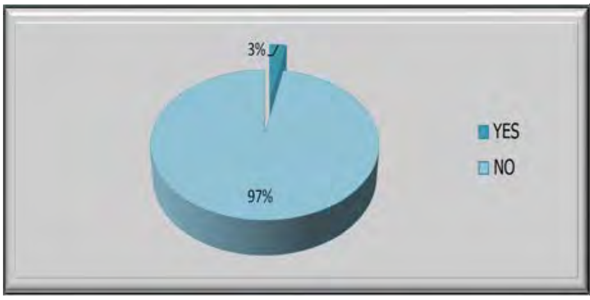

Fig. 1. Have you ever use PV?

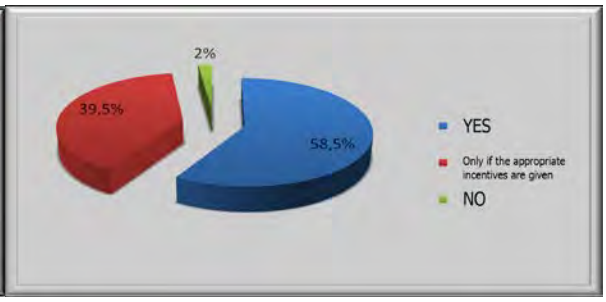

Fig. 2. Are you willing to help in reducing energy consumption by using solar energy through PV?

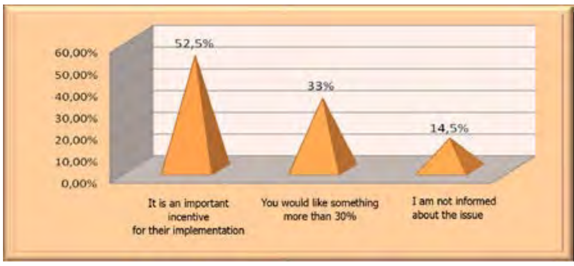

Fig. 3. What about the subsidy by the E.U. for the use of PV?

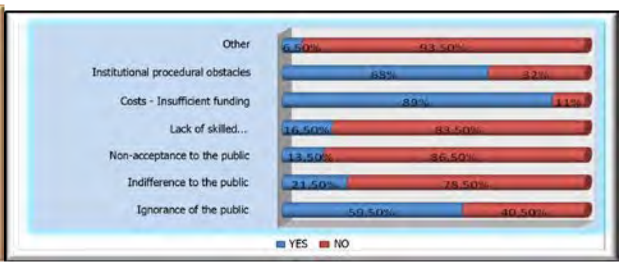

Fig. 4. Obstacles for the use of PV.

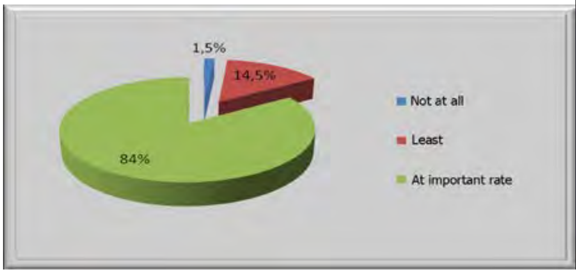

Fig. 5. How PV contribute the Sustainable Development?

Fig. 6. Would you install PV on your rooftops?

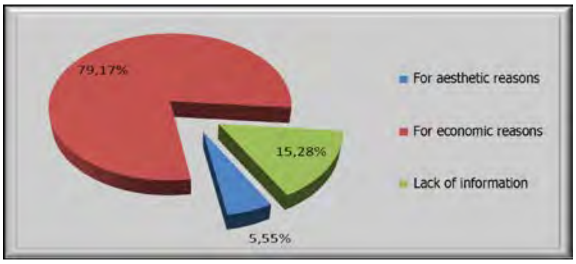

Fig. 7. The others who do not agree with the installation of PV on roofs.

To extract the best conclusion was necessary to examine whether the realization of an event influences another event. To test the degree of dependence between two qualitative variables the X^2 test is used. The X^2 test of independence is a method that allows us to determine whether two variables are dependent.

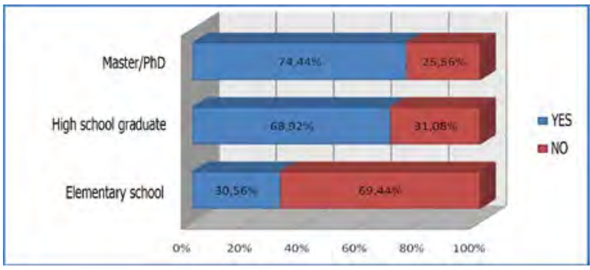

Fig. 8. Correlation of the variables "educational level" and "install PV on roofs"

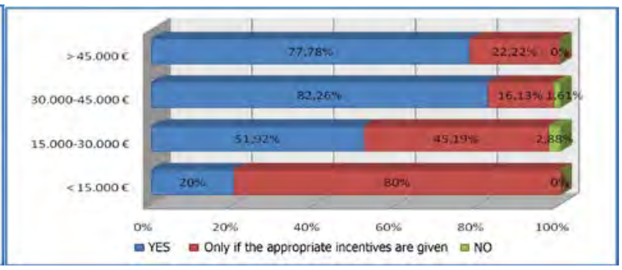

Fig. 9. "annual family income" and "help to reduce energy consumption by using PV

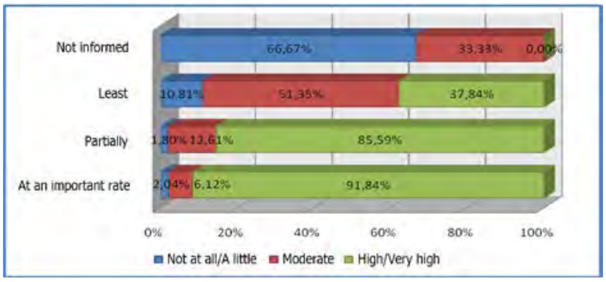

Fig. 10. "information" and "necessity of the installation of PV in the region of Thessaly"

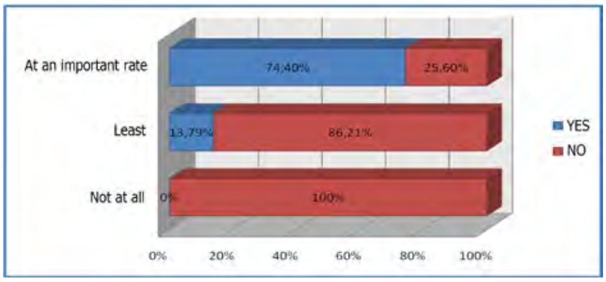

Fig. 11. The intensive use of PV contributed significantly to enhancing sustainable development in the region of Thessaly, the majority agree with the installation of PV on their roofs

4. Discussion

The above survey shows that residents are aware of issues of environmental protection. Furthermore, they are interested in the development of their country and are willing to accept the further use of photovoltaic systems.

97% of the sample have not used PV but are willing to shift to the use of solar energy through photovoltaic systems instead of conventional energy (polluting fuels). On the issue of EU subsidies for application of PV systems exist 2 views exist: in the one hand a subsidy is an important incentive, while on the other hand, a large proportion of the sample considers that the subsidy amount is small compared with the obstacles facing such an action. Also, in the opinion of the sample, there are major institutional problems (bureaucracy, etc.) problems of cost (design, purchase and installation). Therefore, the willingness, determination and environmental consciousness exists, but others are the factors that contribute to the further development of PV systems.

The survey showed that people propose funding from the government, further and better information about the account issues from media and press. Generally, regular information and awareness of public is demonstrated by research that leads to change human behavior, without neglecting the education/training from an early age.

Arguing that the PV systems contribute to sustainable development of the Region of Thessaly, the respondents indicate that the growth sectors that will most affected by the widespread application of PV as a renewable energy, is initially the economy. This is because new jobs, liquidity in the region and independence as a point of fueling are created. The impact on the environment will also be positive, due to reduced emissions, the friendly operation of PV on it, and the recyclability of construction materials. At the same time, the employment of many people working in research on environmentally friendly technology is enhanced.

The subject of the installation of PV on roofs (so-called solar roofs), is a very important part of research because from the results that carried out, is concluded that the largest percentage of respondents who would make installation, are based on the following reasons: they are environmentally friendly, provide reliability and long life, and of course the maintenance cost is very low. Note however that the reason why they would not install, is more economical.

Then, indicated that, the better the educational level of each respondent is, the greater and the eagerness to help in reducing energy consumption by using solar. This happens because the level of education means more knowledge, not just for one particular sector, but general as long-term benefits, impacts, even in conjunction with other sectors. Moreover, in the case of solar roofs, it is concluded that the higher the educational level is, the higher the percentage of respondents are agreeing with the installation of PV on rooftops. It seems therefore, that this feature reduces the hesitation, financial or otherwise, for such an installation.

Another factor that contributes to the willingness of respondents to install PV is the annual family income, even if it undermines the protection of the environment. The higher the annual household income is, the percentage of people who are interested to help in the effort of reducing energy consumption by using PV increases. In addition the needs of one person to the other differ, also differ in their beliefs, willingness and interests that are directly affected by income. Moreover, employment, which is linked to income, is also a factor that influences the views of persons. The above observed from the fact that the majority of workers support the view that the subsidy that is given by the EU for the application of PV is an important incentive, unlike the pensioners, the unemployed and those employed as household who believe that although is a motive, they would like more subsidy. Implicitly/ Indirectly, then is confirmed that the higher the level of awareness of energy saving issues and renewable energy is, the positive attitude of respondents towards the necessity of installation of PV in the region of Thessaly increases, because of long-term benefits that they offer.

Therefore, for the installation of photovoltaic park in the region, openness and condescension increaese as increasing the willingness to the effort of reducing energy consumption by using solar energy through PV instead of polluting fossil fuels for electricity in the region. Finally, it turns out that sustainable development makes/gives a 'functionality', supports the invulnerable and endlessly point of this development over the years, reinforce local and regional development in conjunction with the RES, because the higher the percentage of respondents who believe that the intensive use of PV contributes to reinforcement of sustainable development is, the possibility of installation of PV on the roofs increases.

5. Conclusions

The region of Thessaly is largely dependent on f ossil fuel, but on the potential use of photovoltaic systems is satisfactory level. The above study also demonstrated the positive attitude of the residents of Thessaly toward this type of systems.

In conclusion, the use of photovoltaic systems is significantly close to the new perspectives of balanced development, which seeks to ensure environmental quality, economic development and improving social cohesion. Also emphasized that the region of Thessaly is the second in Greece in the frequency of using photovoltaics for electricity production, resulting in energy to contribute significantly to sustainable regional development.

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Integrated Community Energy Modelling: developing map-based models to support energy and emissions planning in Canadian communities

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Abstract: Urban emissions represent approximately 40% of Canada's current GHG emissions and the need to implement Integrated Community Energy Solutions (ICES) is now broadly recognized. A more consistent approach for characterizing energy and emissions opportunities in communities and the provision of more accurate and comprehensive information to planning processes is required. Integrated Community Energy Models (ICEMs) employ Geographical Information Systems (GIS) to integrate spatial information on a community's land use, building stock, transportation and energy systems and socio-economic characteristics. Using future scenarios, ICEMs support the prioritization of opportunities for energy efficiency and renewable and district technology integration, better enabling planning, policy development and investment decisions.
This paper describes organizations forwarding ICES and ICEM development and selected enabling provincial legislation. Three case-studies are presented: the *Energy Density Mapping Strategy* for the cities of Guelph and Hamilton, Ontario, the *Spatial Community Energy Carbon and Cost Characterization (SCEC³)* model for the City of Prince George, British Columbia and the *Energy Asset Mapping* project in the Strait-Highlands Region, Nova Scotia. For each, core model aspects, required data, highlighted results and their integration into community planning processes are discussed. The article concludes with next steps for implementation and future research and development of ICEMs in Canada.

Keywords: *Integrated Community Energy Modelling, Community Energy Planning, GIS*

1. Introduction

For several years Canadian communities have been developing Community Energy Plans (CEPs) and have demonstrated success in implementing actions within municipal operations. Preliminary studies suggest however, that targets established in plans for community-wide energy and emissions (E&E) reductions are not being consistently achieved. [1] To address this gap, there is a need for improved decision support for community-wide actions, aided by models flexible enough to assess the impacts of a variety of future scenarios.

Integrated Community Energy Models (ICEMs) support the spatial characterization and prioritization of energy efficiency and district and renewable energy opportunities in communities. The models developed in Canada to date have been used largely in the assessment of E&E reduction targets, policies and actions in CEPs, Official Community Plans (OCPs), Integrated Community Sustainability Plans (ICSPs) and for the accelerated deployment of renewable energy technologies.

It is hypothesized here that ICEMs used in the planning process help planning departments, utilities and the broader public to better comprehend energy end-use and renewable supply options within the built environment. Because energy-related decisions are made at various levels of geography [2] the spatial characterization of energy use and supply is seen as critical to the development of practical and effective reduction plans. The information required for comprehensive E&E reduction planning includes: land use zoning, the type and location of residential densities, employment centres and transportation networks; waste recycling systems and potential carbon sinks; and the capacity for renewable generation and district energy systems. An integrated assessment of these landscape features enables targeted investment planning towards strategic energy infrastructure and E&E reduction initiatives.

This paper describes three Canadian ICEMs, each of which explores in different levels of detail some of these E&E information aspects: the Energy Asset Mapping (EAM) project undertaken for the Strait-Highlands Region, Nova Scotia, the Spatial Community Energy Carbon and Cost Characterization ($SCEC^3$) model developed for the City of Prince George, British Columbia and the Integrated Energy Mapping, Modelling and Financial Assessment (IEMMFA) strategy for the Cities of Guelph and Hamilton Ontario.

1.1 Community energy research and development objectives of leading organizations

Natural Resources Canada (NRCan) is a department of the federal government of Canada. The CanmetENERGY works with partners to develop more energy efficient and cleaner technologies. An objective of the Program of Energy Research and Development's Communities sub-program is to develop a standardized methodology for characterizing energy and GHGs at the community scale. In 2009, the House of Commons Standing Committee confirmed NRCan's mandate in this area, recommending that the department "…should continue to investigate the reliable measurement of energy in communities." CanmetENERGY is the proponent of the $SCEC^3$ model, and has supported various Canadian ICEMs, including IEMMFA and the Strait-Highlands EAM.

The Canadian Urban Institute (CUI) is Canada's applied urban policy institute dedicated to policy and planning solutions that enable urban regions to thrive and prosper. A Toronto-based not-for-profit organization, the CUI encourages the application and integration of E&E planning into the decision-making process at the municipal level. The Institute has led a program of research into long-term solutions for urban transportation, waste management and energy supply challenges. CUI is the main proponent of the IEMMFA strategy.

The Strait-Highlands Regional Development Agency (RDA) has facilitated economic development for communities and businesses since 1994. A strategic focus within its business plan is to foster a smart energy region. Key objectives include maintaining an energy and emissions inventory, conducting emissions forecasting, and partnering with municipal and community champions to set and achieve reduction targets. The Strait-Highlands RDA initiated the EAM when developing a local action plan, towards achieving Milestone 3 in the Federation of Canadian Municipality's Partners for Climate Protection program. [3]

1.2 Enabling legislation in the provinces of British Columbia, Ontario and Nova Scotia

Within Canada, provincial governments have the jurisdiction to develop legislation on energy and land use planning pertaining to municipalities.

British Columbia has passed a series of acts promoting energy efficiency and emissions reductions. Bill 27, the Local Government Statutes Amendment Act (2008) [4] links E&E to land use planning processes by requiring local governments to include GHG emissions targets, policies and actions in their Official Community Plans and Regional Growth Strategies. Bill 17, the Clean Energy Act (2010) [5], sets ambitious goals for energy reductions of 66% less increased demand and 93% of electricity to be derived from clean sources by 2020. To assist planning efforts, British Columbia has provided 27 regional districts and 163 local governments with their own Community Energy and Emissions Inventory (CEEI) reports, [6] and is fostering an emerging modelling community of practice.

The energy sector in Ontario is in the midst of a significant transformation, spurred on by an interest in an open market for energy production and distribution and the problems of an aging infrastructure and near brownouts. Introduced in 2008, the Green Energy and Economy Act (GEEA), makes it easier to bring renewable energy projects on-line and encourages a culture of conservation. Changes introduced with the bill include a Feed-In-Tariff (FIT), the establishment of conservation targets for utilities, and the requirement for public sector institutions to develop energy conservation plans. Municipalities and utilities have been assigned electrical demand reduction targets and are using energy mapping to assist with decision making on potential strategies to meet them.

The province of Nova Scotia through the enactment of Bill 146, the Environmental Goals and Sustainable Prosperity Act (EGSPA), [7] has set an ambitious target of 25% of electricity to be generated from renewable sources by 2015. A second target, although not yet backed by law, aspires to a 40% reduction in greenhouse gas emissions for 2020. Targets established under the EGSPA are accelerating renewable energy planning in Nova Scotia.

2. Core Model Aspects

2.1 Energy Asset Mapping (EAM)

The Strait-Highlands Region Energy Asset Mapping (EAM) identifies opportunities for the introduction of alternative and renewable energy sources to serve municipal, commercial and residential energy needs. The energy sources explored include: earth energy, wind energy, solar potential, waste heat from mines, geothermal, synergies between large industries, coal bed methane reserves and small-scale hydro potential. Existing information such as hydrology and wind energy profiles and newly created data including solar and waste resource assessments are represented geographically in map layers. These potential energy sources are evaluated based on annual energy output in kilowatt hours (KWh), estimated GHG reduction potential, and cost-effectiveness when compared with a future rise in conventional energy prices. Some sources, including earth energy, bio fuels and industrial synergies, are better represented non-spatially and were evaluated based on estimated values for the quality and quantity of energy available. There is an accompanying guide that provides other details on the technologies including installation costs and, in some cases, a simple payback analysis.

2.2 Spatial Community Energy Carbon and Cost Characterization Model (SCEC^3)

The SCEC^3 model enables the calculation and spatial characterization of present-day and future energy use, emissions and associated costs for residential, institutional, commercial and industrial buildings in the City of Prince George, British Columbia. It combines simulated energy information for selected housing and building archetypes with BC Assessment Authority (BCAA) building attribute information. The building archetype approach is consistent with that observed in projects internationally [8], [9].

Energy modelling for homes was completed in HOT2000, using ecoENERGY Retrofit Audit records collected in Prince George and held by NRCan. One objective of the research is to explore the use of existing federal government data and tools for community E&E characterization. Seven housing types were selected within the City of Prince George as representative of both the ecoENERGY Retrofit audit records and the housing stock as a whole. In addition to the community's baseline energy, GHGs and operating energy costs, 'low cost' and 'low energy' retrofit scenarios were developed. The model connects data tables containing energy, emissions and cost information to a GIS layer of the City's parcel boundaries via parcel ID (PID) numbers. A dynamic exploration of current and future energy use, emissions profiles and related cost scenarios is enabled through a series of custom queries developed in an MS Access database and custom scripts developed in ESRI ArcMap GIS software. The SCEC[3] model facilitates the exploration of future energy, carbon and cost scenarios through the addition of new buildings in given locations and the retrofit of existing buildings in random locations. Retrofits can also be targeted to select neighbourhoods.

2.3 Integrated Energy Mapping, Modelling and Financial Assessment (IEMMFA)

The IEMMFA model, developed by the Canadian Urban Institute, works to provide communities with the ability to see a clear link between the energy consumption of land-use and transportation and renewable energy systems and utility strategies across an entire community. The approach begins by developing information on building by connecting simulated archetype or actual energy consumption information with building floor area and built form typologies derived from municipal building attribute information. An assessment for transportation follows, using information derived from local trip tables to enable an assessment of energy use for both private and public transit.

The model connects a range of data tables containing information on energy, emissions, cost, alternative technologies and renewable fuels, transportation efficiencies, job creation and other information linked to different GIS layers. The GIS layers are based on parcel boundary information for buildings and trip zones for transportation. The model allows for the ranking and evaluation of current and future scenarios based on different combinations of building efficiency improvements, transportation demand management approaches, emission profiles, as well as the assessment of different built form patterns and their associated energy use.

To assist community members to compare and strategically prioritize opportunities, backcasting and scenario building are central to the IEMMFA approach, as is financial cost sensitivity. Rate of return, and dollar per tonne ($/tonne) of GHGs reduced are key measures allowing identified energy strategies to be compared in their ability to achieve a community target for the multiple criteria including energy, energy cost, GHGs, or other objectives.

3. Results and Implementation

3.1 Energy Asset Mapping

With almost 80% of Nova Scotia's energy coming from imported coal, results from the Strait-Highlands EAM indicate enormous potential for both GHG emission reductions and economic opportunities in the region. Several areas on the coast are suitable for large scale wind energy projects with much of the rest of the region appropriate for smaller wind projects of less than 2 MW. Opportunities exist for commercial scale tidal electricity generation within the nearby Great Bras d'Or Channel with an estimated 2.8 MW of potential tidal power. Potential for PV electricity generation was conservatively assessed at 22,153 MWh per annum, corresponding to an 18% reduction in annual electricity consumption and 22,733 tonnes of equivalent CO_2 saved per year; mass deployment of PV technologies could lead to more than three times higher than in the conservative scenario. Potential SWH generation was an estimated 23,177 MWh annually, or approximately 43% to 58% of current annual domestic hot water use, with potential emissions reduction of 11,342 tonnes of equivalent $C0_2$ per year. The passive solar heating asset is estimated at 25,381 MWh annually constituting approximately 15% of the current annual space heating energy budget. A number of river systems were assessed to have a total output capacity of 28,122 MWh per year, with full implementation of hydro electricity resulting in a reduction of 24,409 tonnes of equivalent $C0_2$ per year.

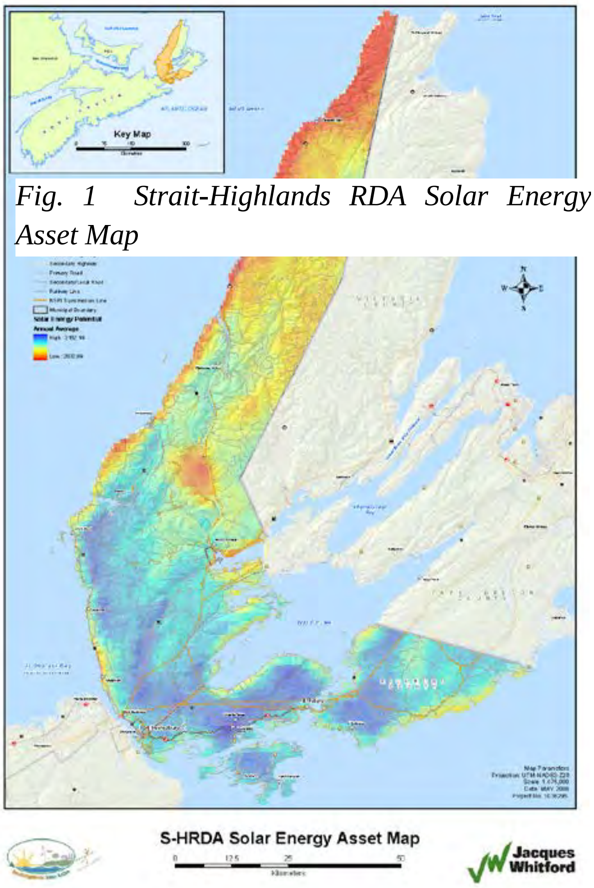

Fig. 1 Strait-Highlands RDA Solar Energy Asset Map

The Strait-Highlands EAM project concluded that capacity exists to supply the local clean energy required to meet a majority of future local energy needs from a number of different sources that could significantly diversify the energy mix in the region.

A consultation session was arranged with renewable energy development experts to discuss findings of the EAM project and determine barriers to development of renewable energy opportunities in the region. The report and map sets were used to develop directives for diversifying energy supply and increasing energy security under the ICSPs of the three partner municipalities. Custom maps were developed for targeted opportunities such as identification of municipally-owned properties ideal for wind energy development. Further to integration in planning, the EAM project has enabled renewable energy projects including solar thermal and PV applications and one demonstration project for a wind turbine in *Les Suetes,* a wind regime with speeds in excess of 150 km per hour. Planning is underway to develop a district energy system with a power plant and paper mill, using the nearby ocean for heating and cooling, a project initiated as a direct result of the EAM. Public consultation has led to a number of small and medium-scale renewable energy projects, including a building project that won the region's *Grass Roots Environmental Excellence Network Award*.

3.2 Spatial Community Energy Carbon and Cost Characterization Model

An example of the type of question that can be answered by the $SCEC^3$ model is: Will the residential sector in Prince George do its part to meet its community-wide target of 2% reduction from 2002 by 2012? When the 'low energy' scenario with multi-family growth for new construction was run, it was found that by 2018 the emissions from residential houses will be 112% of 2002 levels. It was only in 2028 that the residential housing stock would achieve 99% of 2002 levels. Even under the most aggressive scenario, it will be sometime after 2028 that the residential housing stock will meet a target that was to have been achieved by 2012. Based on these results, more widespread retrofits in residential houses, and the introduction of renewable energy technologies are required for the residential sector to do its part to achieve the community's target of 2% reduction from 2002 levels by 2012.

Fig. 2. Neighbourhood level output showing, for the residential sector, total annual energy use (GJ) per suite in the City of Prince George in 2038 under the low energy scenario.

Development of the model began in 2008 in conjunction with the Prince George *Smart Growth on the Ground* initiative to revitalize the city's downtown. [10] In the fall of 2009, Prince George City Council, city staff and community members embarked on myPG, a community-wide planning initiative comprising the development of an ICSP and update to the city's OCP. The SCEC^3 model initially developed data that was used for the baseline for the ICSP process, and provided a more accurate understanding of building energy consumption and associated GHG emissions specific to the Prince George context.

The City of Prince George was awarded the *2010 Community Energy and Climate Action Award* in the Community Planning and Development category; the community's use of innovative energy mapping mentioned in the context of the award. At the time of writing, in preparation for the city's community energy design charrette in the winter of 2011, 4 future land use scenarios developed by the community in the myPG process [11] are being run and information developed to forecast the impact of different types of policies and actions on E&E within the city's housing stock.

3.3 Integrated Energy Mapping, Modelling and Financial Assessment (IEMMFA)

A variety of insights have been gained during the initial use of the IEMMFA model in Guelph and Hamilton, Ontario. For Guelph, building and transportation energy efficiency improvements required for the city to meet its goal of a 50% reduction in energy use per capita were explored. An energy baseline of the existing built environment was established and energy efficiency scenarios developed to identify the most cost effective approach in terms of $/tonne of greenhouse gas (GHG) emissions reduced. A 50% improvement in energy efficiency over the Ontario building code for all new buildings and a 25% improvement through retrofits of existing buildings would be required for Guelph to meet its goals. Results are being used to understand where larger scale energy systems can be most effectively integrated with long range planning. The city is also considering the use of the model to more discretely evaluate how different built forms and associated transportation trips can be maximized to meet the community's energy objectives. Resulting from the identification of the need to dramatically reduce transportation energy use within the existing built environment, policy and program options are being evaluated by the city Community Energy Manager for development through partnerships with the local utility and others.

For the City of Hamilton, the approach taken was to evaluate the most cost effective energy efficiency options that would allow the city to actively address peak oil concerns. The IEMMFA model was run to evaluate various combinations of building improvements and the use of alternative technologies and renewable fuels. A key component of the evaluation was to identify strategies providing a reasonable internal rate of return of 6% assuming different future energy price scenarios. For Hamilton, it was found that the application of GeoExchange across the city would be an optimal strategy for maximizing fossil fuel reduction while promoting resilience against rising energy costs. In terms of cost effectiveness, evaluated on an internal rate of return of 6%, it was found that a combination of alternative technology and renewable fuels, and building energy efficiency improvements for existing buildings and new construction could achieve a 36% reduction in energy consumption. Information is being used to support the Hamilton Community Energy Collaborative, a group comprised of city staff, councillors, local community groups, utilities and others, to develop a comprehensive community energy plan. The local electrical utility in Hamilton is using the baseline electricity map to identify areas that would benefit from conservation programs.

4. Summary

The ICEMs reviewed here are among the first developed in Canada, and although they are all developed with the help of digital map-based models, getting stakeholders thinking spatially about energy and emissions in communities can begin with a hands-on, paper-based exercise. This 'rough-sketch' collaborative approach is an effective means of soliciting local knowledge of and preferences for efficiency and renewable energy options in a community and can be used to kick-start the development of an ICEM in an E & E planning process.

The focus of the ICEMs featured here varied according to the goals of stakeholders, local geographical feature, land use patterns and available data. The Strait-Highlands EAM considered local energy assets towards achieving renewable supply targets and economic development. The $SCEC^3$ model leveraged existing data and simulation tools to assess the energy and emissions reduction potentials within existing and new buildings, demonstrating the use of existing federal datasets and tools to link modelling with policy implementation in communities. The IEMMFA model and strategy can be described as the most holistic of the three approaches, and connected building technology with transportation and land use change to explore the relative influence of changes to the built form, population densities and location, demand-side management and renewable energy generation. Its ability to conduct financial cost sensitivity analysis will be of interest to communities, policymakers and utilities seeking to assess the costs of various energy technology, land use and infrastructure options.

5. Conclusion

In the past few years, the development of Integrated Community Energy Models has emerged as an important piece of the strategic energy and emissions planning puzzle for Canadian communities. Lessons learned through the iterative development of these first map-based models have identified technical barriers and knowledge gaps around issues of data, modelling, visualization and communication of model outputs. Additional research is being initiated to mitigate these barriers and gaps. As required data becomes more accessible and ICEM best practices are developed, the capacity of communities and their collaborators to respond to new legislative requirements around energy and emissions will be enhanced. More importantly, the practice of developing ICEMs and the integration of their outputs into planning processes will assist communities in their quest for Integrated Community Energy Solutions. The use of ICEMs in community planning provides a promising decision support approach towards greater economic, environmental and social prosperity for all Canadians.

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Carbon Neutral Village: The Australian Model

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Abstract: This paper presents a model for carbon neutral land development as a mechanism to help drive innovation and emission reduction within the built environment sector. The carbon content model is comprised of the following:

- The greenhouse gas (GHG) embodied in the materials of the buildings and the infrastructure;
- The GHG emitted during the construction process with different approaches;
- The electrical power and natural gas used in the buildings for different building types;
- The transport fuels used in the construction and the on-going use by residents;
- The GHG produced in the full water cycle
- The GHG from the solid waste.

Understanding the interactions between the six elements of the model allows better decarbonisaton options to be developed. Two remote settlement cases are analysed. Firstly for a mine site camp, we introduce the "Smart Camp" digital control and monitoring concept . This includes sustainable village design, heating and cooling reduction, renewable energy, water use and reuse, and landscaping. Secondly, for the remote Aboriginal settlement, we address the need for sustainable livelihoods, including local food production and rangelands forestry and management.

Keywords: *Carbon neutral, Life cycle analysis, Accreditation*

1. Introduction

The built environment in Australia is currently responsible for around 20 percent of the nation's greenhouse gas emissions [1]). This is largely due to the energy consumed within buildings, as this energy predominantly comes from coal.

In Australia, carbon emission assessments for buildings are limited to operational energy. The Building Code of Australia (BCA) requires predictive calculations of operational energy use based on thermal performance modelling. The National Greenhouse and Energy Reporting (NGER) Act, 2007 requires actual emissions to be reported for facilities when the relevant energy or carbon emission thresholds are met. Analysing only operational emissions is similar to making an investment decision by solely examining the running costs of a building and ignoring the capital cost of development and construction.

If future construction is based on the need to reduce only the operational phase of the building, there is a real risk that further carbon emissions will be generated. from materials to increase operating efficiency. Hence, the proportion of emissions may be shifted from the operating phase to the 'before' and 'after-use' phases, without necessarily reducing overall emissions [2].

This paper is essentially a positioning paper that presents a model for carbon neutral land development as a mechanism to help drive innovation and emission reduction within this sector. The carbon content model is comprised of the following:

- The GHG embodied in the materials of the buildings and the infrastructure;
- The GHG emitted during the construction process with different approaches;
- The electrical power and natural gas used in the buildings for different building types;

- The transport fuels used in the construction and the on-going use by residents;
- The GHG produced in the full water cycle
- The GHG from the solid waste.

It is considered that these elements comprise the major sources of carbon emissions, but it is important to understand how each element interacts with the others in order to reduce overall emissions. This more inclusive and holistic approach to village design is likely to result in reduced carbon emissions over its life. Two cases are analysed with the model: the remote mine site camp and the remote Aboriginal settlement.

2. Methodology

A literature review was undertaken to determine the methodology best suited to analyse the proposed carbon model of settlements. This was conducted in conjunction with a review of available tools to assess the six elements in the model, with project partners Curtin University. Data collection methods to populate the model will include interviews with service providers, surveys with communities and mine site operators, plus an active research method with a remote Aboriginal community. The data collection methods are still being refined.

2.1. Carbon analysis method

In order to fully determine the carbon emissions associated with a building or community, it is necessary to ensure the embodied and operating emissions are both measured in an appropriate calculation method. It is imperative that the method allows for comparability across a range of buildings and settlement types.

Carbon emission calculations can be conducted by a lifecycle analysis (LCA) method as they are for a wide range of products and services. LCA is supported by the International Energy Agency as a valuable methodology for examining the carbon of settlement development and the special assessment needs, such as adaptability of buildings and recyclability of materials can be incorporated [3]. The AS/NZS ISO standard *14040:1998 Environmental Management-Life cycle assessment - principles and framework* outlines the requirements and process for undertaking a lifecycle impact assessment. The standard states that the assessment is conducted for impacts throughout a product's life, or "cradle to grave", including raw material acquisition, through production, use and disposal [4].

Carbon Profiling [2] is a modification of LCA that can also be applied to settlements. This method develops a metric that includes the energy associated with land development, such as embodied energy in existing buildings on site and highlights the importance of the lifespan of linked components within the building system. This method proposes that end-of-life aspects not be incorporated as they are generally not decided at the time of construction but could be incorporated if the site is redeveloped in the future.

On this basis it was decided that a life cycle approach was appropriate and that consideration should also be given to any existing carbon on site and the life spans of linked components. End of life aspects would not be calculated, however the recyclability of materials will be included in considerations. Also the adaptability and transportability of structures that have a longer life span than the settlement requires, such as short term mine sites, would need to be considered where appropriate.

2.2. Review of software

An extensive review of software was undertaken to evaluate their functionality to assess the six elements of the model [5]). The evaluation comprised a literature review to identify software designed to assess settlements, an evaluation of the software's ability to calculate carbon emissions related to each of the six elements and a pilot test of two to determine their appropriateness for mining and remote Indigenous settlements.

The review found that there are only a few software tools that provide the required functionality and none of them fully satisfied the six elements. However it was noted that recognition of life cycle analysis for settlement evaluation is growing and the USGBC has been investigating ways to incorporate an LCA module in its LEED evaluation tool (USGBC, 2006 [6]. The software chosen by the authors for the analysis of small-scale settlements was *eTool*, which satisfies four of the six element requirements: materials, construction process, operating energy and water systems. The software is currently being developed in Western Australia.

2.3. Model design

Based on the reviews above a model was developed to understand the interactions between the six key elements of settlements that generate carbon emissions. The model was then applied to the two remote settlement types: mine site camps and Indigenous communities.

The six elements of the carbon model are all interconnected and impact on each other. For example the choice of energy supply can impact on transport and waste energy. Remote settlements that are dependent on diesel generators for electricity require regular transport of diesel and services for maintenance of equipment and also have fuel drum waste to dispose of or recycle.

A schematic depiction of the key applications,is provided in ***Figure 1*** below.

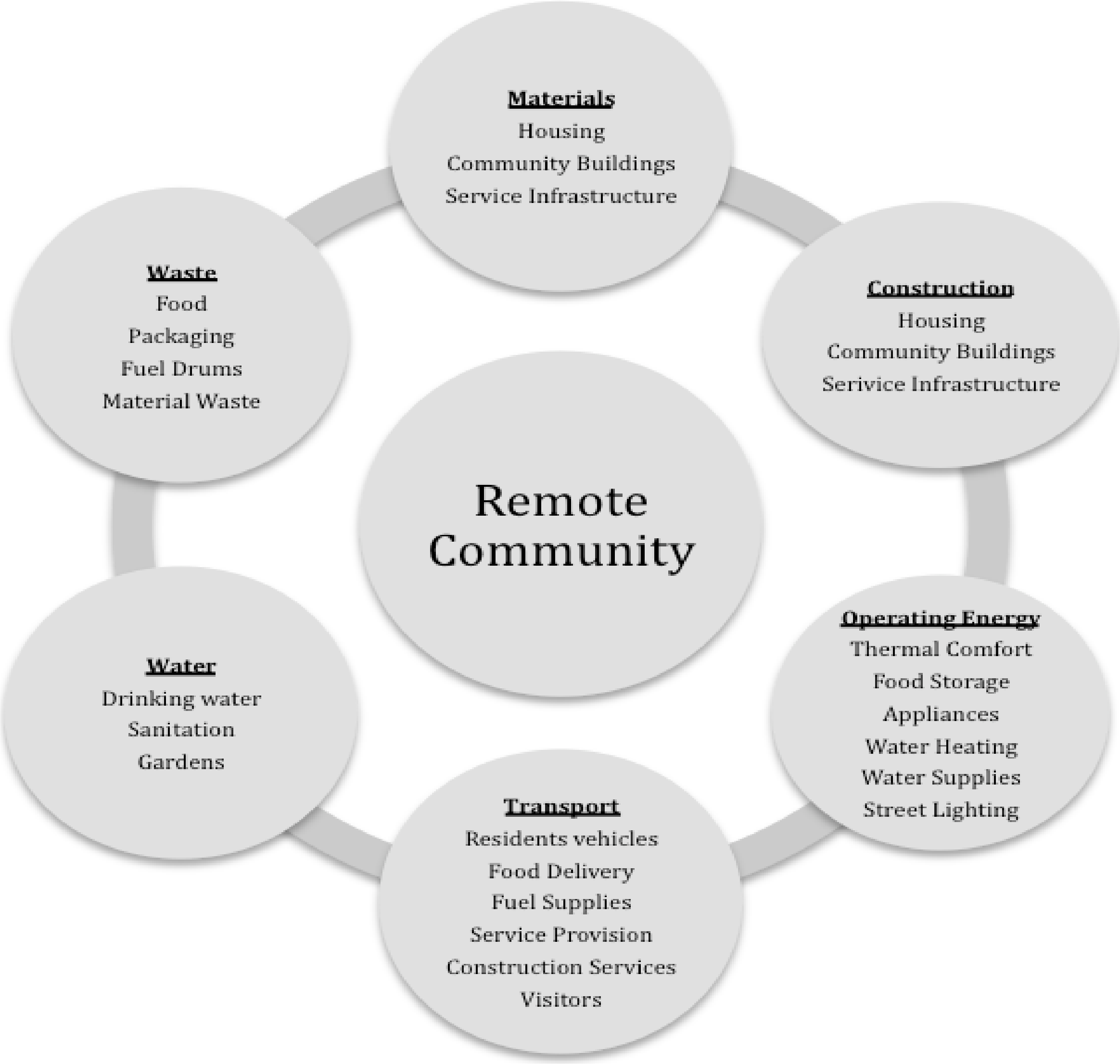

Figure 1 Carbon model with key applications of each element for both settlement types

2.4. Application to Mining Camps

Essentially a mine camp or village is a well defined organism and as such associated GHG emissions can be audited, monitored and controlled as a single entity. This research should, therefore, be able to provide a model for other types of remote community development where carbon reduction is an imperative.

The mining industry has a range of challenges to address in reducing its carbon emissions and providing a sustainable environment in its mine site camps and villages where they house their mining staff. Two known studies have been carried out where suggestions have been made for modifications to these camps and villages in order to reduce their carbon footprint [7, 8]. The majority of emissions in the referenced case studies come from diesel fired generation of electricity to operate camp services. No published audited figures exist. Mining operations are generally set up and budgeted for a specific life. This lifespan will determine the longevity of the accommodation to service it during three main phases, namely: establishment, operation and finally the decommissioning and rehabilitation phase. This research intends to apply the tools and metrics in order to optimise, from a sustainability and low-carbon standpoint, the form and function of mine site accommodation. This way the mining companies are more likely to minimise their costs and maximise their return by creating the most appropriate type of accommodation to suit the prevailing circumstances.

Social behaviour clearly has its influence on carbon emissions research indicates that a change in behaviour will directly result in a reduction in these emissions. However, the task has been shown to be a none-too simple one [9]. This research intends to show that by changing the behaviour of the mine site employee, be they engineer or kitchen hand, that there will be considerable flow on effect in other areas of their lives, thus taking the carbon reduction strategy beyond that specific to the mine site accommodation itself [10].

Anecdotal evidence indicates the profligate use of energy in mine site accommodation is well known in the industry – for example air conditioners being left on in unoccupied buildings during a rostered-off period. Monitoring and control of operational energy is therefore a significant area where improvements could be made to make the camps and villages more energy efficient. In order to develop advanced monitoring and control solutions a collaboration between Furtwangen University, the Digital Ecosystems Business Intelligence Institute (DEBII) of Curtin University and this research has been formed. The interface between the digital world of control and monitoring systems is well established but this research will focus on the connection between them and the process of sustainable practice and education in a manner which to date is otherwise unexplored.

Stationary energy to service camp operations is generally generated using diesel as a fuel with high carbon polluting results. This research will also investigate the practical introduction of renewable energy systems to replace such fossil fuel consumption. These will include photovoltaic, solar thermal, geothermal, wind, and wave power (coastal only), and the appropriateness and sustainability of these technologies. From the mining company point of view a cost-benefit analysis will also need to be attached to the investigations.

2.5. Application to Indigenous Communities

In 2006 the Indigenous population of Australia was estimated to be 517,000, which is 2.5% of the Australian population. Of these it is estimated that 24%, approximately 124,000, live in remote or very remote areas as classified by the Australian Standard Geographical Classification (ASGC) [11]. The communities in these areas range in size from small outstations to town-sized populations with various amenities [12].

While there is little published data on the carbon profiles of these communities, it is expected they are highly carbon intensive, despite their relatively low-income status. This is due to their general reliance on diesel-powered electricity generators, fossil-fuelled vehicles that need to travel vast distances and provision of public housing that is often inappropriate for the climate. They are also often dependent on external service providers and supply systems, all of which increase the transport requirements for goods and service delivery.

Energy use by households in these communities can vary widely from 3 kWh to over 40 kWh per day. This is due to a wide variation in the number of occupants per household, which is often high, and the appliances being used, particularly for air-conditioning and water heating. A community with 100 to 150 people would use between 500 to 750 litres of diesel per day to generate electricity, which emits approximately 1.3 to 2 tonnes of CO_2e per day.

It is also reported that Indigenous communities in the north of Australia are likely to be highly impacted by the effects of climate change [13]. While decarbonising mainly aims to mitigate the effects of climate change, some of the proposed strategies to be employed can provide the twin benefit of adaptation and therefore help negate some impacts.

There are certainly reasons to maintain remote communities as opposed to relocating the residents into urban areas. These include improved health outcomes, such as in the community of Utopia ([11], and opportunities for income generation through natural resource management and carbon offset services [14].

Given the carbon profile in communities is highly influenced by their dependency on external factors such as energy, housing, food and general service supplies and lack of internal resources it is worth investigating the effect of transitioning communities to a more self-sufficient 'sustainable livelihood' model to address carbon emissions and also provide a suite of other benefits.

The Sustainable Livelihoods Framework, provided in ***Figure 2*** below, has been used by international development agencies in attempts to address poverty in developing countries [15]. It also provides a framework within which to apply carbon management programs as livelihood strategies.

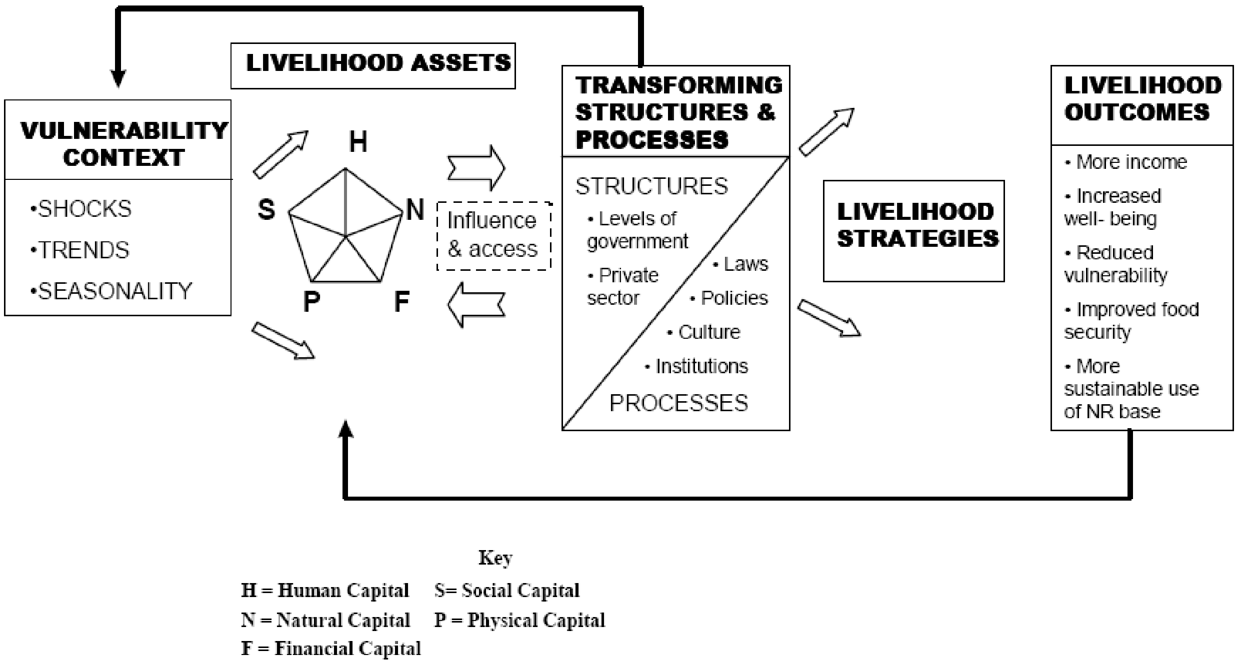

Figure 2 Sustainable Livelihoods Framework (source: Carney cited in [16])

By addressing the vulnerability factors and improving the five categories of assets (human, social, natural, physical and financial) a more sustainable community will develop. The connections to energy and carbon management are considerable. Firstly, using lifecycle analysis, the lifespan of a physical asset should be lengthened in order to maximise use of its embodied energy. The natural assets should be maintained to reduce energy use in relation to thermal comfort of buildings and food supplies and to generate carbon offsets, without upsetting the natural balance of other ecosystem services. Human and social assets are enhanced with skill development and network capability, which alleviate dependency on external goods and service provision, and therefore also transport needs.

3. Results

For both remote settlement types there are clearly links between the six elements in the model and their impacts on carbon emissions. While the general links and possible solutions have been identified, further investigation and analysis is required to understand the exact connections and extent of impact.

As the model has not yet been applied results will not be available until further investigation of the carbon profiles and interconnections between elements have been examined and quantified.

4. Discussion

The model requires verification in the form of energy and emission quantities for each element and the key integration points. This will be conducted using the life cycle analysis method discussed. Identification and quantification of the key contributors to carbon emissions can then be completed. Proposed strategies, including the Sustainable Livelihoods framework and the digital monitoring system, need further research with application in pilot studies at remote settlements, which is currently being arranged. The success of these strategies will also be evaluated using a comparative life cycle analysis. Successful implementation methods that are suited to varying regional circumstances will need to be identified. Finally an accreditation process that certifies and incentivises transition to low-carbon settlements will be investigated with research partners CUSP.

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Improving energy and material flows: a contribution to sustainability in megacities

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Abstract: As cities have become home for 50% of the world's population, urban systems have definitely caught public attention. The urban metabolism can be improved by transforming their linear behavior into a more circular one. This paper is based on a project initiated by the Division of Environmental Technology and Management at Linköping university, financed by Vinnova: *Megatech*. The aim is to study the megacities of Cairo and Mexico City in order to understand some of the problems they are facing. By improving their energy and material flows behavior, these megacities can benefit from the reduction of their dependence on fossil fuels and virgin materials; the protection of part of their social, economic and productive systems from external factors (e.g. political drawbacks, shortage/distribution problems, international prices); an increased effectiveness of their planning activities–as they would be based to a large extent on their own resources–and the reduction of their environmental burden. An *in situ* study will take place with the participation of local stakeholders. Information about environmental problems will be collected and potential solutions will be analyzed and suggested. A tentative model is presented, showing how the reinsertion of the outflows into the urban system could benefit these cities' overall environmental performance.

Keywords: *Flows analysis, Urban metabolism, Urban sustainability, Megacities.*

1. Introduction

Cities seem to be the future's structure for social and economic activities. Today, 50% of the world's population has moved into cities [1] and their uncontrolled growth has brought along problems and challenges. Some of these cities have reached once-unthinkable population levels and have been called 'megacities', after the Greek word 'mega' (μέγας – great).

These highly urbanized agglomerations concentrate people, materials, money, information and knowledge and continue to grow as more people are being attracted by the apparently endless possibilities of wealth and comfort that they offer. However, in a planet constrained by finite resources, unlimited growth is not possible [2]. Under today's circumstances, and especially given the technological and economical lock-in [3] that our societies are suffering from, most of these resources are facing short-term depletion. Nevertheless, from an industrial ecology perspective, urban agglomerations are not lacking resources–i.e. energy and materials; the problem is that important sources are being ignored or mismanaged.

Industrial ecology studies material and energy flows through different systems, with the intention of optimizing their cycles; considering them as an ecosystem, part of the biosphere surrounding it [4]. An analysis of these flows makes it possible to find options for their reinsertion into the social and economic system, while reducing the impact on the environment and helping creating more sustainable urban settlements, where these three aspects are considered. The aim is then to propose a model describing how a better behavior of these flows–i.e. their circularization and reinsertion–reduces the environmental burden and contributes to building more sustainable societies. A description of common urban environmental challenges in two selected megacities is made, followed by a depiction of how industrial ecology can address some of them. Last, some potential results regarding energy use and CO_2 emissions reduction are shown and discussed.

2. Methodology

The *Megatech* project is an explorative research of sustainable business and clean technology markets in the megacities of Cairo and Mexico City. By using a bottom-up approach, the project's team studies these cities' dynamics from a holistic perspective, considering the social, economical and environmental spheres and analyzing their urban metabolism, aiming at detecting potential niches for Swedish CleanTech offerings.

The selection of the cities of Cairo and Mexico City was based on three criterions. The first one–as the definition of *megacity* suggests–was the population size; i.e. more than ten million inhabitants. The second criterion was the access to information, due to concerns of sufficiency and reliability. For this, strategic partners were looked at in each town in areas of interest to the project's objectives. Last, the socio-economic conditions were important for the selection, as important business opportunities can result from them. Specifically, emerging markets were of interest for the project's team, i.e. developing countries.

A case-study methodology was selected as appropriate for the analysis and understanding of the issues intended to be addressed by the project. By consulting official reports and publicly accessible information from, e.g. governmental and supra-governmental organizations, municipalities, environmental and economic councils/agencies, independent studies and local newspapers, an initial description of these settlements was developed, depicting problems and challenges from a sustainability/environmental perspective. With this information in hand, an initial identification of stakeholders gave the team an insight of the groups of interest and the indications for a first set of interviews, in order to confirm the previously acquired information, and especially in order to have the possibility of understanding these concerns from the perspective of those directly involved and affected by them. The latter would help the team build the desired bottom-up approach.

Once this information was collected and confirmed, an industrial ecology approach was used in order to analyze possible solutions for the circularization of waste flows. A tentative analysis was made by identifying sources, directions and disposal activities. Two types of results were obtained: the identification of specific problems in each town and the discussion of the benefits that could be obtained through a flow analysis and the application of the proper technologies and possible barriers and drivers for their implementation.

3. Current situation

Uncontrolled growth, both in the residential and in the industrial sector, is a big problem for megacities in developing countries. The available technical systems are not able to cope with this expansion and the increased demand of energy and waste treatment technologies are common challenges faced by their citizens and governments. More specifically, the problems detected in Cairo and Mexico City are as follows:

Cairo

Cairo has always been an important cultural, economic and commercial center of the Arab world. Such an important role has meant several challenges, embedded in the need of developing and giving its citizens a better quality of life, at the same time that it struggles to survive under the demands of a growth-addicted, competitive economic system.

The most representative environmental problems detected so far by the team are:

- *Water supply/quality.* The Egyptian culture flourished around the waters of the great Nile. However, a growing population and the political and economic demands of modern times have posed a lot of stress on this resource. Several countries share its waters and have their own development programs, which in one way or another affect Cairo–and Egypt in general, being located at the very end of its trajectory. Moreover, the high pressure on irrigation water for the production of wheat–the biggest source of protein in poor countries, thus very sensitive social-wise–is a big problem when the demand cannot be met by local resources and international prices skyrocket (see e.g. [5]). Also, wastewater treatment is not very effective, especially when more and more slum dwellers increase the burden due to their illegal and unplanned nature (see e.g. [6]).

- *Urban waste.* Solid waste is a huge problem in Cairo. The collection of waste in some areas has been outsourced to e.g. Spanish or Italian companies, who have had several problems [7, 8, 9]. Moreover, the traditional *Zabbaleen* people's activities–who make a living out of recycling or from recoverable items and by feeding their animals with the organic fraction–have been affected by the recent swine-flu paranoia, resulting in an overload of unpicked organic material on the streets [7, 10]. Despite of several efforts by the city's administration, 19 500 tons of waste produced everyday in Greater Cairo represent a huge challenge [11].

- *Traffic.* Uncontrolled traffic and air pollution are a big problem in Cairo. An average speed as low as 10 k m/h [12] reflects on higher fuel consumption and reduced productivity. In addition, industrial pollution and the natural characteristics of the region–i.e. sand blowing from the desert–add to the problems of the air's quality and public health.

- *Energy.* Fossil fuel dependency is not only a problem for the transportation and production sectors, as many families depend on them for cooking and heating purposes. It is mainly butane being distributed to households in pipes, highly subsidized by the government [13]. Shortages of this gas have caused discontent among the poorest sectors, unable to pay for higher prices [14].

- *Population.* As stated above, urban population has grown uncontrolled, especially during the last century. The last census (2006) counted around 13.5 million living in Greater Cairo [15]. Such an amount poses an enormous pressure on resources, food, housing and infrastructure in general.

<u>*Mexico City*</u>

The ancient city of *Tenochtitlán* was already an important place back in the 15th century. Today, this city lies hidden under the colossal Mexico City, which under an undoubtedly changed context, struggles to maintain its citizens' quality of life.

Today, Mexico City must face the following environmental challenges:

- *Water supply.* The level of overexploitation is estimated to be 35% [16], making the replenishment rate to be lower than needed [17] and requiring solutions that demand enormous amounts of energy, like pumping water from a 1 100-meters lower region, located 127 km away from the city [18]. In addition, the mentioned extraction has caused the underground layers to collapse, sinking infrastructure up to 40 cm in some areas [16]. Finally, several sources of pollution, both natural and artificial, harm the liquid's quality [16], causing the citizens' distrust on the quality/quantity of the water they receive [20].

- *Air*. Road transport contributes to 50% of the emissions that cause air pollution. Industry and landfills 24% and 14% respectively, followed by combustion practices in residential areas with 10% [16]. In addition, the geographic characteristics of the Valley hinder the natural dilution of these emissions. Although Mexico City has a low average PM_{10} value–around 52 µ g/m^3 [19]–compared to Cairo (roughly 150 µg/m^3 [21]) or Shanghai (around 110 µg/m^3 [21]), levels have reached figures as high as 164 µg/m^3 in some areas in recent years [19].

- *Mobility.* Around 4.5 million vehicles were registered in the city by 2010 [22], with a big share of privately owned cars. In the metropolitan area, there are 397 cars/1000 people, compared to, e.g. 38 in Shanghai [23]. Speed figures are as low as 3 km/h in some places during peak hours, with an average of 21 km/h [24]. Around 20 million work-hours/day are estimated to be lost in traffic or commuting [25], due to an average daily commute time of 2.5 hours–compared to e.g. 1.4 in London [23].

- *Solid waste.* An average of 12 500 tons/day are generated in the Federal District only [16]. The landfill used has already exceeded its capacity but has not been closed due to the lack of a good alternative. Although the administration has several campaigns–e.g. waste oil collection and organic waste-sorting/handling–activities like composting or recycling are still relatively small [26].

- *Energy.* As most of the cities around the globe, Mexico City suffers from fossil fuel dependency. Mexico was the 7th oil producer in the world in 2008 [27] and petrol is cheaper than mineral water [23].

- *Population.* The Metropolitan Area of Mexico City is one of the most populated urban areas in the world, with an estimated 19.9 million inhabitants in 2009 [28], 60% of them living in illegal and informal housing [23], which means gigantic challenges for public services like drinking water, sewage and electricity.

3.1. Bending the arrows: improving the city's metabolism and finding new energy sources.

Industrial ecology looks at the conversion of linear flows into circular flows, by studying both energy and materials in a system. Urban flows are of special interest here, given the important weight that cities have on the overall environmental crisis. Although the study has not reached a mature stage yet where specific figures are available, some insights (as describe above) can help building an initial model of what is happening and how a better flows' behavior can contribute to the goal of reaching more sustainable and independent societies.

Cities are very dependent on e xternal resources for their everyday's functioning and are normally net consumers–energy and material-wise, meaning that they have a passive role in the whole material and energetic cycle (as shown in Fig. 1).

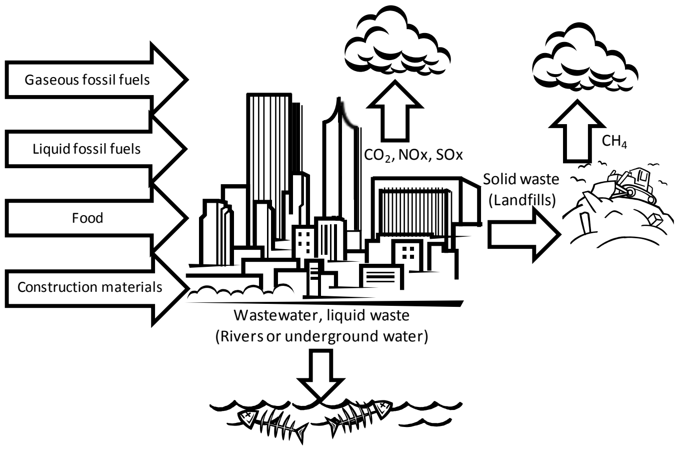

Fig. 1. All urban flows are linear and end up in natural sinks (i.e. water, air and soil).

However, environmental technology and sustainable practices have found innovative and effective solutions for most of these problems, “bending the arrows” and turning cities into more active actors, whilst reducing their environmental burden. Some examples of these solutions are:

- Urban gardening: vegetables production in green areas, roofs and urban greenhouses.
- Biogas from sewage sludge and organic waste: besides cleaning wastewater, reducing sludge volume and producing energy in the form of biogas are additional benefits. An organic fertilizer is a by-product, useful for both urban and rural agriculture.
- Waste incineration: with the proper technology, waste can be used for electrical and thermal energy production, reducing the need of landfilling and the volume of waste as much as 98%. Ashes can be used as a construction material.
- Methane capture in landfills: Landfills are a big source of methane, useful as a fuel.
- Biodiesel from used cooking oil: The collection and further processing of used oils helps reducing the pollution of water sources and the city’s dependence on fossil fuels.

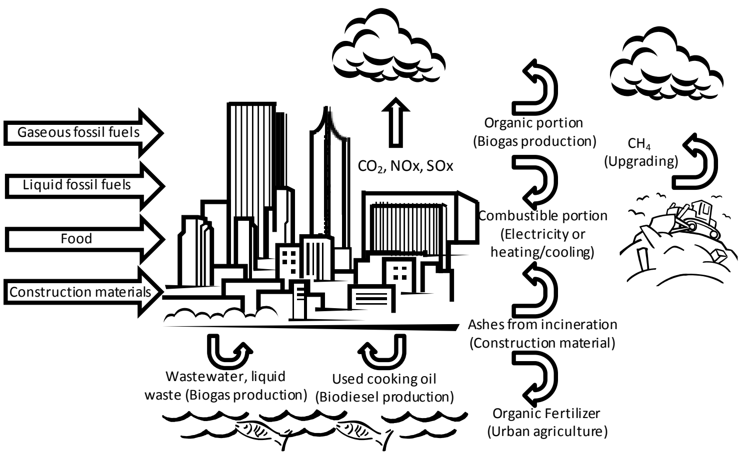

Fig. 2. By closing loops, cities improve their environmental performance.

As Fig. 2 intends to illustrate, flows entering the urban areas can be reduced, diminishing to some extent the city’s necessity of external sources and protecting it against i.e. international prices, political drawbacks or unhealthy dependences. At the same time, the surrounding ecosystem is harmed to a lesser degree, manifested in the improvement of the air and water’s quality and the remediation of soil.

4. Potential renewable sources and CO_2 emissions reductions

An indication of how a circularization of the urban flows could contribute partially to the solution of the energy and environmental crisis can be shown in the Mexico City's case, whilst data from Cairo is still to be collected.

A back-of-the-envelope estimation can be done regarding the potential production of biogas in the federal district, given the biological oxygen demand (BOD) content of its wastewater. Out of 118 m^3/s that were treated in 2008 in Mexico, 3.5 m^3/s (3%) are treated in the federal district [29]. Assuming that the BOD content is equally distributed all over the country (very likely to be higher given the industrial and economical activities and the population in the area), 270 300 tons BOD would be generated every year both by households and industry–out of 9 million nation-wide [29]. Each ton BOD can potentially generate 500 normal cubic meters (Nm^3) of methane by anaerobic digestion [30], meaning that around 135 MNm^3 could be produced annually only from wastewater, with an energy content of roughly 1.3 TWh/year. This is equal to the amount of energy needed by the Cutzamala system, which provides 18% of the potable water to the Valley of Mexico [29] and consumed 0.56% of the electricity produced in Mexico in 2008 [29], contributing roughly 630 000 tons CO_2 [31]. An important challenge arises considering that only 13% of Mexico City's wastewater is treated [32].

Other important sources of raw materials could back up these activities. For instance, 700 tons of organic waste are generated every day at *Central de Abastos* (wholesale market) [33], with a potential production of around 20 MNm^3 of methane/year, an energy content of 200 GWh [30] and an estimated reduction of 170 500 tons CO_2/year [33], not to mention the availability of a high-quality organic fertilizer. On the other hand, the government has plans to extract and take advantage of the methane emitted by the *Bordo Poniente* landfill, with a reduction on CO_2 emissions of roughly 1.4 million tons [33].

5. Discussion

There are technological solutions available for several of the problems that megacities suffer from, including the ones described above. However, the specific context plays a very important role if the actual feasibility of implementation was to be discussed. Social, economic and environmental factors are very variable depending on cultural, geographic and specific current conditions of the city being analyzed, reflected on barriers and drivers, enablers and challenges. For example, the importance of the informal economy both in Cairo and Mexico can become a challenge, especially when approaching the problem of waste management. Hundreds of people rely on the picking of sellable material from the collected waste both in official and parallel markets (e.g. *Zabbaleen* in Cairo and *Pepenadores* in Mexico City). Some powerful unions have been created, influencing greatly political decisions. Any attempt to modify the current situation would affect a lot of people if they are not taken into account in an integral plan that considers actions in order to keep–at least–the current income level of those doing the job and confront in an effective way the problem of illegal activities in the sector.

Another big barrier faced regarding waste management is sorting. In Mexico, for example, 43% [16] of the waste landfilled is organic and the situation in Cairo has gotten worse since pigs are not there anymore to take care of this fraction. Although there are some plans for the proper treatment of this type of waste, no significant activities are taking place currently. Regarding fuels, for example, the low prices of fossil fuels–due to subsidies–and the widely spread use of private transportation, creates a lot of economic disincentives for the production of biofuels from wastewater, used oil or organic waste. The high subsidies that governments pose on these energy carriers and the important position that oil has on their respective country's economy put concerns on a very low level in the ladder of priorities.

Last, the socio-economic situation of developing countries represents a very big barrier for a lot of these technologies. Some of them require huge investments–unreachable for most of them–and long pay-back periods, thus long-term commitments: sometimes too long to be considered.

Nevertheless, governments are conscious of their role in creating a better environment for their citizens and the generations to come. They are aware of the huge opportunities that all these challenges represent and how much international interest they attract. Programs encouraging the use of solar power for heating purposes, landfill gas capture and use and energy efficiency measures in Mexico and the construction of concentrated solar thermal power plants and wind farms in Egypt are a proof of their commitment.

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Renewable energy mapping in Maharashtra, India using GIS

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Abstract: Increasing negative effects of fossil fuel in addition to limited stock have forced many countries to switch to environmental friendly alternatives that are renewable and can sustain the increasing energy demand. In order to tap the potential of various renewable energy sources, there is a need to assess the availability of the resources spatially. Mapping potential sites for tapping renewable energy is the focus of this study. The study employs the Geographical Information System (GIS) to map various renewable energy sources. A case study of Indian state Maharashtra has been taken. Open source software, Quantum GIS (QGIS) is used to analyze the variability of renewable energy considering the spatial aspect. Maps of installed capacity have been prepared. Solar insolation data and wind speed data available for few sites in the state are mapped and then interpolated for the entire state. A macro survey is done to estimate the renewable energy potential available in the state. Spatial interpolation has been done for micro analysis to define the usefulness of such a system.

Keywords: *renewable energy, geographical information system, spatial mapping*

1. Introduction

Energy is one of the most important inputs for economic growth and human development. The sustainability of future energy systems is critical for sustainable development. Renewable energy is a key element for any sustainable solution. One of the first steps for the exploitation of any energy source is its estimation and mapping to identify the most suitable areas in terms of energy potential. To understand the current trend of the renewable energy, it is important to analyse the spatial variation of resources and their deployment.

A Geographical Information System (GIS) is a system that can handle and process location and attribute data of spatial features. Nguyen and Pearce [1] have used an open domain approach to compute insolation including temporal and spatial variation of albedo and solar photovoltaic yield. Ramachandra and Shruthi [2] have estimated the wind energy potential of Karnataka using GIS technology. Celik [3] has estimated monthly wind energy production using Weibull representative wind data for a total of 96 months from five different locations in the world (Cardiff, Canberra, Davos, Athens, Ankara). Sen [4] has used CSV (Cumulative Semi-Variogram) approach to predict the solar irradiation at any point from a given set of known data points. This paper provides a framework for analysing the status of renewable energy situation using GIS and illustrates this for Maharashtra state of India.

Maharashtra is situated in western part of India and covers the entire Deccan region. (Area 1,19,000 square miles, population 97 million as per 2001 census [5]) There are 35 districts in Maharashtra [5]. A district is an administrative division of an Indian state or territory. Maharashtra is the largest power generating state in India with an installed capacity of 22,435 MW [6]. The total renewable energy installed capacity in the State till March 2010 was 2,601 MW [7]. Open domain Quantum GIS (QGIS) is used to represent the spatial data.

2. Methodology

The general methodology for analysis of renewable energy framework using GIS approach is summarised in Fig. 1. Distribution of renewable resources; wind and solar, in terms of wind power density and hourly insolation values respectively is spatially interpolated for the state and maps are created for the same. Current installed sites of various renewable resources, viz.

wind power generation, bagasse co-generation and small hydro power plants are identified and represented on the map. Each site is linked to its corresponding database of location and installed capacity.

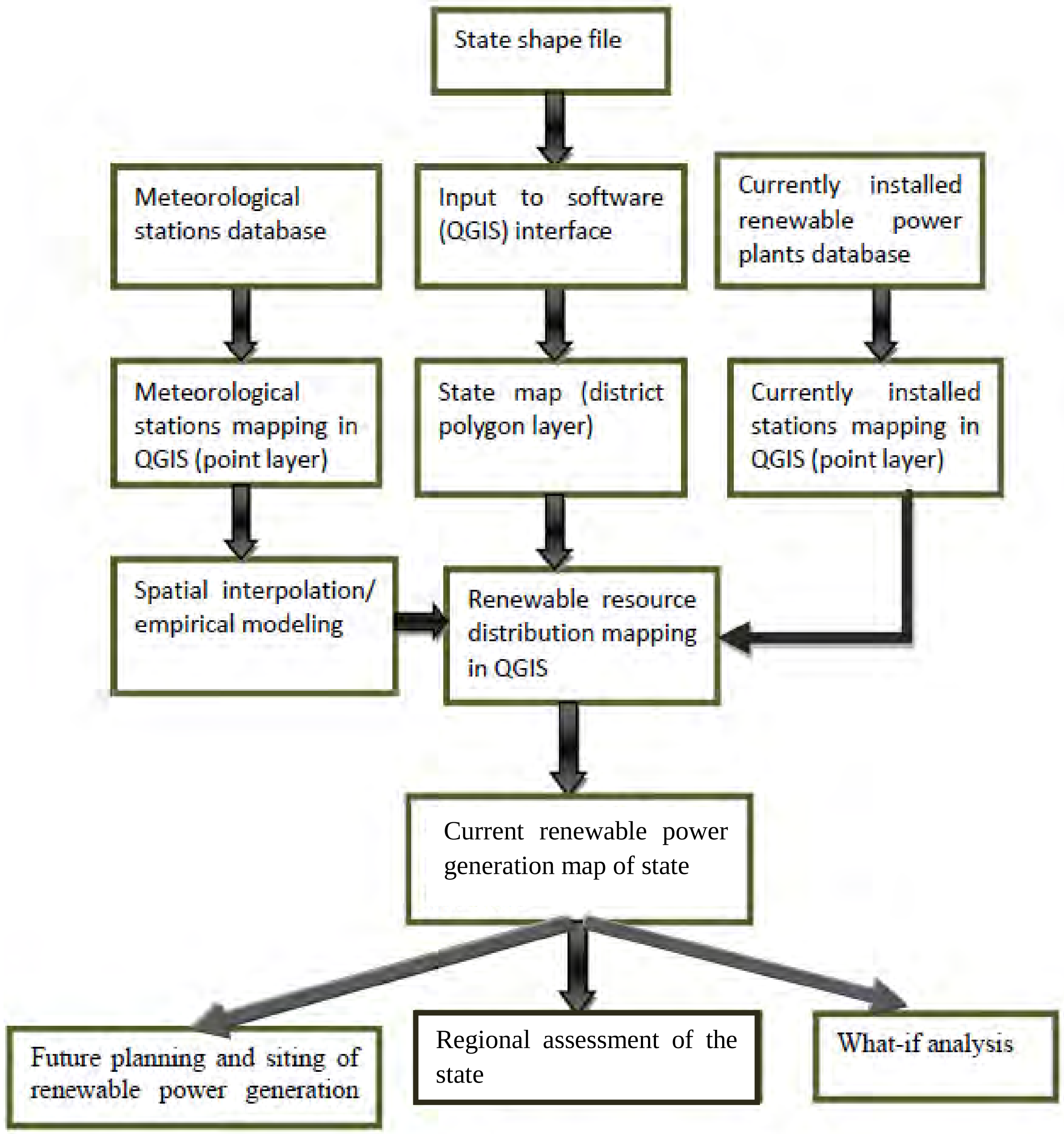

Fig. 1. General methodology to develop renewable energy framework

District shape file for Maharashtra state is taken as the first input to QGIS interface. This shape file may be created in C++ environment or may be directly downloaded. The shape file contains location attributes and area of these 35 districts. Database is obtained for currently installed renewable power generation sites, with their rated power output (MW) and location attributes. The meteorological stations for wind and solar are identified and the corresponding database of instantaneous values of parameters like wind speed, wind power density, Weibull parameters, etc. and global solar radiation are obtained. A summary of database for renewable power generation analysis in the state is organized in Table 1. Various input parameters used to create maps in reference to renewable resources and shape files are summarized in Table 2.

Table 1. Summary of database of renewable power generation in Maharashtra

Renewable energy source	Number of meteorological stations	Estimated potential (MW)	Installed capacity (GW) (2009-10+)	Number of installed power generation sites
Wind	7	4.58	2.01	31
Solar	3	-	-	-
Bagasse co-generation	-	1.25	0.35	39
Small hydro power	-	7.5	0.2	28

Table 2. Summary of input parameters used in QGIS interface

Input parameter	Information available
District shape file	35 districts; location attributes; area
Wind meteorological stations	7 stations, location attributes; hourly wind speed, hourly wind power density; Weibull parameters
Solar meteorological stations	3 stations; location attributes; hourly global, diffuse and direct solar irradiation for each month
Wind installed sites	31 sites; location attributes; installed capacity
Bagasse co generation installed sites	39 sites; location attributes; installed capacity; location of sugar factories
Small hydro power installed sites	28 sites; location attributes; installed capacity

Monthly average values of wind speed, wind power density and solar insolation for the unknown locations are predicted using interpolation techniques and empirical relations from the set of known values of meteorological stations. Predicted values are used to create raster maps in QGIS showing the distribution of wind power density and solar intensity over the state.

Currently installed renewable energy sites are mapped on the spatial layer of Maharashtra state to create point layer for each site in QGIS framework. Each point representing a renewable energy site is linked to its corresponding database of geographical coordinates and installed MW capacity. The Point layer of current installed renewable power generation sites is integrated with the resource distribution raster maps to get the current renewable scenario map for the state.

Usability of the system is defined in terms of future planning and siting of renewable power generation, micro modeling through regional assessment and district wise analysis of the state and what-if analysis to explore some major issues involved in integrating renewable energy framework with conventional electricity transmission network.

3. Renewable energy resource mapping

Distribution of wind power density and solar insolation is estimated for the state and represented as raster maps. Spatial interpolation technique, Kriging interpolation is used for predicting wind power density for unknown locations while Inverse Distance Weigthing (IDW) interpolation is used for predicting hourly solar insolation values for unknown locations.

3.1. Spatial interpolation for wind

Wind energy is the most explored renewable energy in Maharashtra. Out of an estimated potential of 4584 MW, almost 1990 MW has been achieved with an estimated capacity factor of 14% [7]. Seven meteorological stations are identified where actual measurement of various wind parameters (hourly wind velocity, Weibull parameters and average wind power density) are done. These stations are Lonavala, Malwan, Vijaydurga, Panchgani, Deogad, Vengurla and Chalkewadi. The database for the seven stations is obtained from the wind energy resource survey in India by Anna and Mani [8]. There are currently 31 wind power generation sites with their known installed capacities.

Map showing the distribution of wind power density over the state is created to aid in the selection of suitable region for wind turbine installation. Raster map showing the distribution of wind power density over the state is shown in Fig. 2. Current wind power generation sites are mapped to estimate the capacity target. The seven meteorological stations are also mapped and each station is linked to its corresponding data base of geographical coordinates and monthly instantaneous wind speed values. Quantum GIS (QGIS) is used to integrate the conventional database of the seven meteorological stations and 31 wind power generation sites with spatial features to get a complete pictorial representation of current wind power generation scenario.

Monthly average wind power density is predicted for all the districts in the state using the sampled values of seven meteorological stations. The seven stations are represented by and 31 installed sites are represented by in Fig. 2. Raster map of wind power density distribution are created using these predicted values. Kriging interpolation is used for predicting wind power density values.

This is done by generating the experimental semi-variogram of the data set and choosing a mathematical model which best approximates the shape of the function from sample Cumulative Semi Variance (CSV) values [9]. Weights are obtained by converting CSV values into dimensionless values and subtracting from the maximum value, i.e. 1. This appears as a non-increasing function of dimensionless distance and is known as Standard Weighing Function (SWF)[9]

Dimensionless distance of each un-sampled location from each of the seven sampled locations is estimated using the distance tool in QGIS. The distance values are based upon the centroid values of latitude and longitude of locations. For each dimensionless distance; the value of weighing function is estimated from the plot of SWF [9]. Weighted average of the corresponding value of wind power density, weights being the estimated values of weighing function, gives the predicted value of wind power density for unknown locations.

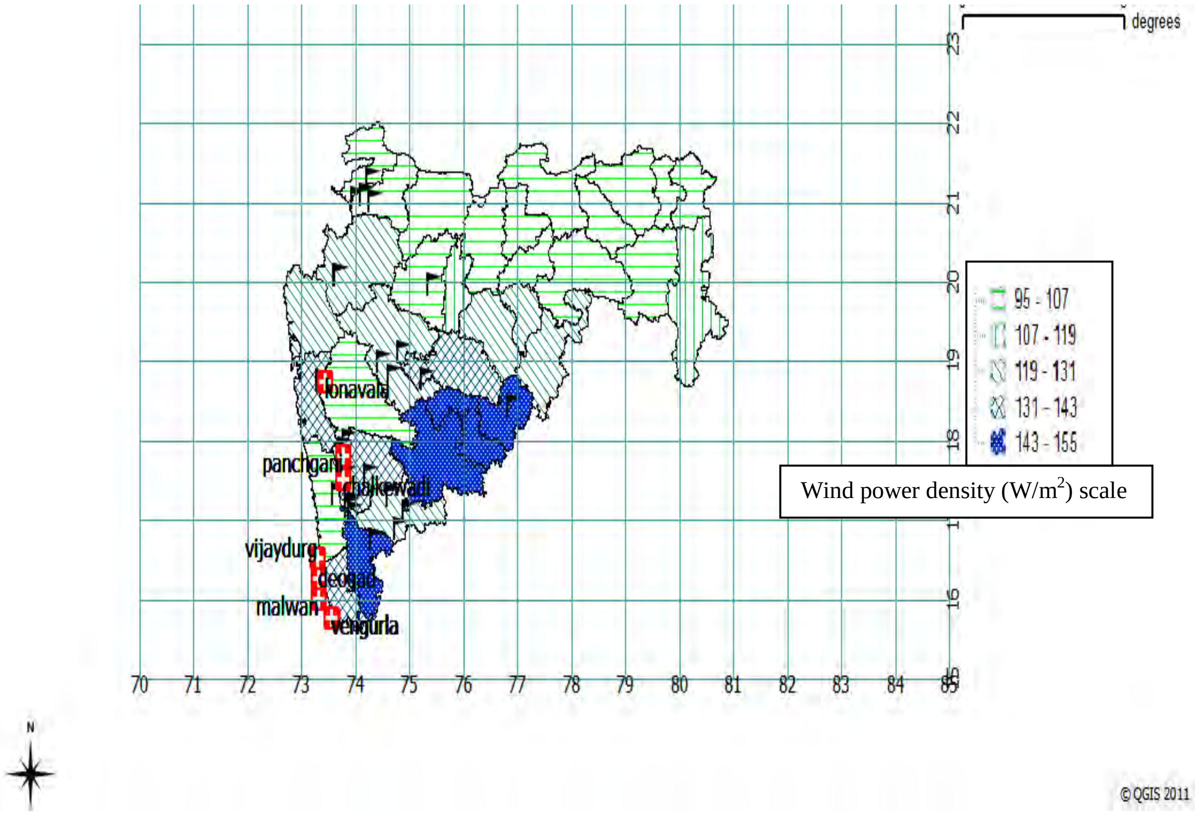

Fig. 2. Wind power density distribution over Maharashtra state

3.2. Spatial interpolation for solar resource mapping

For solar energy, three meteorological stations are identified, viz. Pune, Nagpur and Mumbai. Hourly values of global and diffuse solar radiation for the three stations are taken from solar energy resource survey in India by Anna and Mani [8]. Inverse Distance Weighting (IDW) interpolation [10] technique is used to predict hourly insolation values for un-sampled locations.

In IDW interpolation, weights are proportional to the inverse distance value between un-sampled location and sampled location. This proportionality varies with the power to which the distance is raised and is known as distance coefficient. Distance coefficient of two is taken here.

Raster map showing the distribution of solar energy resource is created using the IDW interpolation plugin in QGIS platform. Hourly global solar radiation estimated for the state are in the order of magnitude of 2000 kWh/m^{2}year which signifies a relatively low value. The variation of solar intensity over the state is also low. Variation of global solar insolation over a year for Mumbai station is shown in Fig. 3. The raster map showing the distribution of solar energy resource is not shown here although the three meteorological stations are represented by ⊞ in Fig. 4.

Since the IDW interpolation technique is based on the distance value between the un-sampled location and the sampled location, the uncertainty in the predicted value increases with the increasing distance value. The three sampled locations for solar energy are at a considerable distance from each other. Therefore using local correlations model for estimating the hourly insolation values would give better accuracy.

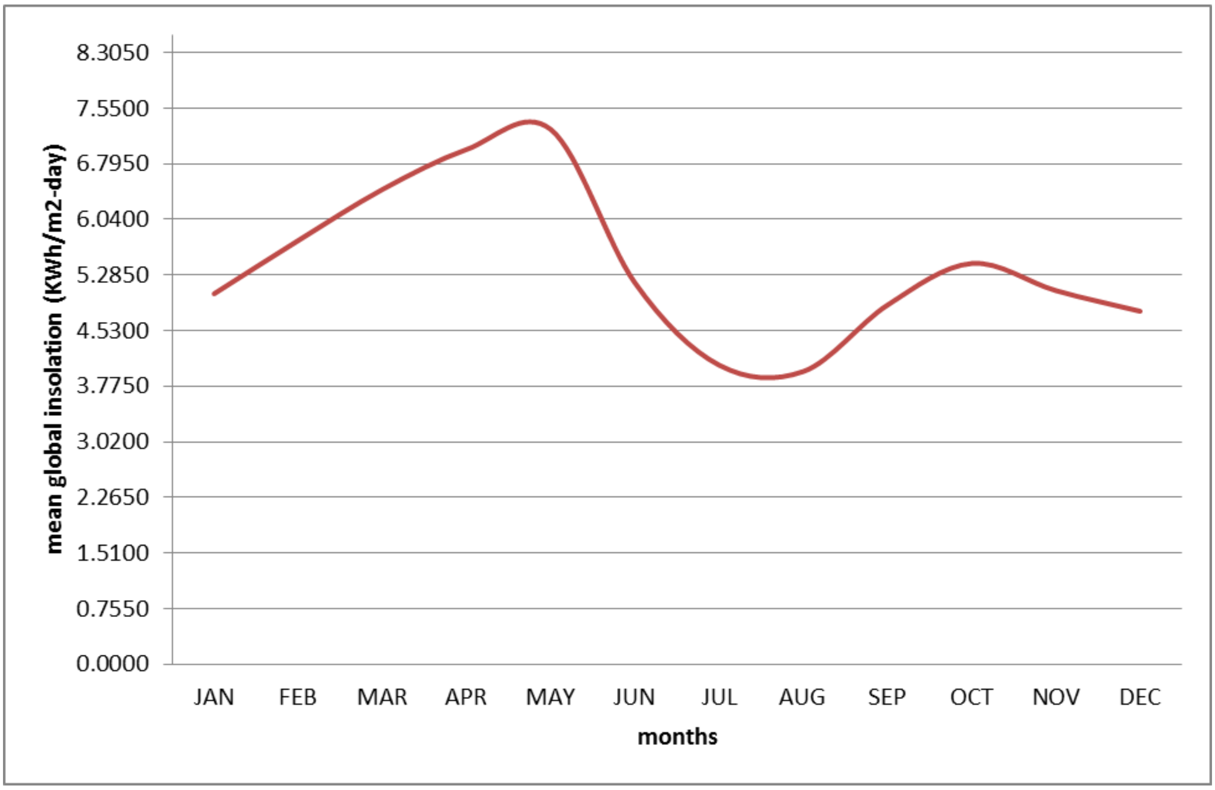

Fig. 3 Variation of global solar insolation for Mumbai

4. Renewable installed capacity mapping

In the field of green energy, the major renewable energy sources in Maharashtra are wind energy, small hydro power plants and bagasse co-generation plants with a small contribution of waste to energy power plants and biomass [6]. 31 sites of wind power generation, 39 sites of bagasse co-generation plants and 28 sites of small hydro power plants are identified and represented spatially [7]. A vector map showing the current installed sites of renewable power generation in Maharashtra is shown in Fig. 4.

Each station mapped is linked to its corresponding data base of geographical coordinates and monthly instantaneous parametric values. A complete database of hourly wind speed data of each month for seven wind meteorological stations (Lonavala, Malwan, Vijaydurga, Panchgani, Deogad, Vengurla and Chalkewadi) is linked with the corresponding location. Similarly database of hourly global solar radiation data of each month for three solar energy meteorological stations (Mumbai, Pune and Nagpur) is linked with the corresponding location. Maps are created representing the spatial data of current installed sites of wind power, bagasse co-generation and small hydro power plants (Fig. 4). Each site is linked with its corresponding database. Every district in the state is also linked to the database of district name, location attributes, i.e. longitude and latitude of the location and predicted values of monthly average wind power density, and monthly average solar insolation. One such database for Satara district in Maharashtra state is shown in Fig. 4.

Monthly average wind power density of seven wind sampled locations and monthly average solar insolation data of three solar sampled locations is used to predicts wind power density distribution and solar intensity distribution over the state respectively.

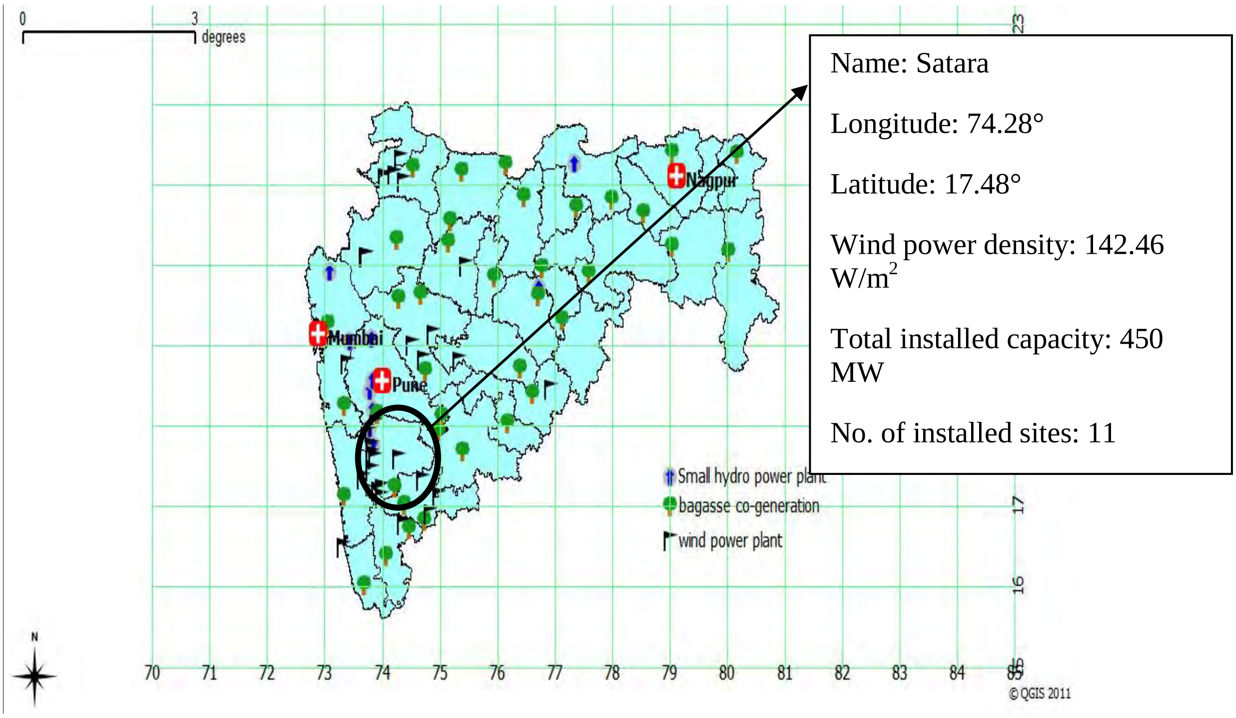

Fig. 4 Current status of major renewable power generation sources in Maharashtra and sample database for Satara district

The GIS approach used is helpful in estimating the renewable energy potential available in the state. Such a system could be useful in future planning and siting of wind power and solar power generation. It helps in analysing the potential areas where wind and solar energy resources can be used exhaustively. Regional assessment of state is also possible as can be seen from Fig. 4 that central region of the state is the major site of wind turbines installation and also the region of high wind capacity (Fig. 2). Satara district in the central region of the state is the site of maximum wind turbine installation with total installed capacity of approximately 450 MW. Eastern part of central region also has high wind potential and hence can be explored more. Similarly southern part of the state was found to be the region of high solar intensity. Bagasse co-generation power plants are distributed all over the state which is in accordance with the distribution of sugar factories in the state [11].

5. Conclusion

A framework is developed for mapping renewable energy resources using an open domain GIS (QGIS) and linking this with the databases for individual stations. Using this framework, it is possible to determine average wind and solar energy densities in selected regions. This is illustrated for Maharashtra state in India.

The QGIS platform is also used to represent the spatial distribution of installed capacities of different renewables. This permits determination of installed capacities for selected regions and renewable energy generation based on estimated capacity factors using the renewable energy resource data for the region.

The framework developed can be used to assist siting decisions. For any site selected, it is possible to determine through Kriging interpolation or empirical correlations the availability (and monthly variation) of wind and solar resource. This can enable determination of the annual capacity factor and the cost-effectiveness of new installed capacities.

Since the method is simple it will be useful, in general, for engineers, architects and solar system designers. The system is also helpful in what-if analysis: if certain percentage of electricity to be achieved through renewable only, is fixed, then what would it imply in terms of capacity of different renewable required to be installed, hybrid scenario of renewable power system, impact on conventional power system, operational and economic implications and capacity savings achieved with penetration of renewable power in the grid.

QGIS being open domain software, the framework can be extended to other states and countries as well and hence can be used extensively for renewable power generation siting and planning for any region.

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Project management and institutional complexity in domestic housing refurbishment with innovative energy solutions. A case study analysis.

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Abstract: Applying innovative energy solutions (IES) in dense residential areas in the Netherlands is a challenge. This paper presents a typology that supports the analysis and understanding of policy implementation processes to encourage the adoption of innovative energy solutions in urban residential areas. The typology uses theoretical concepts from the social sciences, more specifically the disciplines of public administration and policy studies. The two main hypotheses in the paper are that: (a) a high degree of process management will lead to an increasing likelihood that such a policy will be successful implemented, whereas: (b) a high degree of institutionalized interest from other policy areas – especially urban renewal - will lead to failure to implement policy strategies aimed at the adoption of innovative energy solutions. The hypotheses are empirically tested by presenting four case studies in which fitting innovative energy solutions in domestic housing was on the residential site refurbishment project agenda. The paper adds further insights in the fields of environmental energy policy implementation, sustainable cities and energy transition.

Keywords: *Environmental energy policy implementation, Urban renewal, Sustainable cities, Housing, Case studies.*

1. Introduction

Larger energy efficiency can nowadays be achieved in existing dwellings, thanks to longer equipment lifecycles, slow replacement rates, and emerging technical innovations. Opportunities for large-scale energy conservation can thus now be found in neighbourhood revitalization projects [1]. These projects aim at improving the social and physical structure of post-War housing estates in which the houses and their environments are characterized by poor-quality, obsolete physical construction. An additional characteristic is that the poor-quality buildings are accompanied by a poor social structure, as indicated by high unemployment, above-average crime rates and a large proportion of ageing residents. To cope with those problems, neighbourhood revitalization projects are meant to improve both social and physical (construction) structures.

A national government (climate) policy that seeks to link into existing neighbourhood revitalization projects, offers advantages. Such sites contain a large number of dwellings owned by central actors (housing associations) and renovating them will be a major operation in any case, so there will be a low threshold for the house owners to adopt energy conservation measures. Local governments encourage the setting of ambitious goals as a stepping stone to realize high energy efficiency goals [1]. Improving energy efficiency proves to be a difficult task, though. Due to the absence of legal governmental instruments there is a need to rely on communicative and economic policy instruments to convince house owners and stakeholders. Moreover, only ‘soft instruments’ are used, such as information campaigns, covenants and subsidy schemes [2]. This means that governments are dependent on the willingness of their target groups. Although the description applied to the Dutch situation, it is similar to those encountered in other Western European countries [3].

Local governments are able to exercise influence and encourage the uptake of energy conservation appliances by making trade-offs with housing associations, with a strategic use of urban renewal subsidies and legal permits. However, the local authorities remain firmly dependent on the willingness of housing associations and other property owners to cooperate. Lengthy and complex decision-making is unavoidable when a large-scale neighbourhood or building block renovation plan is being scheduled. In short, many institutional barriers exist that prevent the large-scale adoption of technical appliances to stimulate energy efficiency in existing housing [2].

The analytical focus in this paper is on the adoption of energy innovations in projects in which family dwellings are refurbished. The central question of the paper is how to understand and overcome the difficulties that adoption of energy innovations encounters in neighbourhood revitalization projects in urban residential areas. A typology based on theoretical insights derives from network governance and institutional complexity is introduced to support further comprehension. The typology is designed to improve analysis of complex contexts in which energy innovations - especially renewable energy systems - are adopted in highly institutionalized contexts, such as large-scale refurbishment projects in post-War urban residential areas.

2. Theoretical framework

Here we discuss the need to design a new typology to better understand the adoption of energy systems in a highly institutionalized context. The theoretical literature on environmental policy integration is presented as well as governance mechanisms to deal with complexity in similar contexts, drawn from the literature in the disciplines of public administration and policy studies of the management of complex networks, the aim being to achieve collective policy objectives in multi-stakeholder settings. The section ends with the introduction of a typology that covers two dimensions: (1) institutional complexity (as a lack of policy integration) and (2) project management of complex situations.

2.1. Institutional complexity

Environmental policies and energy efficiency goals are not prioritized in major urban settings. Moreover, social and economic aspects of the living environment and the climate for attracting business enterprises are often considered more important. Furthermore, environmental energy objectives may not be fully integrated or coordinated with other policy domains' objectives which also need to be fulfilled in such projects. This is no wonder since problems related to climate change – an environmental problem "at large" [4] – are not limited to a single sector or policy domain and hence are not coordinated optimally. This calls for environmental policy integration [5] - balancing the interests, concerns and priorities of the so-called three pillars: social, economic and environmental dimensions [6] - or arenas in which policy sectors are not competing for attention on the agenda, but which rather converge [7]. In many domains this is not yet the case [5, 8], such as revitalization of post-War neighbourhoods, a domain subject to urban renewal policy. These neighbourhoods are characterized by factors that hamper effective decision-making, such as distributed ownership rights, high 'social infrastructure', and hence complex regulations. For instance, regulation which requires tenants' approval to the project plans in large scale refurbishment projects. To deal with these complex issues many local revitalization projects receive earmarked financial support from government. In turn, local stakeholders are requested to ensure that the project meets urban renewal performance targets. Energy efficiency is no longer considered a significant target in urban renewal practice, at least not in the Netherlands.

2.2. Project management

Realizing the installation of innovative energy systems in local neighbourhood revitalization projects meets complexity in decision-making as multiple actors are involved who have interests and are mutual dependent. Actor-networks dominate negotiations and bargain about how to meet public goals. From a governmental perspective 'steering' towards the achievement of public goals, such as reductions in greenhouse gas emissions, then becomes a difficult task. In this regard, management of decision-making in a multi-actor setting becomes important. Due to the presence of multiple interconnected actors this can be perceived as 'governance of complex networks' [9]. Management of such public-private networks cannot be perceived as just a form of governmental 'steering' which has a broader meaning than strict, administrative control. Given the context, it may be better to define it more accurately as "directed influence" rather than steering [9]. The challenge, rather, is to realize policy in interaction with those other actors, which can engage social support, withstand the test of criticism, and connect other actors to policy efforts. Public agencies therefore fulfil the role of safeguarding that under-represented goals – such as environmental ones - and interests can participate in games. In a multi-actor, decision-making game this requires a balancing act if the actors involved are to achieve the goal(s) successfully and simultaneously [9]. It enables their perceptions to be aligned, visions to be converged, expectations to be discussed, mutual trust to be created, sharing of experiences (especially tacit knowledge), with reflection on how to achieve goals in a feasible manner, and keep environmental goals on the decision-making agenda. This requires a custom approach which fits the particular setting and its actors, for instance by gathering support from stakeholders to facilitate effective decision-making. In such settings, public actors may function as 'network managers': they may act as a 'facilitator' or 'process manager' by facilitating dialogues between actors and employ techniques such as workshops and brainstorming sessions to promote consensus building. By doing this they may attract skilled participants, and gather external resources (such as subsidies or loans), which enables professional leadership and favours learning conditions. Other game management strategies are: covenanting, influencing actor's perceptions, bargaining, introduction of ideas in furtherance of reflection, selective activating of actors (usually not present in the arena), furtherance of facilitation, brokerage, and mediation [9]. In the domain environmental energy 'change agents' [10] aim to have multiple actors adopt green energy technologies [11].

2.3. A typology

Based on the two dimensions introduced in the previous sections, a two-dimensional typology is adduced. The matrix has four quadrants, allowing predictions to be made concerning the outcome of the project's objectives on the adoption of energy innovations. A graphical presentation of the typology is presented in figure 1. The dimension "institutional complexity" is presented on the vertical axis, with the dimension "project management" on the horizontal one. In this study the unit of observation of the typology relates to neighbourhood refurbishment projects in urban residential areas. Besides application to the issue discussed here, the typology may also be applicable to other types of projects with multiple actors, interdependent actors that seek to achieve (collective) goal(s).

The two hypotheses relevant to the dimensions in the typology are that: (a) a high degree of process management will lead to an increasing likelihood of successful adoption of energy innovations by project stakeholders: whereas (b) a high degree of institutionalized complexity - from other policy domains, especially urban renewal - will lead to failure in the implementation of policy strategies aimed at the adoption of innovative energy systems.

The main hypothesis of this paper concerns a combination of these two hypotheses. On the basis of these propositions expectations can be formulated about the influence of the dimensions in terms of four possible outcomes. This is shown in figure 1. Whereas the optimum outcome can be expected in quadrant 4 (Q_4; low institutional complexity and a high degree of project management), the worst outcome can be expected in quadrant 1 (Q_1; high institutional complexity and low degree of project management). The outcomes in quadrants 2 and 3 will lie between the extreme outcomes in quadrants 1 and 4.

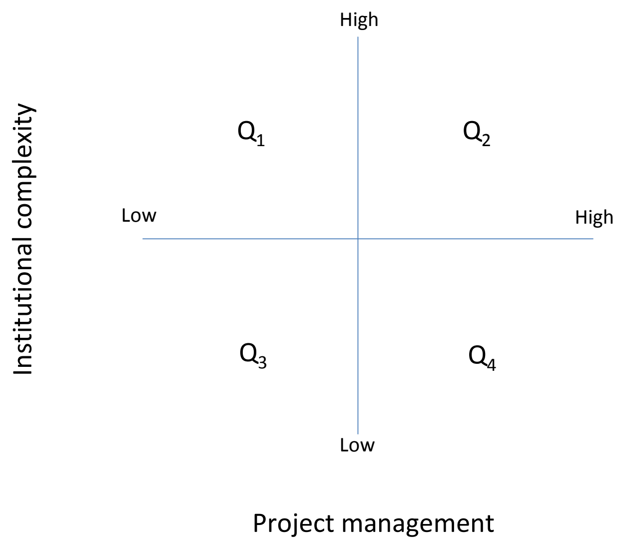

Fig. 1. Graphical representation of the typology.

3. Methodology

The empirical study comprised four case studies concerning residential district renovation projects that featured family housing. The cases were selected from an existing project set that provides information on urban renewal projects and ambitions for energy affairs [12]. The four case study projects all comprise domestic housing built in the late 1960’s and early 1970’s.

Different types of data were collected, both qualitative and quantitative. Among other things, 27 semi-structured interviews were conducted. Additional documentation on the cases was traced both before and after the interviews were conducted. The project documents retrieved included formal policy documents, advisory reports, annual reports, other informative papers, websites, feasibility study reports and geographical maps of project locations. Data were collected between October 2007 and April 2008.

In this study, a cross-case (comparative) research design was applied. The analysis was conducted in order to test the predictions based on the main hypothesis following the typology in the previous section. The dimensions ‘project management’ and ‘institutional complexity were operationalized as ‘ten-point-Lickert-scales. For the analysis the scores-per-case were assigned to the scales on the two dimensions. Next, the positions of the cases were plotted in a graphical display on the basis of the two-dimensional typology.

4. Results

In table 1 key data on the cases studies are presented. The table presents information on the initial objective (ambition) during the early stages of the project and actual outcome (in terms of innovative energy systems being applied). As it turns out, in three out of four cases no innovative energy systems were applied.

Table 1. Key data on four case studies.

Name of site	Name of town	IES (ambition)	IES (actually implemented)
Atol- en Zuiderzeewijk	Lelystad	None	None; only conventional measures
Bijvank en het Lang	Enschede	Solar thermal system	None; only conventional measures
Nieuwstad	Culemborg	Solar thermal systems or district heating from an industrial plant	None; only conventional measures
Groot Kroeven	Roosendaal	Collective biomass installations and heat pumps	Passive renovation

Figure 2 presents the result of the comparative analysis of the case studies. The positions of the cases in the figure relate to the scores on both dimensions 'institutional complexity' and 'process management', presented in a scatter plot. As can be seen, the cases in which a high degree of project management and a low degree of institutional complexity are present, innovative energy systems have been applied in existing apartment buildings. This is to say that the case in quadrant 4 (Groot Kroeven) has a positive outcome, as was predicted by the main hypothesis in section 2.3. The other cases, situated in quadrants 1 (Atol- en Zuiderzee-wijk), 2 (Bijvank en het Lang) and 3 (Nieuwstad) have negative outcomes.

4.1. Discussion

The results of the analysis allow lessons to be drawn. First, in all four cases innovative energy systems were not applied, and in the cases in which innovative energy systems were initially considered the initial objectives were not met. During the project trajectories plans were changed for different reasons. Only the refurbishment project in the Groot Kroeven case may be considered successful. Although the institutional complexity conditions favoured success – the local government did not own property near the site and no serious urban renewal performance targets focused on the project - the outcome was to a large extent due to clever project management. This resulted from a combination of professional leadership, an actor-network of motivated and skilled participants, a high level of trust between the stakeholders, the use of subsidies, and learning capacity. This last point was revealed as initial barriers were overcome. This came at a high price, though, as expertise and personnel capacity had to be hired from abroad, new construction measures had to be designed and tested – in fact experimental houses were established and monitored -, and a difficult decision-making process had to be undertaken to convince tenants and thus to meet the legal '70 percent tenant-approval standard' for large-scale refurbishment projects. All these matters led to delay in the project schedule. Hence, additional costs were incurred. Nonetheless, the infrequently used concept of "passive renovation" was applied successfully in 134 houses. The initiative to adopt this innovative concept had its origin in the housing association (or actually the project manager in situ), not the local authority.

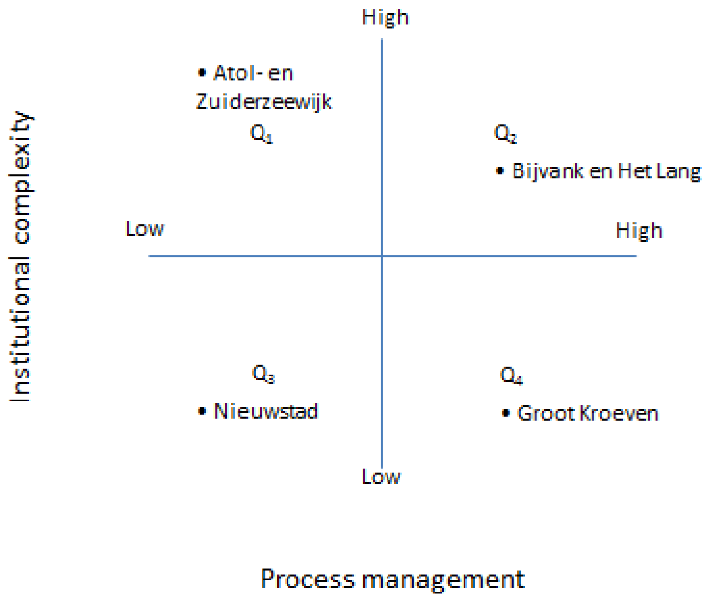

Fig. 2. Results of the case study analysis.

Second, if one's aim is to fit innovative energy solutions in renovation projects with a high degree of complexity, one is prone to encounter problems. When the housing property owner does not have the financial means to invest, on-site housing ownership rights are distributed among many different actors, and urban renewal objectives are given priority, the chances of successfully applying energy innovations are poor. The cases Atol- en Zuiderzeewijk and Bijvank en het Lang provide evidence that non-energy related urban renewal issues are assigned greater importance in the projects. When considered during the initial stages, the innovative energy appliance became an 'end of the bill' objective and was dropped from the agenda when cost estimations were done, and tenants feared monthly rent increases and delays to the project. The latter also applies to the Nieuwstad case.

Third, the cases revealed mistrust between the actors involved. Local authorities initiated a process to have energy innovations applied in local housing projects. They managed to have an energy audit report drafted by an external consultancy agency (paid for with a subsidy from national government). The advice in the audit report considered several options for on-site improvements to energy-efficiency. However, they were met with scepticism by the project stakeholders, especially the housing associations. To a large extent this related to the credibility of the energy audit reports. A difficulty, when the energy audit advice was taken into consideration, was that it remained on the decision-making agenda, especially when the actual costs of installing the systems were looked at. When the actual calculations were done it turned out that the audit report advices left out significant cost aspects, such as the installing costs and the replacement of energy-infrastructure (pipelines), as shown by Bijvank en het Lang and Nieuwstad cases.

In two cases (Bijvank en het Lang, and Nieuwstad) the housing associations complained about the unequal distribution of costs between stakeholders in the revitalization project in respect of the use of innovative energy solutions. Whereas the local authority aimed at having renewable energy systems, it did not participate in sharing in the costs. As a consequence, the housing associations were to bear the costs single-handedly, which was considered de-motivating. These two cases show that it is very important that local government and housing associations discuss a project plan seriously in the project's initial stages. In both cases the housing associations blamed the local governments for their high ambitions but their unwillingness to share in the additional costs, which bred mistrust. In that sense, it was no surprise that the ambitious energy objectives failed as the housing associations were confronted with the high costs of installing the systems, once they were seriously considered and calculated. Ergo, due to non-specific negotiations between the two parties in the initial stages of the projects, the financial feasibility of the objective was never discussed in detail.

Fourth, it may be stated that the cases show that energy innovations are preferably installed in projects that feature newly constructed houses rather than the renovation of existing houses (which means that one needs to cope with social and institutional 'infrastructure'). Theoretically speaking, new construction is favoured by the opportunity to make high investments for the long term, which needs to be done anyway, plus the absence of an existing energy infrastructure. This may also be the reason why the municipality of Lelystad – a national renewable energy frontrunner – did not formulate an ambition for the renovation of the existing neighbourhood Atol- en Zuidzeewijk, whereas there were many recently built residential sites nearby with innovative energy systems (wind power and district heating).

Finally, the cases also provide evidence that tenants fear innovative energy solutions. When requested in a vote, tenants did not accept an increase in their monthly rents as compensation for having a solar thermal system installed in their houses. The outcome of the vote was a reason for housing association to renounce the option of having the renewable energy system used in the project. The tenants' fear may have a background in their unfamiliarity to innovative systems, but may also be related to mistrust between the tenants and the housing association.

5. Conclusion

The installation of innovative energy solutions in urban areas is difficult, as local neighbourhood revitalization projects are highly complex. This paper has introduced a typology to support the analysis and understanding of local projects in which energy innovations are to be fitted. We used a comparative case study research design to test the predictions empirically against the typology. The research design comprised four case studies of local neighbourhood revitalization projects in the Netherlands, concerning refurbishment of domestic housing. The main hypothesis was confirmed as success as predicted only concerned a local project where a low degree of institutional complexity was combined with a high degree of project management.

This case, the Groot Kroeven project, shows that due to a combination of clever project management, professional leadership, learning capacity, an actor-network of motivated and skilled participants, the use of subsidies, and the absence of highly demanding urban renewal context and –project plans, barriers were overcome and positive project outcomes can be realized.

The external validity of the results is limited due to the few amounts of cases we were able to investigate. A case study design – with only four cases - was necessary, though, due to the need to analyse detailed data, which are difficult to collect and require many efforts. More research is necessary to apply our typology and to test its main hypothesis in research designs that feature more observations. This could very well be possible in other contexts, such as different types of buildings, neighbourhoods or geographical entities. One may consider applying the typology to challenges that impede the achievement of 'sustainable cities'.

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Improvements in environmental performance of biogas production from municipal solid waste and sewage sludge

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Abstract: Management of municipal solid waste is an efficient method to increase resource efficiency as well as to replace fossil fuels with renewable energy sources. This is due to that (1) waste to a large extent is renewable in itself as it contains food waste, paper, wood etc. and (2) when energy and materials are recovered from waste treatment, fossil fuels can be substituted. In this paper some of the results from a comprehensive system study of future waste management in the Gothenburg and Borås regions are presented. Emphasis is put on biological treatment of easy degradable waste such as food waste, by-products from food industry and sewage sludge. The project has been performed in cooperation between Kretsloppskontoret (The municipal office for waste and water management), Göteborg Energi (The energy company in the city of Gothenburg), Renova (The waste management company in the Gothenburg region), Gryaab (A water management company in Gothenburg) and researchers from Profu (Environmental and Energy Consultancy).
Several treatment options for the organic waste have been investigated. Different collection and separation systems for food waste in households have been applied as well as technical improvements of the biogas process as to reduce environmental impact. The biogas replaces fossil fuels and the solid residue is pelletised and either used as fertiliser or as fuel. The method used is computer modelling with the ORWARE (Organic Waste Research) model for the waste management system. Deliverables from the model are environmental impact categories as developed within life cycle assessment and financial costs and revenues.
The results show that central sorting of a mixed fraction into recyclables, combustibles, biowaste and inert is a competitive option compared to source separation. The result is however based on several crucial assumptions. Separation and utilisation of nitrogen in the wet part of the digestion residue is made possible with a number of technologies which decreases environmental impact drastically, however to a substantial cost in some cases. There are several advantages with pelletisation of the solid digestion reside. Use of pellets is beneficial compared to direct spreading as fertiliser. Fuel pellets seem to be the most favourable option, which to a large extent depends on the circumstances in the energy system. Waste management integrated with local energy supply, wastewater treatment, agriculture and vehicle fuel supply is thus a cost efficient method to decrease greenhouse gases and promote the use of waste as a renewable fuel.

Keywords: *LCA, ORWARE, Biogas, Costs*

1. Introduction

In Sweden, biogas has been produced at municipal waste water treatment plants since the 1960's. The primary incentive was to reduce sludge volumes. However, the oil crises of the 1970's rang alarm bells, leading to research and development of biogas techniques, and construction of new plants in order to reduce environmental problems and dependency on oil. During the 1980's, several landfill plants started to collect and utilise biogas produced in their treatment areas, an activity that expanded quickly during the 1990's. Several new biogas plants have been constructed since the mid-1990's to digest food industry and slaughterhouse wastes, and kitchen wastes from households and restaurants. [1]

Statistics for 2009 from Swedish Energy Agency [2] shows that biogas to an increasing extent is produced in co-digestion plants and in farm facilities and then used as vehicle fuel. The major biogas production emanates from different types of waste such as sewage sludge, source separated food waste and waste from food industry. In all the production was 1363 GWh in 2009, approximately the same level as in 2008. In Sweden there are in total 230 biogas plants of which 136 are wastewater treatment plants, 57 are landfills, 21 are co-digestion plants, 4 are placed on industries and 12 are farm facilities. The number of upgrading plants is 38 and biogas is injected to the natural gas grid at 7 places. The biogas production is predominantly present in the metropolitan areas. Compared to previous years a larger share of the produced biogas was utilised in 2009. Torching of biogas is decreasing and vehicle fuel production is increasing. The major use was for heat generation purposes (49 %) followed by vehicle fuel (36 %), electricity generation (5 %) and gas flame (torch) (10 %). Gasfuelled cars still constitute a minor share of the total vehicle fleet in Sweden, but the number of gas cars is increasing and more car producers offer more car models as gas cars. Vehicle gas is on average 60 % biogas in Sweden.

In order to illustrate the offset for biogas in Europe figures from 2005 [3] have been used. In 2005 recovered biogas was used for electricity (13 TWh), heat (8 TWh) and vehicle fuel (0.1 TWh). The majority of the heat- and power generation comes from Germany and Great Britain whereas almost all vehicle fuel was generated in Sweden. Figure 1 illustrates the distribution of energy from biogas production in each European country.

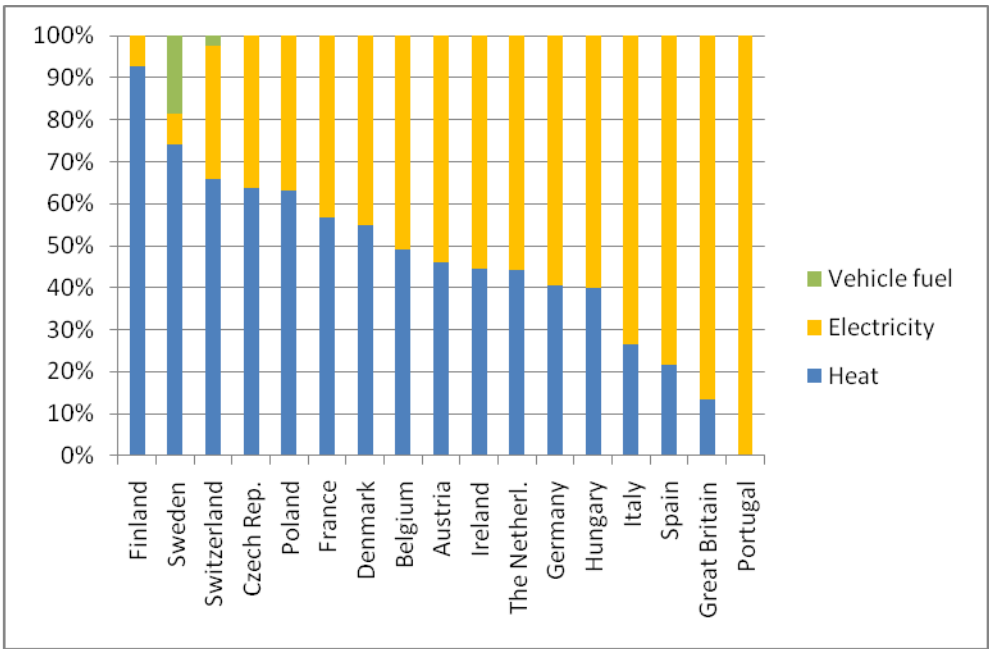

Fig. 1 Distribution for the generation of electricity, heat and vehicle fuel from landfill gas and biogas in each country in 2005. Sources: Switzerland [4], Sweden [5], others [6]

The biogas market is however not saturated. In a report from AvfallSverige (Swedish Waste Management) [7] the total biogas potential from domestic raw products, excl. raw products from forestry, amounts to 15.2 TWh/year, of which the total potential with limitations due to technical and economic reasons is assessed to 10.6 TWh/year. By-products from forestry represent a substantial potential for future bio methane production. Residues from forestry are estimated to 59 TWh/year. The total potential from food waste is 1346 GWh/year, of which 60 % is included above. Residues from industry and agriculture have a potential of 8-11 TWh/year depending on limitations. Digestion of sewage sludge is 7 % of the practically feasible potential.

In a waste management perspective, anaerobic digestion is a preferably immature technology in comparison to landfill disposal and waste incineration in terms of waste amounts treated, when the method entered the waste management market and also environmental and technical standards. That, in combination with high investment costs for biogas plants in comparison to composting and also a historically low demand for vehicle gas (and thus willingness-to-pay), has pushed waste to enter the vehicle fuel market. The transport sector is however tightly bound to fossil fuels, to a higher extent than e.g. the residential sector, and the willingness-to-pay is high in this sector. In a future where the oil price will continue to increase, the incitements for bio-vehicle-fuels, including biogas, will grow. In fact the raw product - the substrate – may switch from waste (a cost for the waste owner) to a commodity (revenue to the supplier). The demands from society on environmental standards and resource efficiency in biogas systems will probably increase during this evolvement. That is why it is interesting to study what improvements can be achieved in such systems. For the interested reader other relevant studies on biogas in a systems perspective are reported in [8-10].

2. Methodology

The method used is life cycle assessment (LCA) [11] and financial cost calculation facilitated by computer modelling with the ORWARE (Organic Waste Research) model [12]. In this study only waste streams suitable for anaerobic digestion are included. ORWARE is a computer based tool for environmental and economic systems analysis of waste management. It was first developed for systems analysis of organic waste management, hence the acronym ORWARE (Organic Waste Research). The model is designed for strategic long-term planning of recycling and waste management and based upon s tatic conditions and on l inear programming (LP). The ORWARE model has been developed since the early 1990s in close cooperation between four different research institutions in Sweden (Royal Institute of Technology, Swedish Environmental Research Institute, Swedish Institute of Agricultural and Environmental Engineering and Swedish University for Agricultural Sciences). The waste management is followed from cradle (waste sources) via collection and transport to treatment plants and further to grave (utilisation of products from waste treatment). Treatment facilities included are incineration with energy recovery, composting, landfill, anaerobic digestion with biogas utilisation, spreading of organic fertiliser on arable land, sewage treatment, material recycling of plastic and paper packages, and some additional technologies. The model delivers substance flows, distributed to emissions to air and water, left in growing crops and in recycled material. Energy flows such as energy use and recovered energy is also provided. Single substances such as carbon dioxide or substances to water leading to eutrophication can be tracked, as well as the amount of plant-available nutrients and emissions of different heavy metals. Emissions are also characterised and weighted using Life Cycle Impact Assessment. At the same time, financial costs (investment and operational costs) and environmental costs and revenues including savings in the surrounding system can be calculated for the whole management chain.

In this particular study, treatment of biodegradable waste by anaerobic digestion producing biogas for vehicle purposes and solid and wet fertiliser is the system in focus. The goal of the project is to conduct a system analysis from economic and environmental perspectives to investigate (1) what is the best alternative for collection of substrate and (2) what is the best alternative for dealing with digestate and reject water. The plants used as the point of departure for the study are a planned biogas plant in Gothenburg and an existing biogas plant in Borås. The plant in Borås is planned to be included in an energy combine with ethanol production.

Upstream to the biogas plant two different collection and separation systems for food waste in households have been applied for the Gothenburg case:
A Kerb-side collection with source separation of food waste

B Co-mingled fraction of combustible and organic fraction which is thereafter mechanically separated

Case A refers to the most common method in Swedish municipalities to achieve source separation of food waste. Data on vehicles, costs etc. has been provided by members of the project group as to reflect existing plans on extended schemes for source separation and collection.

Case B comprises a technical solution present in Ludvika in Sweden [13]. A facility for central sorting of food waste, also called homogenisation plant, has been investigated and data adjusted to the Gothenburg waste management system. The plant is fed with residual waste from households (the remaining waste after sorting out newspapers and packages made of glass, plastic, metal and cardboard). After a sequence of sorting steps (drums) different materials are sorted out, leaving raw compost left to biological treatment. Concerning collection this alternative does not require vehicles with multiple trays.

Downstream to the biogas plant one method for refinement of the solid residue (bio fertiliser) and five methods for refinement of the wet residue have been applied for the Gothenburg case and to some extent also in Borås, see below:
C Drying and pelletisation of the solid digestion reside with application as fuel- or nutrient pellet
D Separation and utilisation of nitrogen in the wet part of the digestion residue

Case C contains different treatment options for the dewatered sludge from an anaerobic digester. There are several potential options for the digestate:
C1 Drying and pelletisation, then used as fuel in a waste incinerator constructed for RDF-fuel
C2 Incineration in a waste CHP without further drying
C3 Spread directly on arable land without further drying and pelletisation
C4 Drying and pelletisation and then spread on arable land as soil fertiliser
In the systems there are two types of sludge available for which the above methods have been applied: one from digestion of dewatered sewage sludge (C1-4) and one from co-digestion of food waste from households and business facilities (C3-4). The sludge dryer applied uses hot water from the district heating system as energy source, and data is taken from design plans.

Finally, in case D different methods for reducing ammonia in the wet part of the digestate are applied. In the reference scenario wet digestate (no dewatering) is spread on arable land. In all other scenarios the sludge is dewatered and the dry digestate is spread on arable land. Following technologies for treatment of the wet part have then been compared to this reference:
D1 The reject water is treated in a wastewater treatment plant (WWTP) (just Gothenburg)
D2 The reject water is first treated in a Sequencing Batch reactor (SBR) and then treated in a WWTP (just Borås)
D3 The reject water is first treated by deammonification in a Moving-Bed Biofilm Reactor (DeAmmon) and then treated in a WWTP (just Gothenburg)
D4 The reject water is first treated by air desorption and then treated in a WWTP
D5 The reject water is first treated by steam desorption and then treated in a WWTP
D6 The reject water is first treated in a membrane facility and then treated in a WWTP

More details on the different technologies are found in [13]. The environmental impact assessment uses CML 2001 baseline [15].

3. Results

Results for CO_2 emissions and costs are presented for the A-D cases. More detailed results (e.g. acidification and eutrophication) for A-C are found in [13] and for D in [14].

When central sorting of food waste (case B) is compared to conventional source separation (case A) there are only minor changes in environmental impact. This is due to that there are small changes in the actual waste treatment, which dominates over collection and transport in terms of environmental impact. The environmental impact is somewhat higher (+400 tonnes CO_2) when central mechanical sorting is applied due to decreased net electricity generation as the sorting facility uses some electricity. The lost electricity generation is compensated for by marginal electricity production (725 kg CO_2/MWh el) mainly consisting of coal condense power. This negative effect is to some extent (-200 tonnes CO_2) compensated for by increased heat and power generation from waste incineration due to a higher heat value of the supplied waste fuel. Hereby marginal electricity and other fuels for district heating are substituted. The higher heat value is explained by that in the sorting facility metals, landfill residue (grovel, sand and other incombustibles) and moisture are removed from the combustible fraction. The result for CO_2-emissions is a slight increase by 162 tonnes which is infinitesimal in relation to the 249 ktonnes of CO_2 from the whole waste- and district heating system. In an economic comparison the net costs are decreased by almost 20 MSEK/year (1 EUR ≈ 10 SEK). The sorting facility costs 16 MSEK/year, but 23 M SEK/year is avoided for the kerb-side collection system. Costs are also lower for waste incineration (11 MSEK/year) which together with some other minor savings adds up to -19 MSEK/year.

In the systems analysis of different treatment of the digested and dewatered sewage sludge and co-digestion sludge the options have been compared to C1 for sewage sludge and C3 for co-digestion sludge. The result is depicted in Table 1.

Table 1 CO_2-emissions and costs for different sludge treatments

GHG (kton CO_2 eq./year)	**Sewage sludge C4**	**Sewage sludge C2**	**Sewage sludge C3**	**Sewage sludge & co-digestion sludge C4**
Waste management system	0.0	-0.1	0.3	0.0
District heating system	2.3	-1.0	0.0	2.8
Background system	1.4	0.8	-1.5	2.5
Sum	3.6	-0.4	-1.2	5.3
Costs (MSEK/year)				
Waste management system	-18	-25	-18	-15
District heating system	7	-5	-1	9
Sum	-11	-30	-19	-6

Eventually the result for case D is presented in Table 2.

Table 2 Climate impact and net costs from system analysis of digestate treatment

Technology	Climate impact (tonnes CO_2 eq./year)		Net costs (MSEK/year)	
	Gothenburg	Borås	Gothenburg	Borås
D0: Un-dewatered biofertiliser for soil improvement	-940	-690	5.0	8.1
D1: Dewatering and WWTP	1340	-	24.8	-
D2: Dewatering and SBR	-	1270	-	6.1
D3: Dewatering and DeAmmon	750	-	5.2	-
D4: Dewatering and air desorption	620	580	7.0	7.5
D5: Dewatering and steam desorption	250	190	8.1	7.5
D6: Dewatering and membrane	590	610	6.6	7.7

The results of the system analysis of digestate treatment (Table 2) show that the best alternative for Gothenburg, both from an economical point of view (column 4) and when considering the climate impact (column 2), is to transport and spread the un-dewatered digestate directly onto arable land (D0). From the economic perspective, the best alternative for Borås (column 5) is to continue with the treatment method used today at the plant, that is, SBR (D2). From the perspective of climate impact (column 3), the best alternative is to spread the un-dewatered digestate directly onto arable land (D0). Now, these methods are aimed at reducing emissions of ammonia affecting eutrophication and acidification. On the basis of acidification and eutrophication potentials, the best alternative for Gothenburg is to treat the reject water with the DeAmmon process and for Borås the best alternative is to treat the reject water with some form of stripping method, or SBR.

4. Discussion and Conclusions

Organic waste (biowaste, food waste) is a renewable resource that should be used in order to avoid as much negative environmental impact as possible. A large benefit of anaerobic digestion of food waste is that the biogas substitutes other fossil vehicle fuels. Therefore, when analysing different methods for improvement of a biogas system, it could be expected that these improvements should reduce potential global warming. This is however not the case for the improvements studied, cf. Table 3

Table 3 Climate impact, costs and CO2-cost in the studied scenarios

	CO_2 eq. (tonnes)	Costs (MSEK)
B-A: Central sorting	+162	-19
C4-C1: Sewage sludge as nutrient pellets	+3600	-11
C2-C1: Sewage sludge incinerated in CHP	-400	-30
C3-C1: Sewage sludge spread direct	-1200	-19
C4-C1: Sewage sludge & co-digestion sludge	+5300	-6
D1-D0: Dewatering and WWTP	+2280	20
D2-D0: Dewatering and SBR	+1960	-2
D3-D0: Dewatering and DeAmmon	+1690	0.2
D4-D0: Dewatering and air stripper	1560 G 1270 B	2 G -0.6 B
D5-D0: Dewatering and steam stripper	1190 G 880 B	3.1 G -0.6 B
D6-D0: Dewatering and membrane	1530 G 1300 B	1.6 G -0.4 B

In most cases the emissions of CO_2 increases compared to the reference system. Costs are both increasing and decreasing in an interval of 50 M SEK. There are only two scenarios where the CO_2 emissions decreases, resulting in a *decreased* net cost! When assessing climate impact sludge should not be dried and pelletised, regardless of use as fuel pellet or nutrient pellet. This comes from that ammonia in the sludge is lost in the drying process and this loss has to be compensated for by conventional fertiliser that uses fossil resources. Other conclusions are drawn when looking at eutrophication and acidification.

An important conclusion from this comparison is that CO_2 cannot be used as the only indicator of which biogas system design is the most environmentally feasible. As the carbon in food waste is of biological origin, also other impact categories such as eutrophication and acidification have to be addressed to fully evaluate the environmental performance of these systems.

Another comment of concern is that it would be politically difficult to introduce mechanical pre-sorting (often called material recovery facility - MRF) on large scale in Sweden due to that source separation is a well established method. It can however be a cost efficient method in countries where source separation is not as well developed and implemented. It may also work as a co mplementary system, e.g. in remote areas where the marginal cost for introduction of kerb-side collection is high and for an additional sorting of waste from areas with poor sorting quality.

It should also be mentioned that upstream and downstream improvements of course can be combined. Future studies will focus on pre-treatment of waste (e.g. hydrolysis) as to increase the gas yield as well as new techniques for upgrading raw gas to vehicle gas. Other points for improvement that have been identified are dry conservation of waste, the performance of biofilters and also the use of sludge pellets in forestry.

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Environmental thermal impact assessment of regenerated urban form: A case study in Sheffield

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Abstract: Urban comfort is becoming increasingly important due to climate change, increasing population and urbanization. Greater use of mechanical cooling is not reasonable due to consuming more energy, discharging anthropogenic heat and CO_2 emissions which all can be minimized by passive strategies. As part of the EPSRC funded project Urban River Corridors and Sustainable Living Agendas, URSULA, two radically different urban regenerations for a site in Sheffield were passively designed and had to be microclimatically assessed upon their thermal impacts. Passive design strategy for the first is wind tunneling and solar shelter effects owed to compact form that provides river bank access by perpendicular streets. The second, park option, offers space for the river to flood into a green channel which provides evaporative cooling. Simulations using ENVI-met BETA4 applied four receptors to record different meteorology and the pedestrian comfort in terms of Predicted Mean Vote, PMV. The increased green coverage showed horizontal shifting of about 0.2 with 2h of urban time lag in PMV records from 14.00-16.00LST in some places. Results give advantage for the park option design but needs more emphasize on indoor performance.

Keywords: *Thermal impact assessment, urban thermal mass, urban time lag, urban regeneration*

1. Introduction

Temperature increases due to climate change are further exasperated within urban areas due to hard urban surfaces, reduced porosity, and deep canyons preventing radiation release and ventilation [1-4]. Careful design of urban form and the use of green infrastructure can mitigate this effect [5]; many studies showed the benefits of vegetation such as trees [6-9] and Parks [10-13]. However there are often many other, sometimes competing, drivers which affect the design of our urban forms. Urban forms are the fabric of a site along with its network and vegetation. From these standing points, a statistical study in Sheffield presented the distances to the nearest green node which is followed by the biometeorological green structure study, GreenSect, to confine UHI effects [14] by the application of park cooling island effect, PCI [15]. In this study, microclimate effects of two radically different urban form designs for one site in Sheffield took place as part of URSULA project. Site is located near the centre of Sheffield, in the temperate UK climate. Although the city is having high levels of vegetation it showed an UHI of 2C on a spring day [16]; with the potential for greater, and more frequent heat waves. Site is approximately 1.2 hectares (c.300mx400m) adjacent to the river Don. The riverside location offers recreational benefits, but also presents a high risk of flooding and the rationales for two urban form designs for this site have been developed in relation with these two issues. The first design alternative has been developed to facilitate and enhance access to the river, through the use of streets running perpendicular to the bank. On the river front the buildings have been stepped back from the river to create new urban squares looking onto the river, and also to reduce the risk of high wind speeds [17]. The streets are designed to a similar scale to the surrounding existing infrastructure and the open spaces have an urban character with hard landscape treatment and urban trees. In the second design the main objective is to make space for water as an adaptation method for present day climate change symptoms. As the risk of flooding was the initial driver, a channel for flood water has been created through the middle of the site. In order to avoid obstruction when it floods, the channel is treated as a meadow planted with only grass and reeds. This long continuous open space is expected to provide cooling effect according to the principle that park land provides cooling up to approximately 300m from the park [7, 18- 20]. The two radically different proposals are designed also differently from passive strategies' point of view. Passive urban form design is believed to affect indoor energy consumption and thermal performance so that energy supplies can be minimized [3, 4, 7, 9]. As the main objective of passive design is to minimize indoor heat gain/loss so that energy is saved, first design case, C1 provide cooling/heating by compact form tunneling and thermal mass effects. The second design case, C2 provide evaporative cooling in summer by the more vegetated area. With respect to URSULA concerns about heat waves and floods in summer, the study was then to find which of both alternatives have the better thermal impact in comparison to their existing urban form.

2. Methodology

Methodology is composed of two steps; first, urban climate conditions of each case is simulated to have meteorological plots at same certain points in each case. Second, average outdoor meteorology for each case is calculated to ensure results from receptors as well as validating the averaging methodology and tool.

2.1. Method

Numerical simulations using ENVI-met were applied for its easy and few data entries as well as the understanding of urban climate it gives [21]. ENVI-met simulates the surface-plant-air interactions with a resolution of 0.5 to 10 m in space and 10 sec in time from microclimate to local climate scale using the fundamentals of thermodynamics and heat transfer as a CFD package [22, 23]. The model formatted on a number of on sub-models to model and analyze surface-plant-soil-air relations, its 3.1 version is validated for radiation and RH and still have limitations [9, 21]. The software is relevant to this study as it assesses the outdoor thermal performance in terms of different meteorological outputs along with pedestrian comfort levels using the modified Predicted Mean Vote, PMV following the work of Jendritzky [24-26]. ENVI-met gives results in terms of thematic maps extracted from results by the Leonardo tool or numerically in terms of meteorological records corresponding to each grid in the simulated urban form [22]. In order to ensure results of the receptors along with having a complete idea about whole outdoor spaces performance rather than only single receptor points, PolygonPlus has been used. PolygonPlus is a visual basic tool used after ENVI-met to generate reference averaged neighborhood meteorology rather than records at single non-representative points [13]. Moreover, comparisons of different urban designs upon their urban spaces meteorological averages can take place against receptors' outputs to validate PolygonPlus.

2.2. Parameterization

Table 1 shows the simulation input data for the 27th of July which is the extreme summer day for Sheffield, UK (Lat; 53.38, Long; -1.46), fig. 1 [28]. Two methods of recording outdoor meteorological data were used, snapshot receptors of ENVI-met and the averaging tool PolygonPlus. Four snapshot receptors were located at the boundaries and the middle of the site to record air temperature T_a, Relative Humidity RH, wind Velocity V, and PMV at 1.5m above ground level, fig. 1/b, c, d. The hypothesis assumes that pedestrian PMV of both cases will be different as the fabric, network and vegetation elements of the built environment are varying. Output were then compared with the whole site averaged records calculated by PolygonPlus tool developed by Fahmy [29] to represent a whole local scale urban spaces' climate condition rather than single points, fig. 2. Due to no modeling measurements for trees foliage, urban trees, U1, U2 and U3, used in simulations were modeled after Fahmy [9] by the application of the value LAI=1, table 1.

Table 1: Inputs used in simulations based on [22, 30, 31].

Parameter	Value
Outdoor T_a	295.45 K
RH	60%
V	3.4 m/s at 10m height
Indoor T_a	293.15 K
Ground temperature	288.15 K from 0-0.5m and 286.35 K from 0.5-2m
Ground humidity	40% from 0-0.5m and 50% from 0.5-2m
U value Walls	1.0 for all buildings walls
U value Roofs	2.0 for all buildings roofs
Albedo Walls	0.475 for all buildings walls
Albedo Roofs	0.45 for all buildings roofs
Albedo Pavement	0.67
Albedo Asphalt	0.20
Human walking speed	1.1 m/s
Pedestrian Clo.	0.50
U1; Alunas cordota	10m total height – 1.8m height to canopy – 3 height of max diameter
U2; Alunas cordota	7m total height – 1.8m height to canopy – 3 height of max diameter
U3; London plane	20m total height – 2m height to canopy – 10 height of max diameter

Fig.1/a: Google maps capture for the site area and the existing fabric.

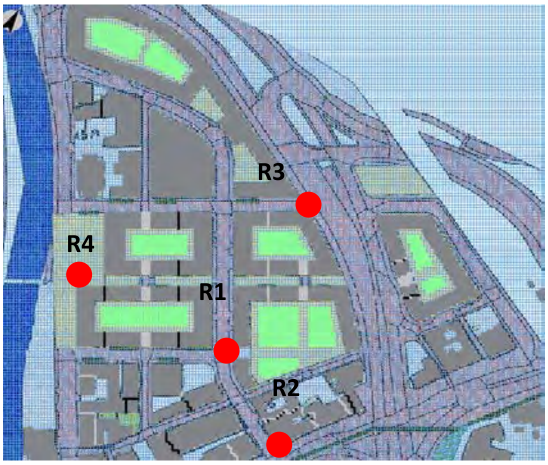

Fig.1/b: ENVI-met Graphical user interface; Modeling the urban form alternative 1 for the case area, R is abbreviation for the receptor placed at points 1-4.

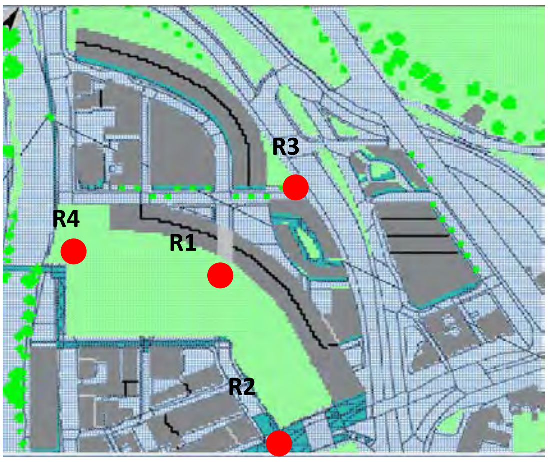

Fig.1/c: ENVI-met Graphical user interface; Modeling the urban form alternative 2 for the case area.

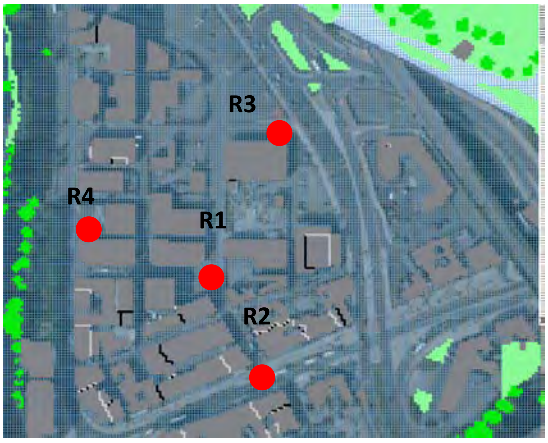

Fig.1/d: ENVI-met Graphical user interface; Modeling the urban form base case.

3. Simulation course

3.1. Results

Fig. 3 illustrates the comparison for T_a, RH, V and PMV extracted from the receptors plotted along with the averaged reference local climate condition calculated by PolygonPlus for 12h except the base case which simulation encountered a numerical flow error at the last simulated hour. However, it didn't affect the comparisons and the concluded remarks as there was 11 common hours from 8-18LST. Good agreement appeared between records from the individual receptors and the averaged values for T_a and RH, whereas considerable difference found between the receptors and the average value for V and PMV, demonstrating a microclimate manipulation on the local scale. All T_a and RH records show the same trend in all cases with reductions in C2 T_a due to the more vegetated area used in comparison to both C1 and BC. The opposite trend in RH occurred attributed also to the different vegetated area used. The sudden drop in PMV record of some cases like C1 at the receptor point R2 indicates the effect of shading. Wind speeds are much higher in C2 than both C1 and BC owed to open fabric used that removed the blockage effect might occur by the fabric in C1. And in combination with the reduced T_a in C2, and resulted more acceptable PMV records at receptors microclimate regardless the reduced PMV of the averaged local records of C2 than PMV at C2R3 as the averaged records is a reference for the whole neighborhood rather than for a single point. The effect of urban thermal mass firstly found by Fahmy [13] has been also found in this study despite the different climatic region. Regardless the close PMV trend of both alternatives' averaged values; increasing green coverage in the park option showed a minor urban thermal mass effect represented by a difference in PMV of 0.1-0.3 at peak time almost with no urban time lag. Receptor, R, no.1 and no.2 showed similar PMV horizontal shifting on the curve of about 0.2 with 2h of urban time lag from 14.00LST to 16.00LST. R3 showed vertical shifting indicating reductions due to the more vegetation in C2. R4 also showed vertical shifting but with increased PMV value at peak time due to the less trees in comparison to C1.

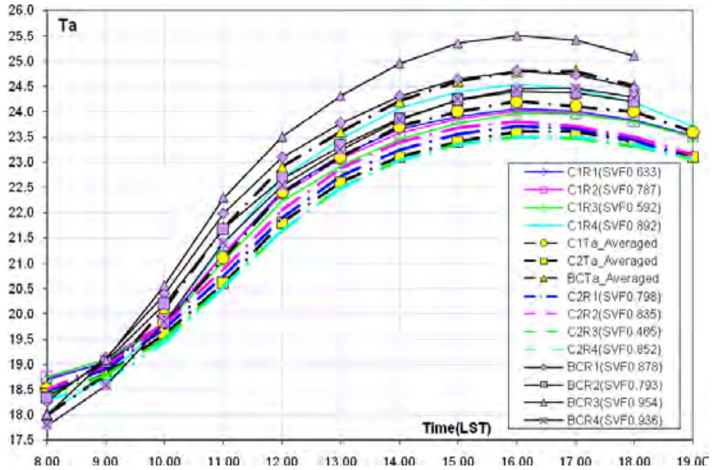

Fig.3/a: Comparison of averaged T_a and the receptors outputs for different cases.

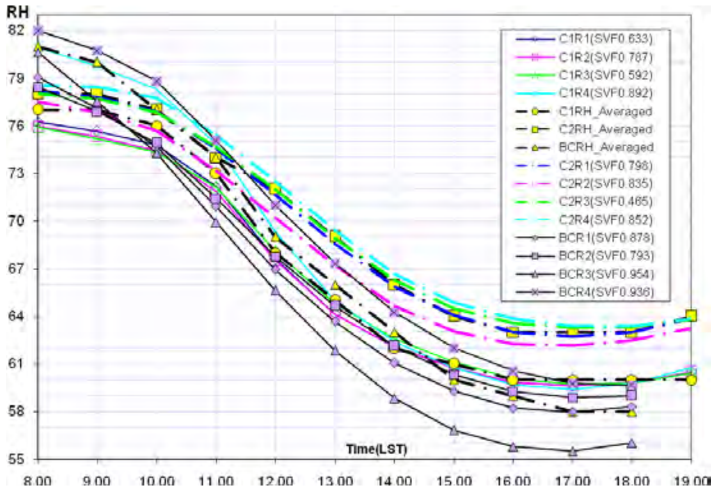

Fig.3/b: Comparison of averaged RH and the receptors outputs for different cases.

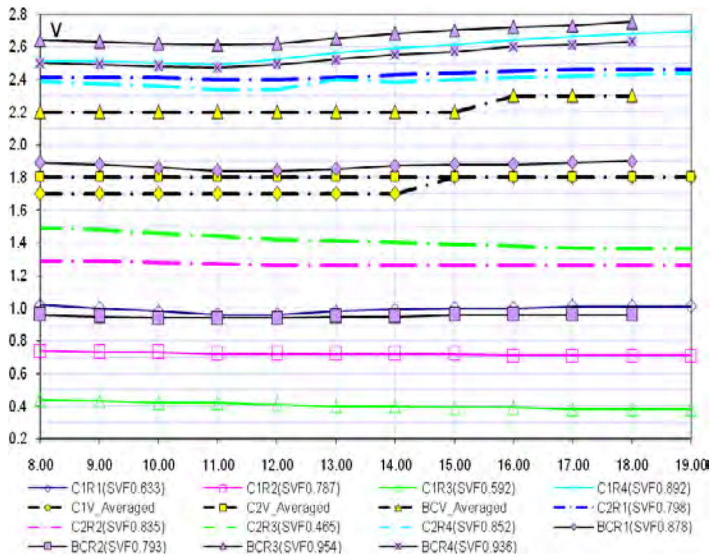

Fig.3/c: Comparison of averaged V and the receptors outputs for different cases.

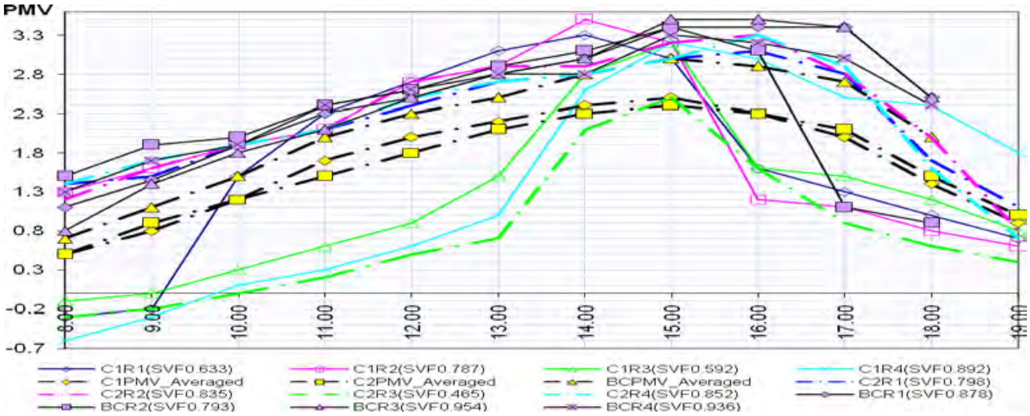

Fig.3/d: Comparison of averaged PMV and the receptors outputs for different cases.

3.2. Discussion and conclusion

This study aimed to assess the thermal performance of two radically different urban regeneration alternatives with their existing case in Sheffield in order to give on of the alternatives an advantage for execution. Methodology composed of two steps; first, urban climate conditions of each case is simulated to have meteorological plots at same certain points in each case. Second, average outdoor meteorology for each case is calculated to ensure results from receptors as well as validating the averaging tool, PolygonPlus. All averages' records occurred between the maxima and minima of receptors outputs of each case which validates PolygonPlus. The more vegetated alternative revealed reductions in the whole neighborhood pedestrian comfort records. This is owed to the open form that allowed more wind speed averages as well as more park cooling effect. On the other hand, an urban thermal mass effect has been noticed. It can be said that the whole C2 urban green structure turned the neighborhood form into *urban thermal mass* that shifted PMV curves from C1 as shown in fig.3 and agrees with Fahmy [13], p-138, regardless the different climate classification of Sheffield's case in this study. After all, outdoor climate assessment suggests that the second urban form design is probably more sustainable with reference to urban spaces simulated in the two alternatives in comparison to the existing site urban form, but further indoor analysis is required to study the impact of each urban form on the energy demand and the green house gases emissions; i.e. coupling whole neighborhood buildings' indoor thermal performances with their outdoors.

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Mitigating Heat Gain Using Greenery of an Eco-House in Abu Dhabi

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Abstract: Two fundamental design strategies should be taken into consideration when designing a residential building in desert climates, they are as follows: minimizing solar heat gain through shading and proper building envelope and maximizing passive cooling through natural ventilation. By introducing extensive vegetation yet carefully distributed, shading of building's facades or roofs will directly mitigate heat gain through building envelope. An eco-house was designed in Abu Dhabi with special attention to greenery. In this study, landscape elements were intensively analyzed with the aim of reducing heat gain and improving overall building energy performance. Landscape elements such as green roofs, grass ground cover and greenery next to external walls were simulated in order to achieve optimum energy performance. The use of outdoor landscape (grass ground cover and shade trees) has made a 9% improvement of performance over the reference case regarding the electrical energy use and greenhouse gas emissions. The energy use of the house dropped down by 16% for cooling and 18% for fan operation. With regards to the green roof scenario, a performance improvement of 19% over the base case has been achieved. The energy use of the house dropped down by 24% for cooling and 27% for fan operation.

Keywords: *Heat gain, Green roof, Grass ground cover, Energy performance*

1. Introduction

Cooling and air conditioning of buildings in Abu Dhabi accounts for 75% of electricity consumption in the summer months and are considered the major consumer of electricity [1]. This leads to very high levels of CO_2 and other greenhouse emissions. Landscape effect on heat gain mitigation on buildings has not been studied in the UAE. With the new policies in the UAE calling for green building such as Estidama guidelines and other codes, the consideration of landscape strategies to improve building environmental performance has become significant. Landscaping is considered as a challenging part due to its high water consumption and the scarcity of water resources especially in arid regions such as Abu Dhabi. In this study, the focus is on how landscape design contributes directly in enhancing the building energy performance; and thus lowering the overall energy consumption. Landscape elements such as green roofs, grass ground cover and greenery next to external walls were simulated to evaluate how it will integrate with other passive systems for an Eco-house design in order to achieve optimum energy performance. Where plants normally take a huge amount of water resources, the suitable plants type was carefully selected to consume least amount of water.

2. Background

Vegetation can reduce the heat reaching the building and penetrating its envelope by increasing the reflection of solar radiation and by providing shading. They can achieve evaporative cooling and taking the heat away through the process of transpiration. In this study, the effect of conventional landscape elements (i.e.; grass cover with shade trees) combined with green roof was investigated in terms of their thermal behavior.

2.1. Green roof

The term "*green roof*" generally represents vegetation and growing medium planted on the building rooftop. There are several environmental benefits associated with green roofs such as energy savings through building envelope thermal regulation, roof membrane protection and thus prolonged building's life cycle, sound insulation as green roofs act as an acoustic barrier and finally other benefits at the urban level such as mitigating urban heat island effect and storm water retention. With introducing circular no. 171, green roofs and vertical landscaping by Dubai Municipality (DM) that became effective since July 2009 [2], both buildings consultants and contractors have to integrate green roofs into their new buildings design taking into consideration the selection of proper vegetation type, irrigation system, insulation materials and roof structural membrane system. Estidama also encourages applying the concept of green roofs and external landscaping in order to mitigate heat island effects [1]. NRC-IRC constructed a field roofing facility at its Ottawa campus to study the performance of garden roofs [3]. This energy demand was reduced from 6.5–7.0 to less than 1.0 kWh/day in the garden roof, a reduction of over 75%. The garden roof was more effective in controlling heat gain than in reducing heat loss because of the various thermal mechanisms involved, shading, insulation, evapotranspiration and thermal mass. It reduced heat gain by 95% and heat loss by 26%. The study also predicted that in warmer regions where cooling rather than heating is the main concern, the results could be more significant. The study also showed how garden roofs can lower the temperature and modify the temperature fluctuations experienced by the roofing membrane, which results in greater durability and an extended service life for the roof membrane. Another study [4] evaluated the life cycle environmental impacts of an eight story residential building, including the addition of a green roof (only 16% of the building's exposed surface area) located in downtown Madrid, Spain using computer simulation. Due to a lower absorption of solar radiation and lower thermal conductance, the addition of a green roof was estimated to reduce annual energy consumption by 1.2%. This was primarily due to summer cooling load reductions of over 6%. For the upper floors, the peak hour cooling load was reduced by as much as 25% relative to the common flat roof.

2.2. Shade Trees

Akbari et al. [5] quantified the effect of shade trees on the cooling costs of two similar houses in Sacramento, California and the results showed that the trees reduced seasonal cooling costs by between 26% and 47%. The same study modeled the effect of the trees on both houses using the DOE-2.1E3 simulation program and found that the model underestimated the energy savings of the trees by as much as twofold. Another study by Akbari and Taha [6], used simulation to study the effect of trees on energy use in four Canadian cities, concluded that increasing the vegetative cover of a neighborhood by 30% and increasing the albedo of houses by 20% would decrease heating costs by 10–20% and decrease cooling costs 30–100%. A simulation study by Simpson and McPherson [7] found that trees shading the west side of houses in California had the biggest effect on cooling costs and that adding shade trees to a house on the west side and east sides reduced annual cooling costs by 10–50%. Another study by McPherson and Simpson [8] used simulation modeling and aerial photography to estimate the energy savings of existing urban trees and new plantings in California indicated that existing trees could reduce peak energy load by 10% resulting in annual savings of $779 million. They estimated that planting an additional 50 million trees on the east and west sides of houses would further reduce peak load by an average of 4.5% over the next 15 years, which would result in total savings for consumers of $3.6 billion or $71 per tree. In a recent study Donovan and Butry [9] estimated the effect of shade trees on the summertime electricity use of 460 single-family homes in Sacramento, California. Results showed that trees on the west and south sides of a house reduced summertime electricity use by 185 kWh (5.2%), whereas trees on the north side of a house increased summertime electricity use by 55 kWh (1.5%). Results also showed that a London plane tree, planted on the west side of a house, can reduce carbon emissions from summertime electricity use by an average of 31% over 100 years.

2.3. Grass ground cover

Vegetation surfaces and pavement materials heavily influence outdoor thermal environments. Field measurements performed in Singapore revealed there were clear effects of hard versus vegetation surfaces on globe temperature and mean radiant temperature (MRT) [10]. The characteristics of heat and water transfer processes in porous block pavement, asphalt, grass and ceramic porous pavement was analyzed using numerical modeling. The model revealed that the surface temperature of permeable pavement is appreciably lower than that of impermeable pavement [11]. A filed experiment conducted in Eastern Saudi Arabia found a good correlation between pavement temperature and air temperature [12]. Other experiments in Singapore showed that granite slab, terracotta bricks and concrete interlocking blocks provide lower surface temperatures and heat output than conventional asphalt concrete pavements [13]. An empirical study was performed on five pavements in three areas of Taiwan to study the seasonal influence of pavement on outdoor thermal environments [14]. The study found that asphalt concrete and concrete have higher temperature than interlocking blocks or interlocking blocks with grass infilling, and grass always has the lowest air temperature. The surface temperature of artificial pavements was 10°C higher than that of vegetation surface at noon in the summer, but the difference among the various pavement types were not significant in winter.

3. Methodology

One of the most important and challenging architectural targets in this design exercise was the proper landscaping. Landscape design went hand in hand with other passive and active design components of the eco-house. Grass ground cover and greenery next to external walls (LS case) was simulated and considered as the first scenario. The effect of the green roof element was simulated in a separate scenario (GR case) and the results of both cases were compared against the reference house (REF case). All three cases were simulated using Enerwin-EC software [15]. The window to wall ratio (WWR) as 0.20, 0.15, 0.20, and 0.10 for North, East, South, and West facades, respectively, was used in all three cases.

Landscape design and location (whether horizontally or vertically) tend to maximize shading around the house especially near the windows, and minimize the load due to ground reflected solar radiation by using appropriate ground cover such as grass. The impact of the grass ground cover along with the shade trees on energy was evaluated in this eco-house. The exterior shade trees were set to provide only 50% shading on walls and windows. Where plants normally take a huge amount of water resources, the suitable plants type was carefully selected. Palm trees, ornamental trees and aqueous plants such as Yucca Filamentosa and Yucca Aloifolia were recommended [2]. These desert plants are suitable for intensive greening, yet consume least water. They are normally watered by drip irrigation and consume from 50-60 liters/day for palm and ornamental trees, and as little as 15-20 liters/m^2/day for the aqueous plants. According to Estidama credit (PW-2.1: Exterior Water Use Reduction: Landscaping) in areas with low rainfall or seasonal droughts, up to 60% of total seasonal water usage can be attributed to irrigation [16]. As mentioned earlier, the main system used of plants irrigation is drip irrigation (mainly for roof gardens) besides a bioswale for the house central courtyard. A bioswale is a densely vegetated open channel designed to attenuate and treat storm water runoff. It has gentle slopes to allow runoff to be filtered by vegetation planted on the bottom and sides of the swale (see Fig.1).

As for the green roof structure [17, 18], the whole roof area was 150 mm solid concrete slab, lined with a waterproof membrane insulated with Polyfoam Roofboard 200 mm thick

(2x100mm), covered with Polyfoam Slimline membrane. The Slimline membrane was overlaid with a root barrier/ moisture reservoir as specified ensuring there were no gaps and edges were overlapped. That was covered with a filtration layer, and growing matter as specified by Estidama [16] in order to match desert plants. That typical green roof section (see Fig. 2) has a U-value of 0.15 W/m^2K without considering the insulation value of the soil which varies with the water content.

Fig. 1. Landscape elements distribution in the Eco-House

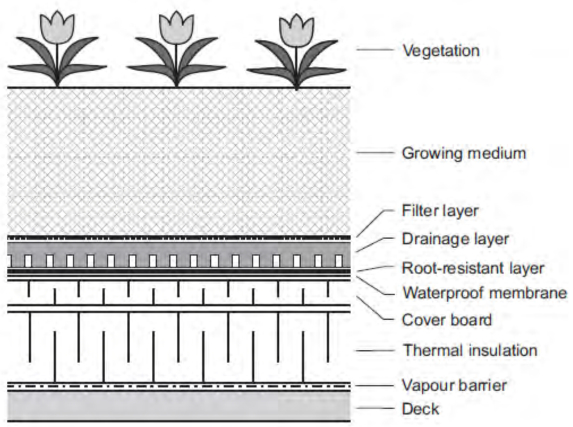

Fig. 2. Green roof structural elements, adapted from [17].

4. Results and Discussion

Typically at the UAE latitude (24° N), the heat gain through the roof component is usually the highest; then comes heat gain through the windows and walls; other building components have usually smaller effect compared to these main components. Thus, before improving the house performance by proper design of the greenery, it was necessary to optimize its form design so that distribution of load becomes a bit more uniform with smaller magnitude at each component, and thus easier to solve. That was done in a previous stage in which the courtyard form was tested and evaluated against a typical Emirati house [19]. The typical house yielded load distribution as follows: 25% for roof, 23.5% windows solar, walls 20%, and 30% for other components. The courtyard configuration (referred to as the reference house or REF case in this study) helped to distribute the cooling loads as follows: 24.3% for roof, 18.1% for windows solar, 27.4% for walls, and 30% for other components; this helped to decrease the windows solar and roof loads' contributions.

4.1. Landscaping results

The first decision was to minimize direct and reflected solar heat gain by maximizing shading on walls and windows and improve ground cover. This would help to reduce the walls and windows-solar loads. Landscaping has great potential to provide these benefits and in the meantime attain other Estidama credits such as LV-R1: Urban Systems Assessment, LV-R2: Outdoor Thermal Comfort, RE-1: Improved Energy Performance [16]. This resulted in great reduction of the windows-solar (63.7%), windows transmission (22.1%), walls loads (20.7%), and mass effect (16.9%); and 21.5% reduction in the total annual cooling load, compared to the base case. The energy use of the house (compared to the REF case) dropped down by 16% for cooling and 18% for fan operation. It also helped to reduce the greenhouse gas emissions and the electrical energy use by 9%.

4.2. Green Roof

The second decision scenario was to improve thermal resistance for the roof heat gain. This resulted in great reduction of the heat gain through roof (99.6%), compared to the reference case. The energy use of the house (compared to the reference case) dropped down by 24% for cooling and 27% for fan operation. It also helped to reduce the greenhouse gas emissions and the electrical energy use by 19%. See figures 3, 4, and 5.

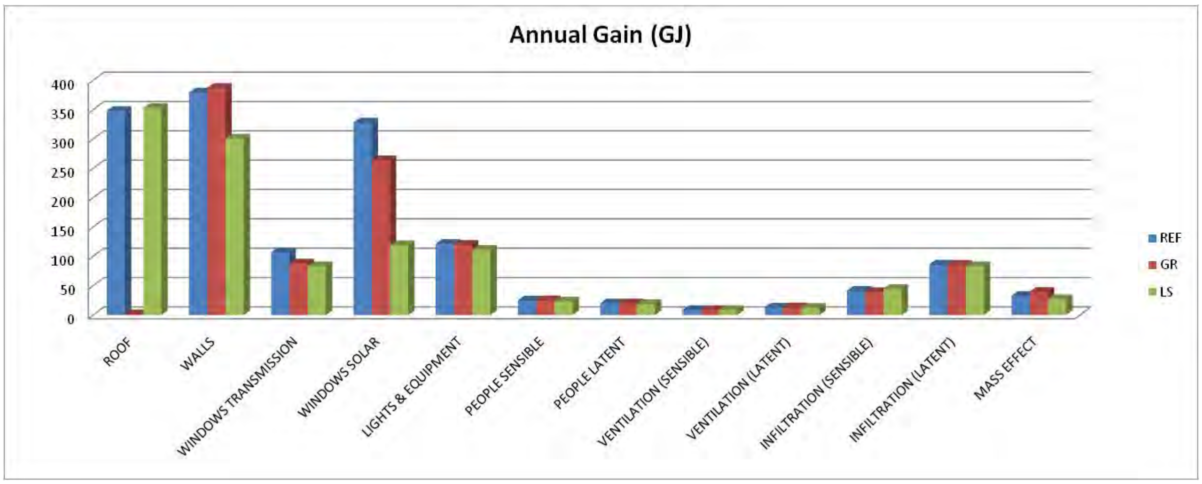

Fig. 3. Annual heat gain by component for the tested cases.

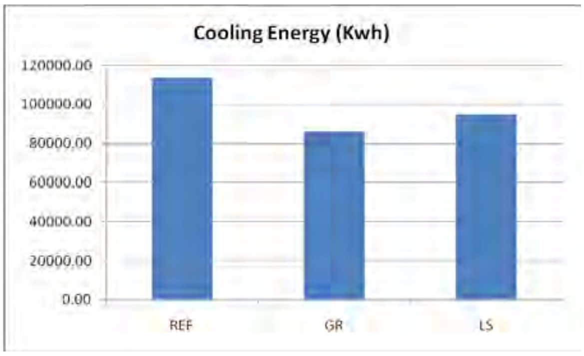

Fig. 4. Cooling energy of the tested cases.

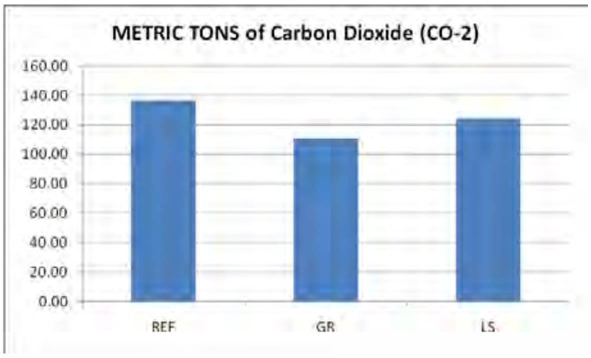

Fig. 5. CO_2 emissions of the tested cases..

5. Conclusion

In a hot climate such as Abu Dhabi for an envelope dominated building, most of the heat gain comes through the roof, the windows and the walls (approximately 70%). This indicated the critical need to minimize solar gain and improve the thermal conservation level of the building envelope. Using greenery to improve the building thermal performance can also result in other benefits such as improved air quality, visual comfort via daylight uniform distribution, noise reduction, prolonged building structure (as green roof), outdoor and indoor thermal comfort, and aesthetics. The use of outdoor landscape (grass ground cover and shade trees) has made a 9% improvement of performance over the base case regarding the electrical energy use and greenhouse gas emissions. The energy use of the house (compared to the reference case) dropped down by 16% for cooling and 18% for fan operation. With regards to the green roof scenario, a performance improvement of 19% over the base case has been achieved. The energy use of the house dropped down by 24% for cooling and 27% for fan operation. Such strategies and improvement of performance would eventually help to earn several points in Estidama Pearl Rating System for Villas such as: LV-R1: Urban systems assessment, LV-R2: Outdoor thermal comfort, LV-9: Indoor noise, IP-1: Innovative cultural

& regional practices, IP-2: Innovating Practice, IDP-R1: Integrated Development Strategy, IDP-1: Life Cycle Costing, NS-R1: Natural systems assessment & protection, NS-1: Landscape design & management plan, NS-2: Landscape enhancement, PW-2.1: Exterior water use reduction: Landscaping, PW-3: Stormwater management, and RE-1: Improved Energy Performance.

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Solar energy in urban community in City of Salzburg, Austria

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Abstract: Lehen is the largest district of City of Salzburg, close to the city centre and with high quality of infrastructure of public transport. Since the last decades the district was confronted with essential changes. The use of the area of the former utility means a huge potential for further development of the district. High share of renewable energy should be the main focus of the project, considering existing heat supply with district heating. High standards of buildings and large-scale solar system are the main elements of the energy concept. The use of a heat pump ensures an efficient increase of solar gains and leads to low primary energy demand resp. CO_2-emissions. The new building area was also seen as a chance for modernization activities in existing building stock around. Energy efficient pumps and lightning as well as PV modules in the facades will ensure high share of renewable energy also for electricity demand. First results show the way for further projects – concerning effective steering of complex processes and technologies to achieve total CO_2-reductions in urban areas.

Keywords: *General development plan, Urban communities, Process of energy planning, Solar optimization*

1. Introduction

The district of Salzburg-Lehen is situated quite close to the city centre of Salzburg. The appearance of Lehen was for long years dominated by residential buildings from 1950 to 1970, high amount of school buildings, the main soccer stadium of Salzburg, the head-quarter of the utility and a main traffic road. Obviously caused by the living situation in mostly not renovated buildings and the traffic situation the district was endangered to get more and more social problems. Considering the very attractive location the potential for establishing a new and attractive district in Salzburg was seen. With the opening of a new train station Lehen is now connected to the new city train which means another improvement of living quality of the district. The movement of the utility and the football stadium to other sites mean new chances for further development. Meanwhile the main city library was established on the site of the former soccer stadium.

On the site of the former utility a new residential and commercial area was initiated. In a competition a master plan of the launched project "Stadtwerk Lehen" was developed. Residential buildings with apartments and commercial areas, a kindergarten, a student's hostel and a "Competence park" with four live science buildings, a hotel and the renovation of the former office building are foreseen. Besides that, there is an existing building stock around the areas of the utility with residential buildings from 1950 – 1960, most of them without any thermal renovation and equipped with individual heating system with oil or gas. So the new-built area was seen as a chance also for the surrounding retrofit areas. Energy efficiency of the buildings and the integration in the energy supply concept of the new buildings of "Stadtwerk Lehen" became a concrete perspective for city planners. This causes an over-all renovation as a requirement for the further project development.

Table 1. Key figures

Total area	155.000 m²
Owners	Social and commercial housing associations, city of Salzburg
Existing buildings	50.000 m²
Number of dwelling	623
Average age of existing buildings	60 – 70 years
Type of buildings	85% residential, 15% commercial
New buildings	105.000 m²
Number of dwellings	550
Type of buildings	80% residential, 20% commercial

Table 1 shows the key-figures of the area. Besides the goals of urban development and motivated by the discussion of a new communal development plan which fulfils criteria of sustainability the project of "Stadtwerk Lehen" was created as a pilot project for sustainable urban development. Main performance criteria concerning energy were defined as:

- Low energy standard for buildings
- Energy efficient pumps and lightning of public areas
- High rate of renewable energy for energy supply

In addition to that energy supply system and integration of renewable energy should also be optimized related to existing district heating system, since district heating is based on high shares of available industrial waste heat resources. Thus the main focus of project development was the optimization of the energy supply concept. As there are different approaches for new buildings and renovation, a couple of involved partners and clear targets defined by funding programs the definition of an optimized methodology for the realization process became an important issue. Project realization is scheduled for 2005 – 2013, Table 2 shows the concrete time-table.

Table 2. Time Table

Preparation phase	2005 – 2007
Planning phase	2007 – 2010
Construction phase	2009 – 2011 (for housing, commercial buildings will be finished later)
Completion	2013 (for housing, commercial buildings, renovation will be ongoing)

2. Methodology

Successful realization of the project has to be built on two main focuses. On the one hand the steering of the realization process with involvement of many institutions and stakeholders is essential for project success. On the other hand the optimization of technologies on energy efficiency and renewable energy is crucial for achieving performance criteria.

2.1. Realization process

Effective steering of the realization process needs first identification of the relevant players and their roles. Furthermore binding instruments for realization and effective monitoring of the process itself are essential.

Partners and their roles: Besides the City of Salzburg several social housing associations / project developers and the former utility that is/was owner of the area involved. This needs clear identification of their roles in the project, because partly the partners have different roles in the project.

Quality agreement: A quality agreement was worked out and signed by all partners. This agreement includes a commitment to the performance criteria, minimum requirements of building standards and the obligatory fulfillment of the energy supply concept.

Steering group / Working groups: A monthly steering group of leaders of key actors was installed to monitor fulfillment of quality agreement. The steering group is chaired by the city of Salzburg. In addition to the steering group working groups were established.

Fig. 1 shows the different involvement of partners depending on their specific roles.

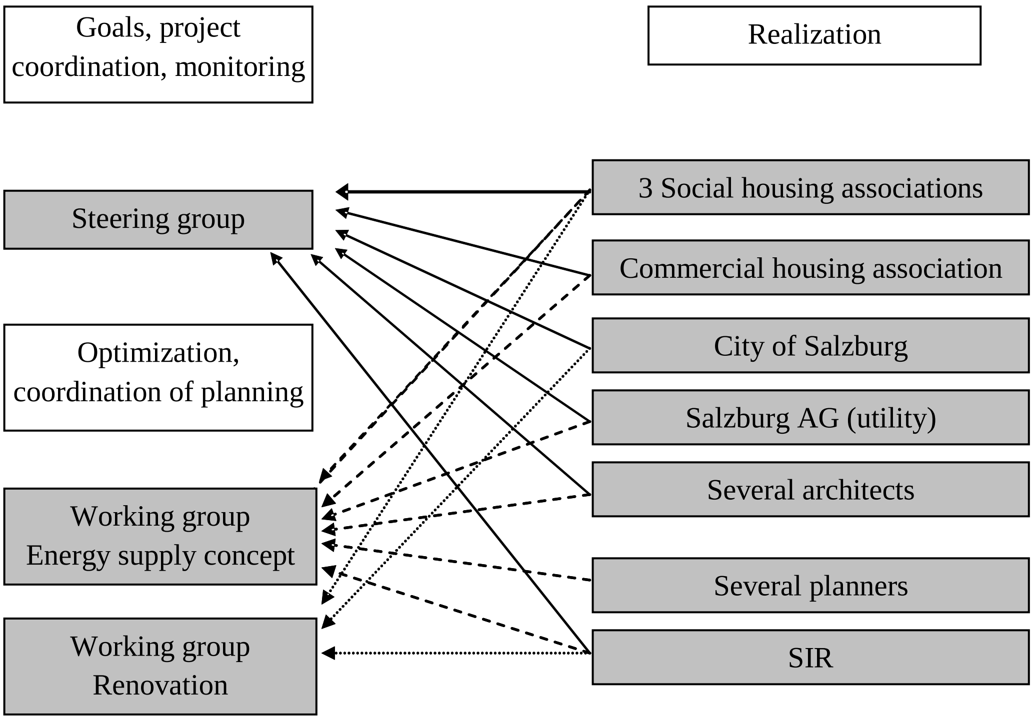

Fig. 1. Process organization

2.2. Building standards

Focus of Stadtwerk Lehen was put on high share of renewable energy, both for heat and electricity demand. Ambitious energy performance of the buildings was seen as the basis for achieving the targets. On the other hand there are existing rules of funding schemes which are limiting the investment costs for social housing. Thus low-energy standard was required as minimum instead of more ambitious passive house standard. Table 3 shows the targets for new buildings and renovation. Based on this target minimum U-values for new buildings and retrofit were defined.

Table 3. Minimum requirements of building standards

	Specific heat demand (kWh/m².a)
New buildings	< 20
Renovation	< 30

For new buildings required standards were contracted with involved housing associations and included in the calls-for-tender. For existing buildings project had to start with increasing motivation for renovation since there was no instant need for overall renovation within the tenants. Thus a detailed study on chances of modernization was done in one part of the existing area called "Strubergassensiedlung". This study was explicitly performed by an external expert, who has also no fear on possible conflicts and who has no expectation of further planning jobs. Goal of this study was to show the chances of renovation – concerning improvements in energy consumption but also related to issues of quality of life (quality of apartments, quality of public space …) and economic benefits. Based on detailed analyses of the buildings and concerned to energy standards several variants were analysed:

- Standard-renovation
- Factor 10- renovation
- Passive-house-standard-renovation resp. for addition of another storeys

Table 4 shows needed standards of main components of renovation.

Table 4. Thermal standards of main components of renovation

Building Component	Stock	Variant 1 Standard		Variant 2 Factor 10		Variant 3 Passive-house	
	U-value	Insulation	U-value	Insulation	U-value	Insulation	U-value
	W/(m^{2}K)	cm	W/(m^{2}K)	cm	W/(m^{2}K)	cm	W/(m^{2}K)
Outer wall	1,015	16	0,180	20	0,138	25	0,114
Basement ceiling	1,111	12	0,231	20	0,151	25	0,124
Ceiling above upper floor	0,812	20	0,143	25	0,119	30	0,101
Pitch of the roof	1,127	27	0,154	30	0,131	35	0,113
TH-wall to cellar	1,722	16	0,194	20	0,146	25	0,119
TH-wall to attic	1,722	16	0,194	20	0,146	25	0,119
Outside door	2,800		1,250		1,250		0,800
Interior door to unheated	2,800		1,250		1,250		0,800
Window			0,9		0,85		0,8
Outer wall to soil	1,596	16	0,192	20	0,158	25	0,129

Considering the different standard of each building of the "Strubergassensiedlung" and individual approaches concerned to actual standards a renovation plan for the whole area was elaborated. For buildings where criteria like quality of apartments are already high standard renovation is suggested. Other buildings where there will be total renovation necessary are suggested to be in passive house-standard.

2.3. Energy supply concept

The challenge to integrate renewable energy in existing supply system of the city was solved by following a strategy based on solar energy and district heating system. But there are additional improvements necessary to meet the goal of high share of renewable energy. Increase of solar fraction is achieved by installation of a heat pump in order to increase efficiency of solar collector fields. In addition to that also an own micro-net for heat supply of the whole area is foreseen. This micro-net in combination with planning directives for all of the housing projects allows low temperatures and thus higher solar gains. Fig. 2 shows the hydraulic scheme including the main components solar collector, storage tank, heat pump and micro-net.

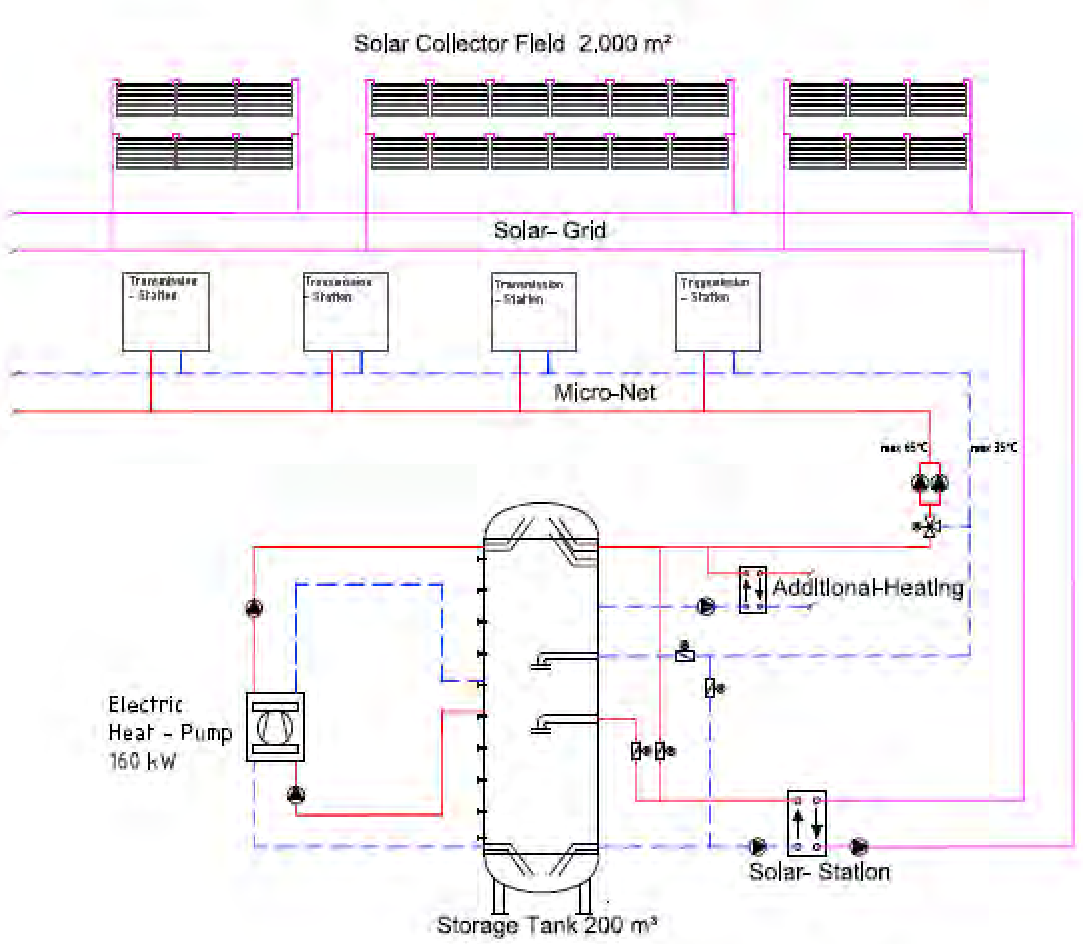

Fig. 2. Hydraulic scheme

Based on the heat-supply concept detailed simulation were done in order to optimize the whole system. Different scenarios were calculated:

- Assumptions of heat-demand because of different time-tables of planning (new residential buildings
- New commercial buildings, existing residential buildings
- Size of collector field
- Size of storage tank
- Size of heat-pump
- Return temperature of micro-net
- Type of heat pump (electricity, gas)

As an example Fig. 3 shows the influence of the return temperature of the micro-net on the collector yield. It is evident, that return temperature has generally a high influence on efficiency of the district heating system (high temperatures mean lower efficiency of solar system and lower capacity of storage tank). By using a heat pump the influence of return temperature on solar yield can be reduced. Simulation shows that there is a higher solar yield in case of 50°C return temperature and heat pump in comparison to solution with 30°C return temperature without heat pump.

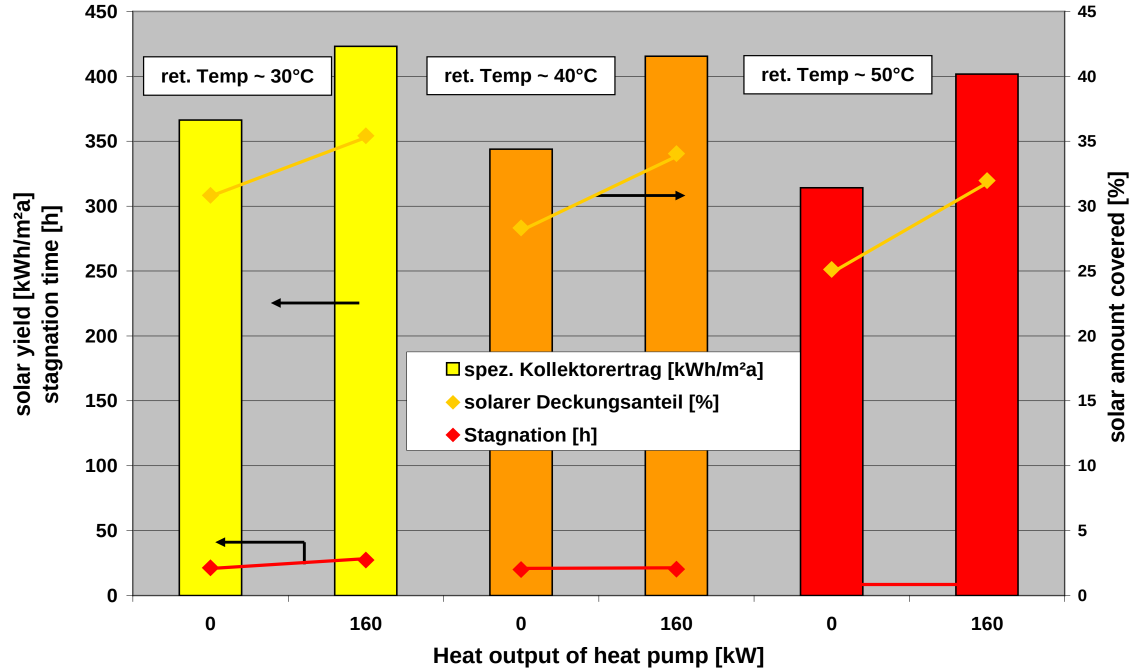

Fig. 3. Influence of return temperature

3. Results

Yet new buildings are under construction, required building standards will be achieved. Optimized energy supply concept is based on 2.000 m² solar collector fields and 2.000 m² of storage tank in combination with a heat pump and an own low-temperature-micro-net for heat distribution. The calculation of primary energy demand for several variation of energy concept (Fig. 4) showed, that system with solar collectors in combination with electric heat pump leads to the maximum reduction of non-renewable primary energy demand, compared to energy supply based on district heating and solar energy. But it is essential, that the result depends very much on the primary energy figures of the electricity.

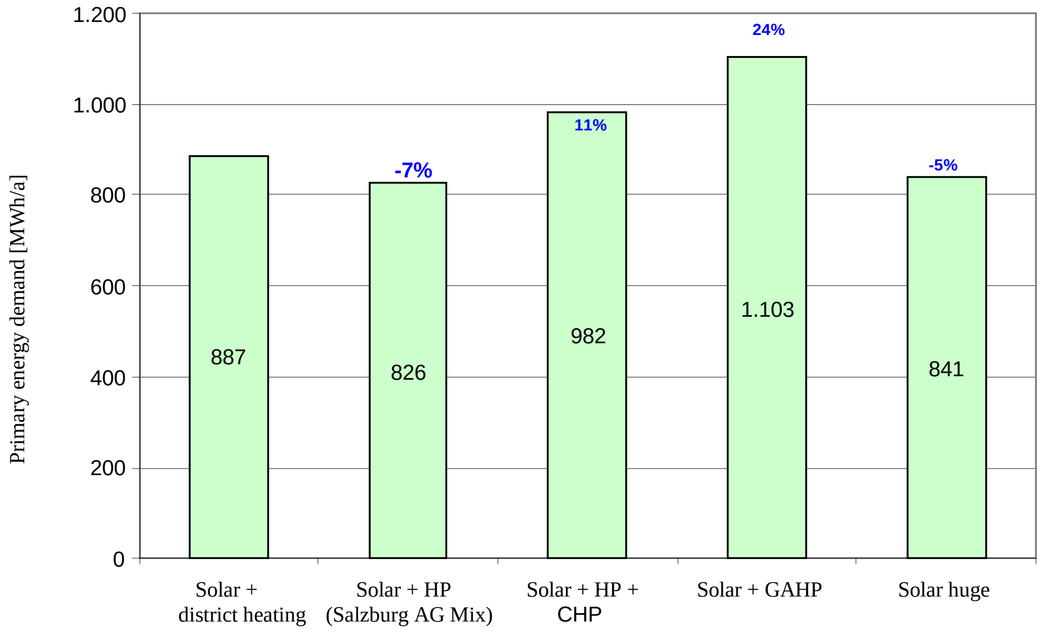

Fig. 4. Primary energy figures

At least, a reduced electricity demand for public areas will be achieved with efficient lightning systems and pumps. Demand will be covered with PV-modules on the several buildings.

4. Discussion and Conclusion

Driving forces
For project of "Stadtwerk Lehen" funding programs were the main driving forces at the beginning. Without this opportunity there would be no discussion on development of an ambitious project like it is now neither a development of an energy concept for new building areas and existing community. So for further projects driving forces have to be identified.

Clear roles
In addition to that funding-programs have led to a signed partnership of relevant institutions and persons. Furthermore roles of partners are defined; in particular there is the defined mission for developing an overall energy concept for the whole area and with defined interfaces to the several planners of the buildings.
Thus further projects which have do be developed need to have clarified before

- who will define the overall energy concept,
- purchased by whom,
- financed by whom,
- at which time of project development?

These questions can become an important issue for development departments of local administrations, although they may not understand as being responsible for energy planning.

Process design for successful renovation projects
Decision making for renovation of existing building stocks is a complex process if there are a couple of stakeholders with each with his own interest addressed. The implementation of a detailed showcase-study was very helpful to show the possibilities of total renovation and its

options for the overall refurbishment of the district. Thus renovation does not only include insulation of buildings. In fact modernization means more than renovation and offers more possibilities to address the expectations of the tenants. Furthermore it is important that specific interests of tenants are addressed with modernization activities, although they might not be energy-related. This helps to get tenants support for renovation process.

Ambition versus market situation
Renovation of multi-storey building is planned to achieve high energy standards. In opposite to social housing sector commercial buildings are highly depending on market situation. If there is less interest on commercial areas with high energy standards (and thus also higher rents) it is very difficult to implement ambitious projects.

Optimized energy concept for whole community
Energy concept for new buildings can be planned and optimized since relevant figures and stakeholders are known. Integration of building stock causes several further questions such like:

- Figures about actual heat demand
- Figures about expected heat demand after renovations / modernizations
- Schedule of renovation process

Thus optimization has to consider several uncertainties respectively planning has to be modular. Further it has to be discussed who has to take the risk for additional costs.

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Towards a 2kW City – the case of Zürich

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Abstract: In 2004 the Council of the Federal Polytechnics of Switzerland proposed that the country's per capita primary energy demand should be reduced by a factor of three from its current average of around 6kW to 2kW – the current global average – by 2150. During the past six years the semantics of this proposition have been much debated, but the concept has won overall favour, with several cities voicing their support. Indeed in November 2009 the inhabitants of the city of Zürich voted in favour of applying the 2kW city concept to their city, but targeting the year 2050. Thus, the city of Zürich is now committed to understanding which strategies should be employed and when, to achieve 2kW city status. But the city is not naïve, it fully appreciates that this target is ambitious and will only be realised through commitment and a multiplicity of transition strategies; some of which have already been implemented. But to understand, which are the most promising future strategies will require some form of predictive model. In this paper we describe one such model, which is currently under development, and the strategies that may be tested by it as well as outlining the already implemented strategies.

Keywords: *Urban sustainability, Environmental politics, Micro-simulation*

1. Introduction

In 2009, the total end energy use in Switzerland amounted to about 878 PJ [1] of which 55.1% are covered by petroleum products and 23.6% by electricity. Approximately 55.8% (*cf. Fig. 1*) of Switzerland's overall electricity conversion comes from hydropower, which forms the main part (96.5%) of electricity produced by renewables [2; 3]. Nuclear power plants account for 39.3% of domestic conversion and conventional thermal energy/other renewable energy plants for approximately 5% (*Fig. 1*). And while hydropower has been, historically, Switzerland's longest-serving and most important source of renewable energy, other renewables including solar, wood, biomass, wind, geothermal and ambient heat are starting to play an increasingly important role in Switzerland's energy supply [1; 2]. Private households, industry, services and the transportation sector account for almost 29, 19, 16 and 35% of Switzerland's energy use, respectively (*Fig. 1*).

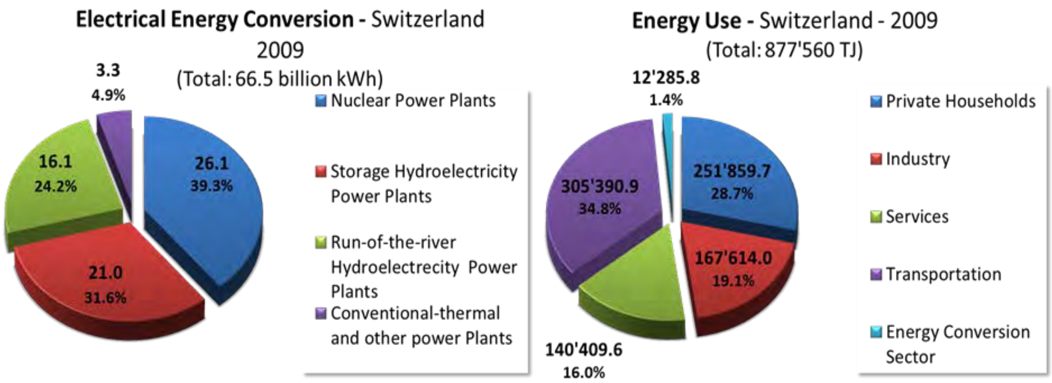

Fig. 1. Electricity conversion (left) and total energy use (right) by sector in Switzerland for 2009 [1; 2]

Ten years ago, the Swiss Federal Institute of Technology (ETH) in Zürich developed the vision of a "2000-Watt Society" which represents Switzerland's approach to tackling climate change and the upcoming conflict of resources. It is based on the idea that the Swiss citizens limit their energy use to the global average value of 2000 watts by the year 2150. Should other developed countries follow suit, this would enable the per capita energy demands of developing countries to increase, to meet their inhabitants' aspirations for improved living standards, without further increasing the global average. Furthermore, renewable energies should be used to satisfy at least 75% of these 2000 Watts, so that on an annual basis only one tonne of carbon dioxide equivalent is emitted per capita and year. The use of nuclear energy should also be completely phased out [4]. The implications of this approach are summarised in Fig. 2.

By closely analysing the unexploited efficiency and substitution potentials in Switzerland, scientists of the Swiss Federal Institutes of Technology (ETH) and other institutions have shown that the vision of a 2000-watt society is indeed feasible. They concluded that a period of between 50 and 100 years would be needed for this to become a reality [4].

Following from this, the citizens of Zürich participated in a referendum in November 2009, with around three quarters voting in favour of committing to achieving the 2000 Watt society status, but by **2050** [4]. This follows from a long standing commitment in Zürich to reducing the city's energy use. Indeed in 2000 the city acquired the label "Energiestadt®", which has since become a Europe-wide initiative, the "European Energy Award®". Four years on, the city was recertified and obtained the label "Energiestadt® Gold" [5].

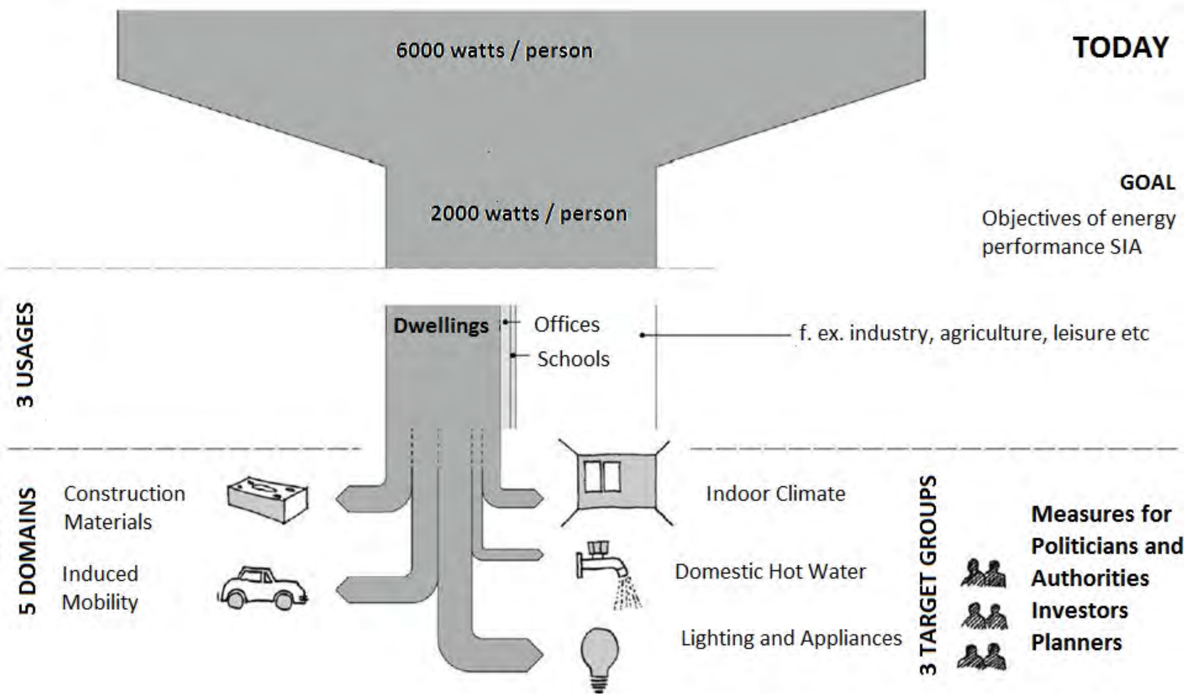

Fig. 2 The strategic plan to achieve a 2 kW-City-of-Zürich (original figure taken from [6])

2. 2 kW City of Zürich

2.1 Current energy breakdown: magnitude of improvements required

Private households and transportation are together responsible for around 60% of energy use in Zürich, with the remaining 40% being used by industry, commerce, services and retail sectors (economy and administration) (*Fig. 3*). Of these latter the non-industrial uses are dominant in Zürich. As such the city's efforts should be focussed upon transport, housing and other non-industrial building uses.

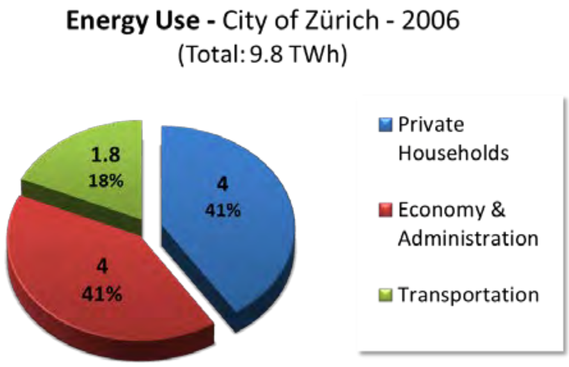

Fig. 3. Energy use by sector for the city of Zürich for the year 2006 [7]

The city has identified that, amongst the required improvements is reducing the energy use through better conservation and improving energy efficiency, while developing and exploiting innovative technical solutions. Thus, it is important to encourage the intelligent and efficient use of eco-friendly resources and materials, the utilization of waste heat and renewable energy, but also to promote social learning processes, new life styles and management concepts [8; 9].

Following from the above observations, the city is currently focusing on the following strategies to achieve its 2kW status:

- Building Sector: Implementation strategies regarding the use of better insulating construction methods and energy-efficient technologies. The target here is to demonstrate the feasibility by renovating and constructing "demonstration" buildings with low initial, running and maintenance costs, while ensuring a high quality of living [10].
- Mobility: Promotion of a more expansive and energy-efficient public transportation system whilst facilitating pedestrian and bike traffic. The city, in collaboration with the Canton of Zürich, has also proposed to launch a road pricing initiative to encourage the switch to more sustainable transport modes [10].

2.2 Initiatives under way since 2004

As part of its commitment to the European Energy Award the city has already established several initiatives which may be further reinforced during the coming years. And while Zürich promotes energy-efficient measures, companies and individuals can benefit from a vast variety of information and advice, including:

- Advising/educating/energy coaching: for eco-friendly lifestyle/behaviour in buildings and the induced mobility by various departments of the city to different actors (constructors, investors, operators and users) [11; 12; 13].
- Assessing existing buildings/construction projects: A methodology has been designed which makes use of the comprehensive international Life Cycle Inventory database "ecoinvent" [14]. This database contains indices relating to embodied energy and gaseous emissions (e.g. CO_2-equivalent) for a broad range of composite materials and their constituent parts [15].
- Environmental policy guidelines/regulations: Defining specific thresholds of energy use to assess the progress of energy savings in the building sector as well as its induced mobility [22]. The City Council also uses this document to formulate environmental policy

guidelines. For the construction sector, specific guidelines have been conducted regarding HVAC systems, electrical appliances and sanitary fittings [11].

- Financial Support:

  To promote and support the required transition strategies several incentive schemes have been established for energy-efficient investments. This includes subsidies provided to private citizens, firms as well as institutions, on a communal, cantonal and federal level:

  - Cantonal support program: Information and financial support (also for expertise of impartial consultants) of energy-efficient refurbishments [16].

  - Electricity Savings Fund of the City of Zurich: Subsidises investments for the efficient use of energy and the integration of renewables [17].

  - Subsidies from CO_2 tax on heating oil [18]: At the federal level, insulation improvement measures of the building envelope are subsidized for buildings which have been constructed before 2000. Furthermore, in the Canton of Zürich the use of renewable energy, modern building technology and the use of waste heat is supported [19].

  - Reduction of interest rates on credits for investments in energy-efficient measures: Environmental reductions up to 0.8% for new construction and renovation according to the MINERGIE® standard, investment in renewable energies, energetic refurbishments and other ecological projects [20].

  - Tax deductions: Investments in energy-saving renovation of old buildings can be partially deducted from tax [21].

3. A bottom-up model of urban energy flows

As noted above, the city of Zürich is very aware of the need for some rational basis to guide their decision making processes with respect to the choice and implementation of strategies for making the transition from the current per capita energy use of around 5kW to just 2kW within the next forty years. Ideally, this should be some form of model with which alternative hypotheses may be tested. Now, since the principle uses of energy within Zürich are to condition buildings, support the activities accommodated within buildings and to transport goods and people between buildings (see section 2.1), it follows that our decision making model should represent buildings and transport systems. Such a model may be spatially aggregated (or macroscopic), treating the city as an ensemble in which we model the stocks and flows of resources between compartments of this ensemble. Or we may have a spatially disaggregated model, in which we explicitly model individual buildings in their spatial context as well as individual transport journeys between these buildings. Or we may opt for some compromise between these two: for example grouping buildings into clusters and explicitly modelling an example from within each cluster and extrapolating to the remainder.

As part of a project funded by the Swiss National Science Foundation, we have elected to develop a spatially explicit or micro-simulation program, which combines the modelling capabilities of two complementary tools: CitySim for buildings and MATSim for transportation.

CitySim [22] is a detailed simulation program for predicting the energy demands of buildings as well as the supply of energy to them, whether using building-embedded or district scale energy conversion systems. It takes as input a 3D description of the scene to be simulated, in which each building is attributed according to the thermal and optical properties of its construction, characteristics describing its occupants as well as the heating, ventilating and energy conversion systems. Either the buildings, or the district to which they belong, are then associated with characteristics describing their energy conversion systems. This scene description is parsed to an integrated dynamic model which simulates energy demands for heating, hot water, lighting, ventilating and cooling as well as for electrical appliances. These simulations account for the stochastic nature of occupants' presence and their interactions with the building envelope and its active systems as well as the effects of adjacent obstructions on surface radiation exchanges (accounting for occlusions to sun and sky as well as reflections from these occlusions). CitySim is thus a comprehensive and detailed program for simulating building-related energy flows at the urban scale.

In complement to CitySim, MATSim [23] simulates the sub-hourly transport of individual people within our urban scene. For this a geometric description of the scene is required, consisting primarily of the transport network nodes and the links between them as well as the locations of activities (work, home, education etc) located at or adjacent to these nodes / links. Using geo-coordinated census data a population of households may then be created. The members of this population are then associated with activity chains such as home-work-leisure-work-home and the locations and preferred timing of these activities. With this initialisation complete the scene may be simulated. Following from an initial shortest route finding algorithm, an optimisation algorithm is employed to optimise travellers travel plans: identifying departure times following each activity which maximise travellers utility, based on minimising travel time and maximising the time spent performing the required activities. With agents' daily travel plans chosen, their final journeys may be simulated and the associated fuel consumption calculated, using empirical performance data.

The means for coupling CitySim and MATSim is via the exchange of people. Upon launching a simulation a population of agents is generated, with each agent being associated with socio-economic characteristics, travel plans, building locations (e.g. residential and workplace) corresponding to these plans, environmental comfort preferences to be applied whilst within these buildings etc. MATSim is then launched to simulate agents' arrival and departure times at the geo-referenced buildings. These agent IDs and their arrival and departure times are then parsed to CitySim which simulates each buildings' energy demands as well as the supply of energy to them. Thus we have a comprehensive platform in which we are able to test a range of strategies, including:

- Inhabitants' investments in: building renovation measures, more efficient vehicles, public transport season tickets etc.
- Energy service company investments in distributed heating, cooling and power systems.
- Uptake of subsidies to encourage more widespread uptake of building-embedded renewable energy conversion systems.
- Changes in buildings' use to reduce transport energy demands and improve the match between energy demand and distributed energy supply system etc.

And of course the energy implications of the above measures.

Having now developed a first prototype of this coupled building-transport modelling platform we are currently in the process of testing this in conjunction with a district of the City. Our next step will then be to prepare and calibrate a whole city model and to test hypotheses for improving its energy performance; strategies that we will define in liaison with the City stakeholders.

4. Conclusions

Following from a longstanding commitment to reduce its use of energy and associated adverse environmental impacts, the citizens of the city of Zürich recently voted in favour of reducing its per capita primary energy use from its current level of more than 5kW to just 2kW within the next forty years. Other complementary commitments are to reduce per capita greenhouse emissions to below 1t CO_2 equivalent per Capita and to eliminate the use of electricity derived from nuclear sources. In pursuance of these objectives the city has already implemented a range of programs to contribute towards the required transformations, but so far these are relatively modest in their ambitions. The city understands that to achieve its ambitious objectives, will require serious commitment and a multiplicity of initiatives. To assist in this process the two Swiss Federal Institutes of Technology (Lausanne and Zürich) are collaborating in the development of a new urban energy modelling platform, integrating micro-simulation programs of buildings, distributed energy conversion and storage systems and transport systems.

A first prototype of this new modelling platform has been developed and is being applied to a sample district of the city. Following from this initial application a full scale city model will be prepared and a range of scenarios defined and tested, with the solicited contributions of key city stakeholders. It is also intended that a working model of the city will be handed over to the city, to support its continued updating and application to test future strategies.

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Application of mechanical heat treatment for the recovery of plastics as energy resource

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Abstract: The mechanical heat treatment (MHT) is one of the pre-treatment alternatives for conditioning the municipal solid waste (MSW) before its further separation, recovery and reuse. The MHT would result in the change of properties of constituents of MSW, making it suitable for separation. For example, the plastics may be softened and shrunken. Therefore, the MSW via the pre-MHT can be more easily separated into various fractions of resources such as metals, plastics, compost-like and primary refuse derived fuel (RDF) or bio-char for further re-utilization.

The objective of this study was to examine the efficiency and effective of energy recovery and volume downsize of plastics via MHT process. The commonly used plastic, high-density polyethylene (HDPE) was tested. The changes of weight, triple components, true density and calorific value of target plastic before and after the MHT with saturated steam at 100, 150 and 180 ^{o}C were examined. The effects of temperature on the performance of MHT were assessed. The results indicated that an increase of MHT temperature induces more significant shrinkage and higher volume density, enhancing its feasibility for the separation from non-plastic materials. The information obtained in this study is useful for the rational design and proper operation of MHT system for treating the used plastics in the MSW and separating it for the re-utilization as energy resource.

Keywords: *Energy resource, Mechanical heat treatment, MHT, Municipal solid waste, MSW.*

1. Introduction

The ultimate goal of the waste management aims at the complete collection of the garbage, proper treatment for the thorough energy recovery and material reuse targeting at a sustainable utilization of all resources. Traditional waste treatments processes include landfill, incineration and recycling. Incineration is a process which directly combust or incinerate the waste to generate heat and then recycle the energy through the production of steam or hot water with the help of heat recovering facilities. The incineration residues including sand, ceramic, glass, metal and little incomplete combustion of organic matter are sent to landfill. The process of incineration not only wastes a significant amount of reusable energy, but also produces secondary pollutants such as ash dregs or fly ash [1-3]. Further, if the plastics are directly recycled without any pretreatment, it will cause the lack of storage space and the consumption of transportation expense. Therefore, the new generation of energy recovery technique of the waste to replace incineration must take into consideration all kinds of factors such as the complex varieties and properties of the waste, the availability of waste as a resource, the technique for its transportation and storage, the constrain of economics and relevant regulations and the energy or environmental benefit for the whole systems. Thereafter, in addition to the enhancement of performance and the reduction of the cost, it has become a trend converting the waste into energy of different forms. According to a report of Environmental Protection Administration of Taiwan (TEPA) in 2008 for the Municipal solid waste (MSW) composition, there are 44.54% of paper, 2.63% of fibrous cloth, 1.99% of wood, bamboo and fallen leaves, 30.56% of kitchen waste, 17.28% of plastics, 0.36% of leather and rubber, 0.33% of ferric metals, 0.33% of non-ferric metals, 1.11% of glass, 0.5% of ceramic sands and 0.48% of other combustible materials [4]. These data reveals that there is a high content of plastics in the MSW. With certain kinds of pretreatment techniques, the separation of MSW and the followed resources recovery and reutilization may become more complete and efficient. The so called cooking assorting or mechanical heat treatment (MHT) is one of the techniques that are worthwhile to be evaluated [5,6]. The MHT would result in the change of properties of constituents of MSW, making it suitable for separation. For example, the mass of non-plastics decreases while the volume density increases. The cellulose and hemi-cellulose of biomass in MSW are decomposed for easy torrefaction. The plastics may be softened and shrunken. Thus, the objective of this study was to examine the efficiency and effective of energy recovery and volume downsize of plastics via MHT process. In this research, we investigated over the changes of weight, triple components, true density and calorific value of high density polyethylene (HDPE) before and after the cooking process for the reference need in plastic recycling from MSW via cooking separation process.

2. Methodology

2.1. Devices

Cooking apparatus used for this experiment is illustrated in Fig. 1. This apparatus includes a steam generator that can produce saturated steam and a high temperature (398-593 K) and high pressure (5-205 kg cm^{-2}) autoclave equipped with stirring accessory. The autoclave is made by stainless steel 316 with inner volume of 1.5 L. The stirring axes are composed by outer and inner axes. The inner axis is enclosed in the outer axis and driven by the outer axis with magnetic force. The bearing is cooled by cooling water. The outer axis is connected to 0.25 hp motor. The upper cap has six holes with three for thermal couple, pressure gauge and release valve, while three for spare port. The steam generator is constructed by an autoclave and an oven. The heating wire of oven is made of nichrome. The oven temperature is controlled by a proportional-integral-differential (PID) controller with K-type thermal couple in the vessel.

2.2. Experimental conditions

HDPE, the most common plastic that can be found in MSW for the experiment, was selected. Then the cooking experiments was performed 60 minutes with 100, 150 (P_g = 5.15-5.4 kg cm^{-2}) and 180 ^oC (Pg = 8.05-10.25 kg cm^{-2}) saturated high temperature steams via cooking apparatus. The dry weight changes, triple components (including water, ash and combustible components), true density and calorific value for the HDPE before and after the cooking process were examined.

2.3. Analytical methods

The thermal stability of HDPE was analyzed by the thermal gravity analysis (TGA) (model TGA51, Shimadzu Co., Kyoto, Japan). The calorific value was measured by a calorimeter (model 6775, Parr Instrument Company, Moline, Illinois, USA). The triple components were analyzed by a high-temperature oven (model muffle furnace DF 40, Deng Yng Co., Taipei, Taiwan).

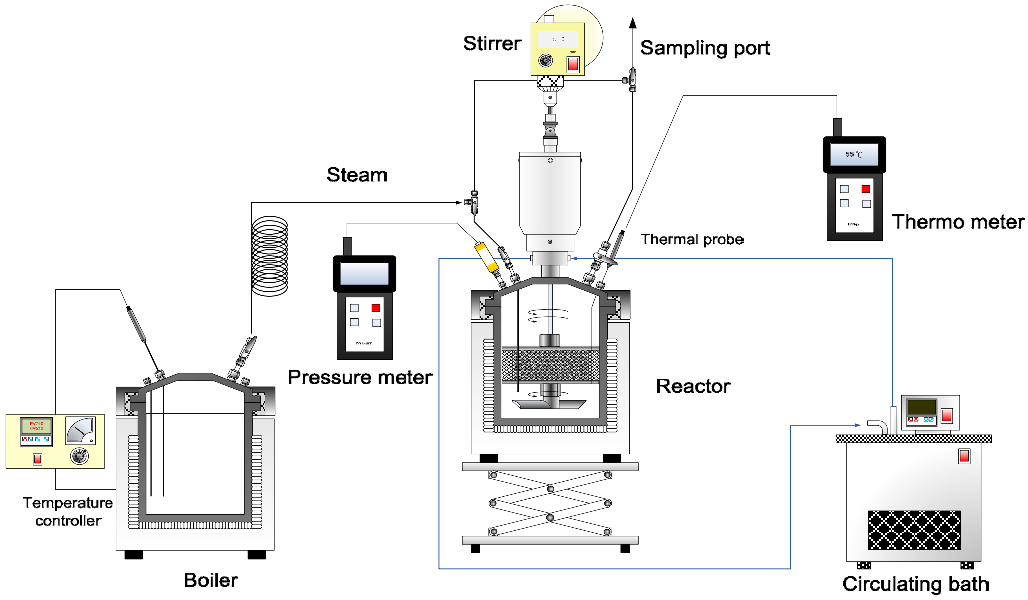

Fig. 1. Mechanical heat treatment (MHT) apparatus used for the recovery of plastics as energy resource.

3. Results

3.1. TGA of HDPE

TGA has proven to be a useful and efficient technique of the estimation of thermal stabilities of plastics. TGA is also widely used in studying pyrolytic processes. In this research, we investigated over the TGA to observe the degradation point and thermal behavior of HDPE. Fig. 2 is the TGA result generated on the HDPE at an applied heating rate of 10 ^{o}C min^{-1} before cooking process. As displayed in Fig. 2, weight loss curve is smooth, with one inflection point during reaction under nitrogen atmosphere. Figure 2 also shows that the decomposed point of HDPE is about 377 ^{o}C. Decomposition reactions for the heating rate of occurred at the temperature range from 630 K to 850 K.

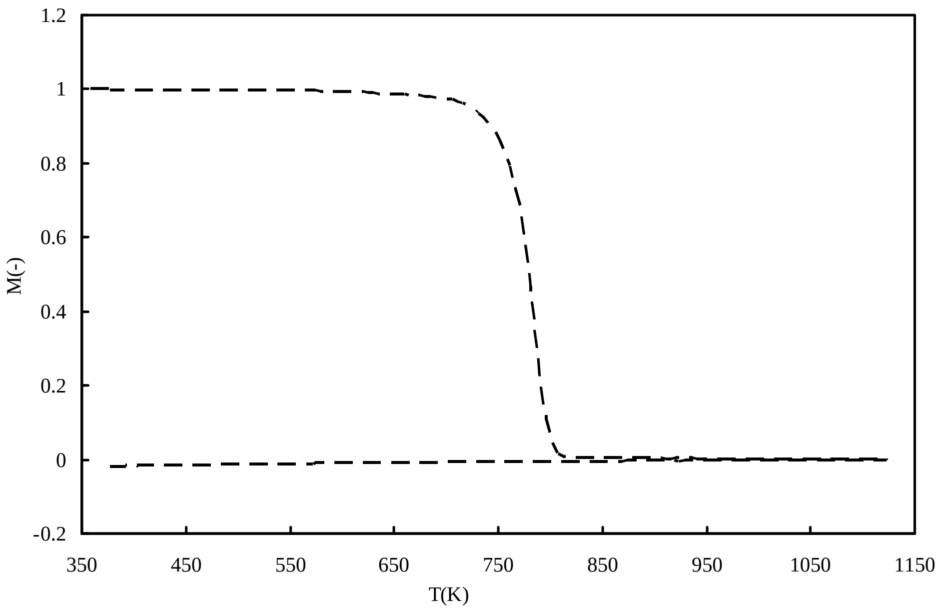

Fig. 2. The TGA curves for high density polyethylene (HDPE).

3.2. Dry weight changes after cooking

We can roughly speculate the thermal characteristics of the HDPE samples by the observation of weight changes in samples. As shown in Fig. 3, there is no significant dry weight change before and after cooking process in a steaming condition of 100, 150 and 180 °C. As HDPE has a melting point of 130-140 °C and a degradation point of 350-380 °C [7], the results indicate that the melting of HDPE at 150 and 180 °C has negligible effect on dry weight reduction.

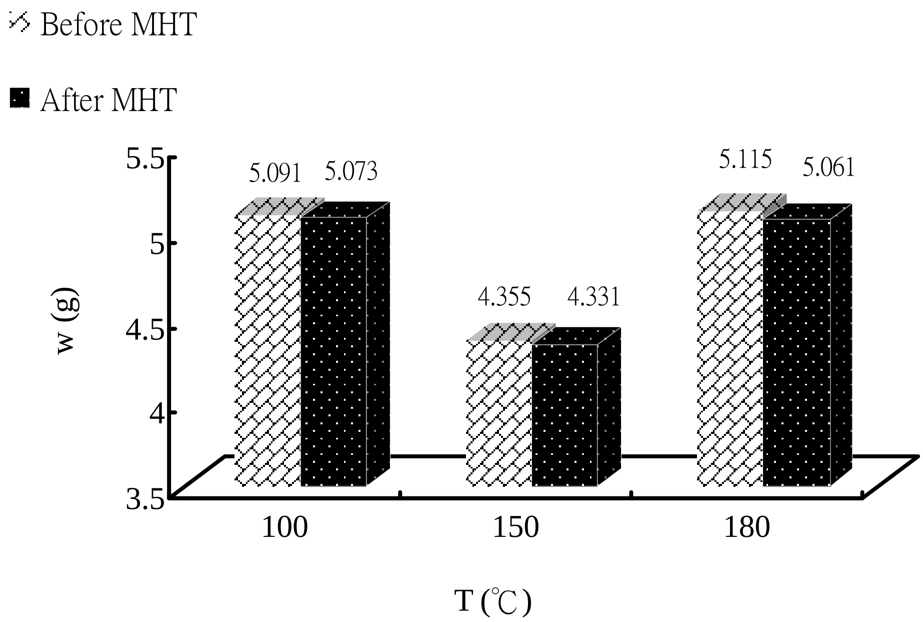

Fig. 3. Dry weight changes for HDPE before and after the MHT with saturated steam at 100, 150 and 180 °C. w: Dry weight.

3.3. Triple component analysis

With the analysis of triple components (including water, ash and combustible components), we can know if there's any change in the organic components of the samples. Moreover, a high quality of RDF would possess a higher value for the combustible component, and lower values for moisture and ash contents. Thus, the triple components analysis is also an important index to assess MSW if it is suitable to be utilized as RDF. The results of Fig. 4 show there is little change in the amount of combustible component existed in HDPE after cooking. The combustible component content is 99.62% before cooking and 99.02, 98.98, 98.21% after being cooked in saturated steam condition of 100, 150 and 180 °C, respectively. Therefore, we can conclude that the organic component does not reduce in those steaming conditions of 100, 150 and 180 °C. The results also indicate that the combustible component (> 98%) of HDPE is very high, which is larger than that of the unprocessed MSW (30-40%). Thus, if we recycle the plastics as energy resource or RDF via MHT process, the energy utilization of MHT will be more efficient and effective than that of direct incineration treatment of MSW.

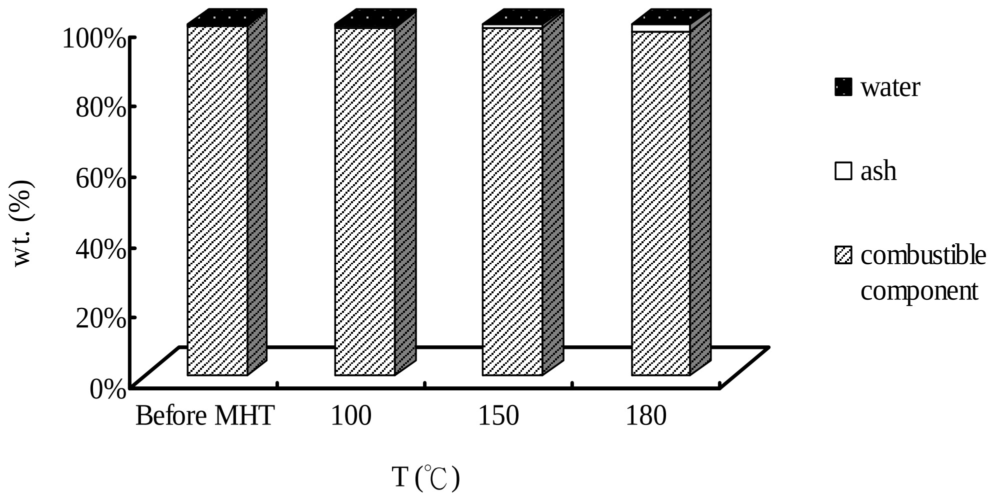

Fig. 4. Triple component analysis before and after the MHT with saturated steam at 100, 150 and 180 ^{o}C. *wt.: Weight percentage.*

3.4. True density changes

Figure 5 indicates that with an increase of temperature of steam introduced, the true density after cooking offers increases, reaching a value of 0.983 g cm^{-3} at 180 ^{o}C. This is due to that thermoplastic material fluidizes and swells after being heated. It then solidifies and shrinks from the melt status during cooling. Taking advantage of this characteristic, cooking process offers a very promising volume reduction effect for thermoplastics and can reduce the storage space and transportation expense drastically. Moreover, plastics soften and shrink into pellet shape with an increasing density and thus can be easily separated from other components existed in the MSW and enhancing recovery of plastics for utilization.

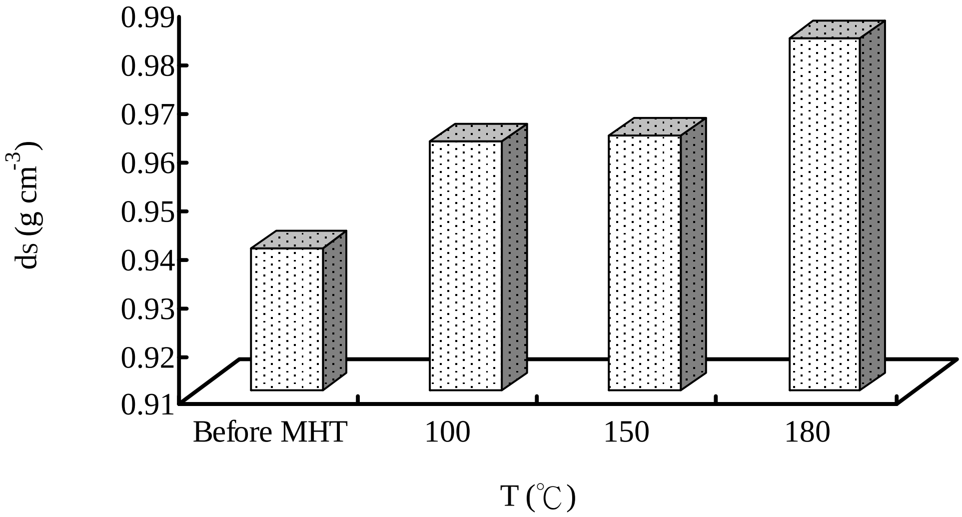

Fig. 5. True density changes before and after the MHT with saturated steam at 100, 150 and 180 ^{o}C. *d_S: True density.*

3.5. Calorific value changes

As shown in Fig. 6, the heating values (H_V) of HDPE before and after MHT are higher than that of coal of about 7000-8000 kcal kg^{-1} [8]. It has a value of 10654 kcal kg^{-1} before cooking and 10834, 10680 and 10669 kcal kg^{-1} after cooking in saturated steam condition of 100, 150 and 180 ^{o}C, respectively. We observed that H_V did not have a big change for the said cooking conditions. We can therefore conclude that the cooking process does not cause the degradation or other chemical changes of HDPE which may further influence its heating value. As contrasted with the H_v of 1889 kcal kg^{-1} of unprocessed MSW [4], it is clear that the separation of non-combustibles in the waste (glass and metals) can increase heating value and energy generation. From the point of view of maximization of energy recovery of MSW, MHT is a good pretreatment process for the separation of non-combustibles and energy recovery in MSW.

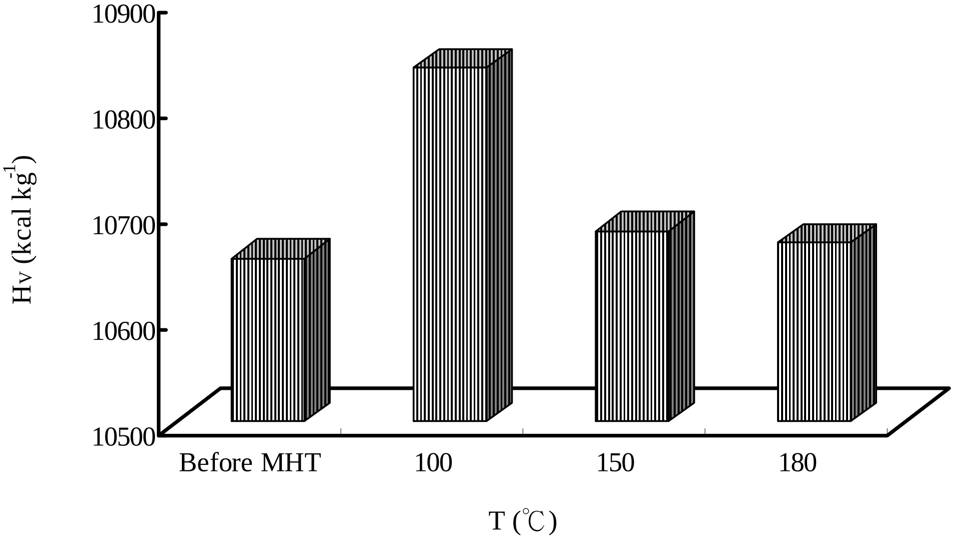

Fig. 6. Changes of heating value before and after the MHT with saturated steam at 100, 150 and 180 ^{o}C. H_V: Heating value.

4. Discussion and conclusion

In accordance with the theme of sustainable material management (SMM), the waste is viewed as the used material. The ultimate goal of SMM is targeted at total recycling and reuse without discharge of waste. To follow the appeal of SMM, this study applied the MHT for the recovery of waste plastics from waste stream, aiming at the feasibility of its recovery for the re-utilization as energy resource. As shown in Fig. 7, the recovered plastics can be directly utilized as RDF. The ferric materials and gravels can be separated via magnetic or gravity separations. The MSW containing cellulose (including organic fiber (fiber) and cotton (floc)) can partially hydrolyze after cooking to form bulk powder materials, which can help the decomposed cellulose granulation to produce renewable fuels. The treated MSW containing cellulose can be torrefied together with other agricultural and forestry materials to produce biocoal, or use as an agricultural soil improvement materials. Therefore, we can summarize that MHT has the following advantages including the disinfection, deodorization of the waste, ease of sorting and recycling and effective utilization of resources especially for energy use.

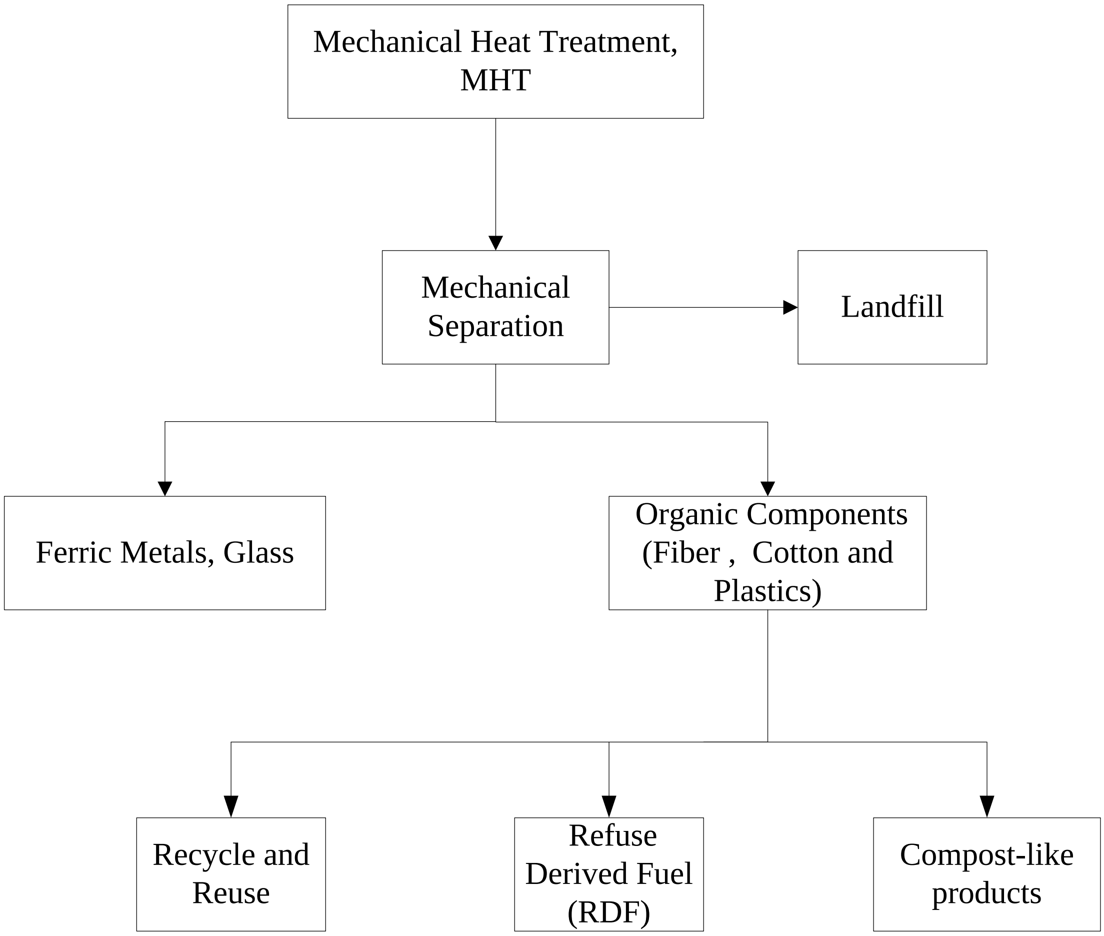

Fig. 7. The flow chart of Mechanical heat treatment (MHT) used for municipal solid waste (MSW).

Among these resources, the treated plastics can be easily separated, stored and transported, because the plastics are deformed and shrank into pellet shape with an increasing density after MHT. Further, the chemical characteristics, such as dry weight, combustible component and H_V, do not have significant changes for the said cooking conditions, which can be concluded that MHT is a good and interesting process to completely recycle the plastics as energy resource if compared to incineration treatment. The information obtained in this study is useful for the rational design and proper operation of MHT system for treating the used plastics in the MSW and separating it for the re-utilization as energy resource.

We can draw the following critical conclusions through the experimental results cited above.
(1) With the cooking technique, it can achieve a volume and size reduction of HDPE.
(2) The true density of HDPE reaches a high value of 0.983 g cm^{-3} with a 180 ^{o}C saturated steam condition.
(3) HDPE has a very high calorific value and exhibits no significant changes in dry weight, triple component composition and calorific value after MHT. It is very suitable to be used as RDF.
(4) As compared with the calorific value and combustible component of HDPE and unprocessed MSW, the energy utilization of MHT will be more efficient and effective than that of direct incineration treatment of MSW.

Acknowledgments

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Integrated waste management as a mean to promote renewable energy

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Abstract: Management of municipal solid waste is an efficient method to both increase resource efficiency (material and energy recovery instead of landfill disposal) and to replace fossil fuels with renewable energy sources (waste is renewable in itself to a large extent as it contains paper, wood, food waste etc.). The paper presents the general outline and results from a comprehensive system study of future waste management. In the study a multifunctional waste management system integrated with local energy systems for district heating and electricity, wastewater treatment, agriculture and vehicle fuel production is investigated with respect to environmental impact and financial economy. Different waste technologies as well as management strategies have been tested. The treatment is facilitated through advanced sorting, efficient treatment facilities and upgrading of output products. Tools used are the ORWARE model for the waste management system and the MARTES model for the district heating system. The results for potential global warming are used as an indicator for renewable energy. In all future scenarios and for all management strategies net savings of CO_2 is accomplished. Compared to a future reference the financial costs will be higher or lower depending on management strategy.

Keywords: *LCA, Waste management, ORWARE, Martes, Costs*

1. Introduction

Management of municipal solid waste is an efficient method to both increase resource efficiency (material and energy recovery instead of landfill disposal) and to replace fossil fuels with renewable energy sources (waste is renewable in itself to a large extent as it contains paper, wood, food waste etc.).

In this paper the general outline and results from a comprehensive system study of future waste management in the Gothenburg region is presented. The purpose of the system study was to evaluate new waste treatment options for municipal and industrial waste from a system perspective. In the study a multifunctional waste management system integrated with local energy systems for district heating and electricity, wastewater treatment, agriculture and vehicle fuel production is investigated with respect to environmental impact and financial economy. Different waste technologies as well as management strategies have been tested. The treatment is facilitated through advanced sorting (source separation of recyclable materials and MRFs (Material Recovery Facility) for both bulky waste and source separated household waste), efficient treatment facilities (thermal and biological treatment) and upgrading of output products (biogas as vehicle fuel and pelletisation of digestion sludge for use as fuel or as fertiliser in fields or forestry). The future district heating system comprises waste CHP and waste heat (excess heat) as base load and bio-CHP, natural gas-CHP and heat pumps as intermediate load while oil is peak-load. Thermal and biological treatment of waste is included and several scenarios of future waste management have been developed comprising a number of parameters for the background system and different waste amount growth rates.

The project has been carried out as a part of the project Thermal and biological waste treatment in a systems perspective – WR21 [1]. The focus has been set to the waste and district heating system in Gothenburg. The project has been running for 2.5 years with an active group consisting of persons from Renova, Kretsloppskontoret, Göteborg Energi, Gryaab and Profu. The work on development of models and of methods of handling strategic questions within the field has gone back and forth within the group.

2. Methodology

The method used is life cycle assessment (LCA) [2] and financial cost calculation facilitated by computer modelling with the ORWARE (Organic Waste Research) model [3] for the waste management system and the MARTES model [4] for the district heating system including CHPs (Combined Heat and Power). In this study waste streams suitable for thermal and/or biological treatment (including waste water treatment sludge) are included whereas fractions for material recycling are excluded.

ORWARE is a computer based tool for environmental and economic systems analysis of waste management. It was first developed for systems analysis of organic waste management, hence the acronym ORWARE (Organic Waste Research). The model is designed for strategic long-term planning of recycling and waste management and based upon static conditions and on linear programming (LP). The ORWARE model has been developed since the early 1990s in close cooperation between four different research institutions in Sweden (Royal Institute of Technology, Swedish Environmental Research Institute, Swedish Institute of Agricultural and Environmental Engineering and Swedish University for Agricultural Sciences). The waste management is followed from cradle (waste sources) via collection and transport to treatment plants and further to grave (utilisation of products from waste treatment). Treatment facilities included are incineration with energy recovery, composting, landfill, anaerobic digestion with biogas utilisation, spreading of organic fertiliser on arable land, sewage treatment, material recycling of plastic and paper packages, and some additional technologies. The model delivers substance flows, distributed to emissions to air and water, left in growing crops and in recycled material. Energy flows such as energy use and recovered energy is also provided. Single substances such as carbon dioxide or eutrophication substances to water can be tracked, as well as the amount of plant-available nutrients and emissions of different heavy metals. Emissions are also characterised and weighted using Life Cycle Impact Assessment. At the same time financial costs (investment and operational costs) and environmental costs and revenues including savings in the surrounding system can be calculated for the whole management chain.

MARTES is a model for district heating systems with production of heat, steam and electricity. The model simulates the use of different plants to satisfy the demand for district heating during a year. As a result the effects on costs and emissions are calculated, based on the energy conversion in the district heating system. The development of MARTES started on a mainframe computer at the Department of Energy Conversion in 1983. It has been commercially available on personal computer since 1990. Today it is the most widely used tool for strategic planning of district heating systems in Sweden, since it covers nearly 70 % of the produced heat [5]. The MARTES model captures operation of all facilities for district heating generation, given a exogenously given total need for heat. The heat demand is based on a load curve and described with a detailed time slice division into day and night periods. The model includes fuel and electricity prices and policy tools. The simulated plants are modelled with efficiencies (and with part load performance for CHP plants), minimum load for operation, availability, emissions of carbon dioxide, sulphur and nitrogen oxides. Annual fixed costs for equipment purchase and installation as well as variable and annual fixed costs for operation and maintenance are also included in the model. The output from the model is heat generation for all plants, power generation in CHPs, use of electricity in heat pumps and electrical boilers, fuel consumption and emissions to air.

As mentioned above the focus in the study has been the waste treatment and district heating system in Gothenburg. However, to generate a fully system analysis one also has to consider effects that occur in surrounding systems, such as the transport sector (biogas from waste substitutes petrol and diesel oil), the electricity production system (electric power from waste incineration with energy recovery replaces electricity generation from fossil fuels), the agricultural sector (nutrients from anaerobic digestion of waste and sludge are used instead of mineral fertiliser) etc. In this study; two different types of scenarios that reflects the situation of year 2030 has been set up: local scenarios and external scenarios [6]. In a local scenario we define the waste treatment processes that are assumed to be in operation in Gothenburg's waste treatment system in year 2030 (e.g. waste incineration, anaerobic treatment). Furthermore, an external scenario reflects the situation in the surrounding systems (e.g. price of electricity, fuels and CO_2-allowances). The local scenarios thereby describe developments that the actors in Gothenburg can influence, while the external scenarios describe developments that the actors have to adapt to. The main principles of the local scenarios that have been set up are as follows:

-Business-as-usual: This local scenario is characterized of a traditional development of the waste treatment system in Gothenburg, i.e. a significant share of waste incineration. The capacities in existing facilities are adapt to the amount of waste that are assumed to arise in year 2030. Today's central composting is still used for treatment of biological degradable waste from households. Sludge from the wastewater treatment plant is first treated in an anaerobic treatment facility, thereafter composted and finally sold as a soil product.

- Maximized return of nutrients: In this local scenario more of the arising waste is treated in biological treatment facilities, compared to "Business-as-usual". The capacity of the source separation system in Gothenburg is expanded and an anaerobic treatment facility is built that replaces the central composting. The capacity of the anaerobic treatment facility is set to 60 000 tonnes/year. The capacity of waste incineration is thereby decreased in comparison to the case in the local scenario "Business-as-usual". Sludge from the wastewater treatment plant is treated in an anaerobic treatment facility and thereafter used as fertilizer in the agricultural sector.

- Maximized electricity production: the source separation system is expanded and an anaerobic treatment facility is being built, similarly to the local scenario "Maximized return of nutrients". Furthermore a part of the combustible waste is going through a mechanical treatment process to create a refuse derived fuel. This fuel is used in a new waste incineration facility with a slightly higher electrical efficiency than the existing ones. Sludge from the wastewater treatment plant is treated in an anaerobic treatment facility. Thereafter the sludge is dehydrated and turned into pellets that are used as fuel in the new waste incineration facility.

Within the project a number of external scenarios capturing several parameters that describe the state in the economy, the energy system, the waste system (such as waste amounts etc.) etc. were discussed. Eventually three of these were selected for a more careful analysis.

- Reference: is a scenario that reflects a conservative development in the surrounding environment. The background system is changed but mainly the same impact and policy as of today prevails. The Reference scenario is not to be interpreted as the most likely scenario.

There is no valuation of which of the three external scenarios is the most likely one. All three projects constitute a “window of development” which is assessed as possible and realistic.

- Material lean growth: is a scenario that reflects a development where the society in general puts a lot effort in reducing environmental impact on a long term and evident environmental improvements are achieved compared to the system of today by policy measures and a change in values. The most important change in this study is that the trend of increasing waste amounts is broken and a decoupling effect (i.e. the waste amounts are no longer increasing at the same rate as economic growth) is present. This effect means that waste amounts follows the population trend in the region. This scenario also captures savings in energy use and more ambitious environmental targets which in turn affect the results of the system study. The magnitude of the economic growth is assumed to be on the same level as in the Reference scenario.

- Material intense growth: this scenario is characterized by an economic growth in society which exceeds the one in the other external scenarios, and a continuously increased consumption of material based products resulting in a higher growth rate for waste amounts than for the economy. This external scenario should not be looked upon as an opposite of material lean growth, also in this scenario there are assumptions on a development where the society is directed towards a decreased environmental impact.

A vast number of parameters have been studied and varied in the different external scenarios. A vital part that has been kept constant is however the tax system. Present levels of taxes on petrol, diesel, and natural gas to CHP etc. are used also in 2030. In reality these will probably change several times during the period to 2030. These changes are however very hard to predict, thus this conservative assumption.

3. Results

In table 1-2 aggregated results of the analysis for the three local scenarios is presented. Each local scenario has been evaluated from four different aspects: economy, climate, acidification and eutrophication of which the two latter is not presented here. The results are shown in scoreboards where the three scenarios have been given a gold, silver or bronze medal. The local scenario with the best result receives a gold medal while the worst result receives a bronze. The interval between these two results is then split into three. If the result for the local scenario not yet given a medal is placed in the upper third of the interval, the scenario receives a gold medal, a result in the middle interval return silver, while a result in the lover third gives a bronze medal. Each scoreboard is followed by a text that describes the results.

*Table 1. Scoreboard for the economic results from the systems study. The choices for development of the waste management system (the local scenarios) are compared to each other and scored by gold (**G**) silver (**S**) and bronze (**B**) bullets.*

Economy External scenario/ Internal scenario	Reference	Material lean growth	Material intensive growth
Business-as-usual	S	S	B
Maximized return of nutrients	G	G	G
Maximized electricity production	B	B	B

From the economic aspect, the local scenario “Maximized return of nutrients” present the best result irrespective of which external scenario that is being studied. Factors that contribute to this result are revenues for biogas to the transport sector and avoided costs for expanding the waste incineration capacity. It's important to remember that we've been studying a situation around year 2030, which means that new investments in waste treatment capacity must come in place in order to meet a rise in waste amounts. This is another situation compared to today where existing treatment capacity is enough to meet the demand in the region.

The result is sensitive to some input data, where of one can mention the price of biogas, the investment costs for anaerobic treatment and waste incineration, the transport costs for wastewater sludge and sludge from anaerobic treatment to the agricultural sector and the costs for the source separation system.

*Table 2. Scoreboard for the results of emissions of climate gases from the systems study. The choices for development of the waste management system (the local scenarios) are compared to each other and scored by gold (**G**) silver (**S**) and bronze (**B**) bullets.*

Climate gases External scenario/ Internal scenario	Reference	Material lean growth	Material intensive growth
Business-as-usual	B	B	B
Maximized return of nutrients	S	G	G
Maximized electricity production	G	G	G

Table 2 shows that the local scenario ”Maximized electricity production” receives the best results for emissions of climate gases. Also ”Maximized return of nutrients” receives good results. The local scenario “Maximized return of nutrients” receives better results compared to “Business-as-usual” partly because this scenario includes production of biogas that keep out the use of fossil fuels in the transport sector. A second reason is that more electricity is generated within the system that keeps out electricity production outside the system with higher emissions of climate gases. The reason for the increased electricity production is that new waste treatment capacity partly consists of a facility for anaerobic digestion, which decreases the need for investments in waste incineration. With less waste incineration, more district heat will be produced from other combined heat and power plants within the district heating system. These units have a higher electrical efficiency compared to waste incineration, thus more electricity will be produced within the system. The local scenario “Maximized electricity production” receives even better results for emissions of climate gases. The reason for this is that in this scenario the electricity production from the system increases even further. This is partly because we in this scenario study the effects of investing in a waste incineration facility with higher electrical efficiency compared to existing. This is also because this scenario includes investments in a sludge dryer, heated by district heat. This causes an increase in the heat demand, thereby combined heat and power plants within the district heating system may run during a longer period of time.

The local scenarios “Maximized return of nutrients” and “Maximized electricity production” reduces the emissions of greenhouse gases by 4 -7 % (17 000 – 29 000 tonnes CO_2-eq./year) compared to “Business-as-usual”. Another figure to relate to is the total emissions of CO_2 from Göteborg Energi, which in 2009 amounted to 545 000 tonnes CO_2 [7]. As seen before, the local scenario “Maximized return of nutrients” yield a decrease in the system cost, in other words the cost for reducing the emissions of greenhouse gases by choosing this path is negative. In contrast the system cost increases by the local scenario “Maximized electricity production”, hence the cost for reducing greenhouse gases by the measures stapled in this scenario can be calculated to between 80 and 550 SEK/tonne CO_2 (depending on which external scenario you choose to study).

4. Discussion and Conclusions

The following ten conclusions have been drawn from the project.

I. From an economic point of view, new waste treatment technologies have difficulties in the competition with the type of treatment options that already exists in Gothenburg today. The conclusion holds even when comparing new investments in new or existing technologies.

II. Having said so, we can consider that the only new technology found to be economically competitive to existing treatment options are anaerobic digestion of food waste. The conclusion holds for a situation when the treatment capacity has to increase in order to meet the demand in the region. This is not the situation of today, but it is most likely that the situation will arise in future because of increased demand for waste treatment or because the existing treatment facilities become too old.

III. Increasing the share of electricity generated from waste incineration is a clear advantage in order to realize a decrease of emissions of climate gases. This is partly because the fact that the electricity produced from the incinerator keep out other electricity production with higher emissions of climate gases. A second positive factor is that a higher share of electricity production results in a minor share of district heat production, which in turn results in increased production in other combined heat and power plants in the district heating system. Thereby even more electricity is being produced within the system, keeping out other electricity production with higher emissions of climate gases.

IV. Another good way to reduce climate gases is to produce biogas from waste and use it within the transport sector. The reason for this is partly that the biogas is used as a substitute for fossil fuels, but it is also because of the fact that the need for waste is decreased. As described above, this lead to increased use of other combined heat and power plants within the district heating system, resulting in more electricity produced from the system.

V. Results from the project show that today's composting of food waste and anaerobic digested sludge from wastewater treatment result in emissions of acidifying substances. A better option for treatment of food waste is anaerobic digestion followed by spreading of the digestate on agricultural land as fertilizer. The sludge should also be utilised as fertilizer, or alternatively used as fuel in waste incineration.

VI. In a comparison between source separation and central sorting of food waste, the latter turns out to be a better choice when regarding economic aspects. The main reason for this is that the capital costs related to central sorting are lower compared to the costs for a system with sources separation of the food waste. Regarding the environmental aspects, the two systems are almost equal. Uncertainties within the results primarily concern the performance of a central sorting system. Even though it's not evident, the assumption made is that the sorted fractions from the central sorting facility hold an equal quality with the one from a source separation system.

VII. When comparing waste incineration with gasification of waste the latter turns out to be in favour regarding emissions of climate gases. On the other hand, waste incineration is by far the best choice when regarding economy. The reason for the good result for gasification of waste when comparing emissions of climate gases is first of all that the district heat output from the technique is much lower than the output from waste incineration. As described earlier, this results in increased electricity production within the district heating system, keeping out other electricity production with higher emissions of climate gases. Secondly, gasification of waste by itself has a higher output of electricity compared to waste incineration.

VIII. In the analysis we've blocked the possibility of importing waste to the system in study. This restriction has been evaluated in a sensitive analysis, which shows that import of waste for treatment in waste incineration within the system give positive effects on the emissions of climate gases. The main reason for this is that the import of waste results in a decrease of the amount of waste going to landfills outside the system. Since landfilling of organic waste result in high emissions of climate gases it is highly desired to decrease this activity.

IX. Composting of food waste and anaerobic digested sludge from wastewater treatment also result in emissions of substances that leads to eutrophication. However, spreading digested sludge and digestate from anaerobic digestion of food waste on agricultural land will also lead till eutrophication. From this perspective, it is better to use the digestate as fuel in waste incineration.

X. In a sensitive analysis regarding handling of anaerobic digested sludge the result shows that the best treatment method from an economic point of view is to spread the sludge on agricultural land. As discussed above (in conclusion IX), when considering eutrophication it is better to use the sludge as fuel in waste incineration. The different treatment options studied for sludge gives equal results when concerning acidification and emissions of climate gases.

In general we can conclude that the results are almost equal irrespective of which external scenario we choose to study. This means that the results hold even though changes occur in the surrounding systems. The external scenarios differ significantly and create varied prerequisites for the waste treatment system; nevertheless the results show that the same treatment methods should be chosen.

Having said so, we also have to be aware of the uncertainties that exist in the analysis. For example we've not studied how the economic results would react from a change in competitiveness for the waste treatment facilities. It is also important to notice that this, first of all, is a scientific project which points out interesting future waste treatment technologies. This means that the result should not be seen as a comprehensive material for an investment decision. Furthermore, the analysis is based on today's tax system, which of course is a simplified description of the situation of year 2030. It should also be noticed that it's difficult to find valuated data for new techniques. The data can both be overestimated, caused by to ambitious thoughts regarding the technique, and underestimated as further developments of the technique can result in decreased costs and increased performance.

Regarding the results for the aspect of climate change the assumptions for the development of the electricity production system plays a significant role. If the electricity production in northern Europe will transform into a system with less emissions of carbon dioxide the worth of electricity production in Gothenburg will decrease, and vice versa. Furthermore the results for acidification and eutrophication are difficult to interpret as these environmental problems are regional and not global. Therefore the question of where the emissions are made becomes essential. This fact has not been taken into consideration in the main results, however an alternative analysis has been made that describes this factor in more detail.

We will emphasise that many but not all aspects have been analysed for the waste treatment and district heating system. For example we have not included toxic effects or the consumer perspective. Furthermore, we have not included effects from the fact that some natural resources used within the system may be limited on a global scale; this is for example the case for phosphor and biofuels.

Finally we conclude that the three external scenarios that have been created within the project reflect three very different outcomes of the situation in 2030. Most significant we see large differences in the amount of waste that arise and needs treatment. The increase of waste differ from + 24% up to + 80%, compared to the situation of today. This results in large differences in the costs and environmental effects for the waste treatment system. A conclusion from this is that minimization of the increase of waste is essential for a more sustainable development of the society. However, in this project the focus was set on different waste treatment options and regardless of the amount of waste the choice of waste treatment method is solid.

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Determination of the Operating Regimes of CHP Turbines with Stage-wise Heating of District Heating System Water

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Abstract: Today, the district heating (DH) is often based on cogeneration power plants with steam turbines for combined heat and power production (CHP turbines and plants). As the heat is supplied as steam with the given parameters, so CHP steam turbines are realized with controlled steam extractions. In case of stage-wise heating of the district heating system water the entire heating is realized in a number of successively connected water heaters by steam extracted from the turbine. The aim of stage-wise heating is additional production of electricity, because the heating steam extracted for the first stage in the direction of system water flow has lower pressure than for the second stage. In this paper the results of determination of heat-supply operating regime with two-stage heating of the system water for CHP turbine of 120 M W power (T-100-110/130-3) installed in Cogeneration Power Plants Zagreb (TE-TO Zagreb), obtained by means of original developed computer program, will be presented both in analytic form (by equations) and by means of diagrams.

Keywords: *Cogeneration, CHP turbine and power plants, Operating regimes, District heating (DH), Stage-wise heating*

Nomenclature

c *specific heat……………………… $J\cdot kg^{-1}\cdot K^{-1}$*
$\dot{E}_1$ *specific production of electricity by heat-supply flow rate at one-stage heating…………………….........$MW_e\cdot MW_{to}^{-1}$*
h_{zvv1} *enthalpy of condensate of the upper heating extraction............................$kJ\cdot kg^{-1}$*
h_{zvv1} *enthalpy of condensate of the lower heating extraction............................$kJ\cdot kg^{-1}$*
q *flow rate...$kg\cdot s^{-1}$*
$\eta_{g.m}$ *electrical and mechanical efficiency .... -*
ϑ *temperature………………………………....^0C*

Subscripts

m measured data obtained on the actual turbine during operation
prog calculation results obtained by the program or equation
v.z. ambient air
w system water

1. Introduction

District heating is a system for distributing heat generated in a centralized location for residential, public and industrial heating requirements such as space heating and water heating in a large area. The heat is obtained from a cogeneration power plant burning fossil fuels (but now increasingly from renewable energy sources such as biomass, as well as nuclear power). District Heating (DH) based on cogeneration power plants with simultaneous production of heat and electricity (also called Combined Heat and Power – CHP) provides high system efficiency, low emissions and higher degree of fuel flexibility than single-purpose energy systems (e.g. localized boilers).

The number of DH systems associated with CHP plants has been increasing in the last decade due to their energy savings (up to 30%), environmental improvements and reduction of life cycle costs [1]. New CHP plants have a power-to-heat ratio of about 1.0 compared with 0.4-0.5 for traditional condensing steam turbines. However, only 13% of electricity generated in EU today is based on CHP; however, it is regarded by the European Commission as a possible way to improve energy efficiency and reduce the environmental impact. DH plays a minor role in the overall European energy system today, but it is significant in Denmark, Finland and Sweden [2].

Therefore, this paper pays special attention to DH based on CHP turbines (plants). The advantages of stage-wise heating of the district heating system water over one-stage will be presented. With the aim of studying further the possibilities of energy efficiency increase, first of all, by improvement of an operating regime in specific conditions of simultaneous production of power and heat, an original computational program for determination of the operating regime diagrams for different types of CHP turbines has been developed [3]. The program is based on operating regime diagrams (i.e. of energy characteristics), manufacturers' data, results of normative measurements and data obtained during exploitation. The results of calculation by means of the developed program will be presented for CHP turbine of 120 MW power installed in the Cogeneration Plant Zagreb (TE-TO Zagreb) for the heat-supply regime with two-stage heating of district heating system water.

2. Characteristics of CHP turbines and CHP plants

CHP steam turbines are characterized by a diversity of probable operating regimes which can be divided into two groups depending on the heating load: condensing regimes and heat-supply regimes. In a condensing regime, the steam flow rate to controlled extraction is equal to zero. This regime is identical to the operation of a condensing turbine. Heat-supply regimes are characterized by a certain heating load carried by the turbine. A heat-supply regime may be carried out by either heating or electric schedule depending on the nature of the heating load. In operation by heating schedule, the electric power is determined by the heating load and cannot be changed without changing accordingly the heat consumption. Under such conditions, a certain (minimal) quantity of steam is however passed through the low-pressure part of the turbine in order to absorb the heat of friction of the rotating elements. In operation by an electric schedule it is typical that turbine carries a certain heating load which limits the possibility of reducing the electric power blow to a certain minimum, but it is possible to increase the electric power up to the maximum by passing more steam to the condenser.

Thermodynamic characteristics, design, techno-economic indicators and other characteristics of CHP turbines and plants are described in more detail in [3-9].

The heating load is characterized by significant changes during the year and its value changes depending on the temperature of the ambient air. The maximum output of heat is at the minimal calculation temperature of ambient air which is determined on the basis of climatic conditions. During the summer period there will be only the heating load for the heating of hot water, which accounts for on the average two thirds of the mean value in winter [3-4].

The heating load and parameters of the district heating system water are connected by the equation

$$Q_{to}^{TE} = q_w c_w (\vartheta_{pol} - \vartheta_{pov}) \tag{1}$$

where Q_{to}^{TE} is the heating load of the cogeneration power plant, ϑ_{pol} and ϑ_{pov} are the starting and the returned temperature of the system water.

The change in the starting and returned temperature of the system water in dependence on the ambient air temperature is called a t emperature diagram. Fig. 1 shows the temperature diagram constructed for the climate conditions in the city of Zagreb [3].

The steam of heat-supply turbine extractions is used for covering the heating load. Uniformity of load of turbine heat-supply extraction can be achieved if the extraction is used only for covering the base part of the diagram, and its peak is covered e.g. by peak hot-water boilers, Fig. 1 [3].

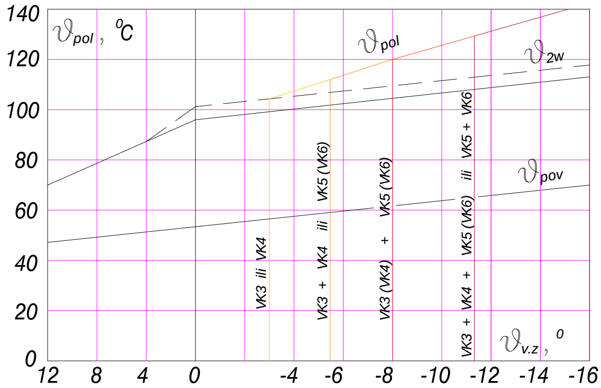

Fig. 1. Temperature diagram of the district heating system: VK3, 4, 5, 6 - peak hot-water boilers;
-- -- -- -- - using the heat of steam leaving the condenser [3]

The ratio of heat load of the turbine heat-supply extractions and the total heating load of the cogeneration plant at minimal calculation temperature of ambient air is called the coefficient of heating α_{TE} [3-4]. With $\alpha_{TE} < 1$ part of the heating load is covered for example, by peak hot-water boilers, and in a thermal power plant with cogeneration also separate production of heat appears.

The temperature diagram of the district heating system and accepted coefficient of heating determine the starting temperature of the system water after regenerative heaters ϑ_{2w} which are fed with steam from the turbine heat-supply extractions. At the minimal temperature of the ambient air, the value is determined from the equation

$$\vartheta_{2w} = \vartheta_{pov} + (\vartheta_{pol} - \vartheta_{pov})\alpha_{TE} \tag{2}$$

For any given ambient air temperature is

$$\vartheta_{2w} = \vartheta_{pov} + \frac{Q_{to}^{TE}}{q_w c_w} \tag{3}$$

For the heat-supply period, when the peak boiler is switched off and the entire heat load is covered by turbine heat-supply extraction

$$\vartheta_{2w} = \vartheta_{pol} \tag{4}$$

In case of turbines with controlled extractions of steam, efficiency increase can be achieved by using heat of the steam leaving the condenser [3-6].

3. Stage-wise heating of district heating system water

In case of stage-wise heating of district heating system water (Fig. 2) the whole heating is realised in a number of successively connected water heaters by steam extracted from the turbine. The required pressure of the extracted steam is determined by the temperature of water at the exit from each heating stage. The steam, extracted for the first stage in the direction of the system water flow, has lower pressure than for the second stage, which ensures additional production of electricity in comparison with one-stage heating, when the whole steam is extracted at a pressure which is determined by the final heating temperature of the system water. Therefore, the aim of stage-wise heating is additional production of electricity by means of the heating steam [3-4].

Effectiveness of stage-wise heating of the system water is determined by a large number of factors, including the primary ones: the number of heating stages and the distribution of the heating load between stages; heating load values, flow rate and temperatures of system water and their change during the year; dimensions, design and temperature diagram of district heating system, climatic conditions and coefficient of heating, parameters of fresh steam, design of turbine and auxiliary plant, etc. [3-6].

Fig. 2 presents the stage-wise heating of the system water (two-stage) which corresponds to the type scheme of the modern CHP turbines with the following characteristics:

- System water heaters are supplied by steam from extractions of one turbine.
- There are no governing valves on the steam pipelines of extractions.
- The flow rate of the system water through all heating stages is equal.
- Condensate from single heaters of stage-wise heating by pumps is carried into the line of regenerative heating of feed water.

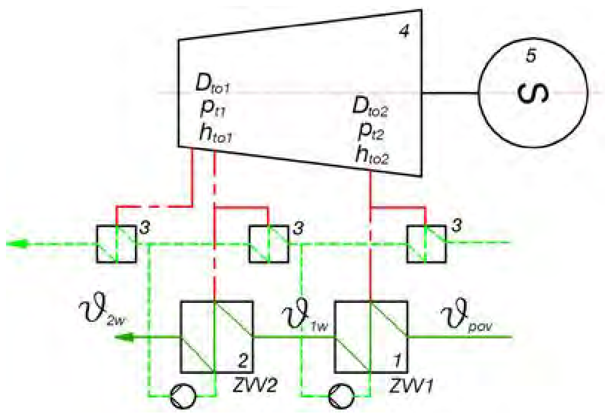

Fig. 2. Principal diagram of a CHP turbine with two heating steam extractions: 1- the lower heating extraction; 2- the upper heating extraction; 3- regenerative heaters; 4- turbine, 5- generator; D_{to1}, p_{t1}, h_{to1} - flow rate, pressure and enthalpy of the upper heating extraction; D_{to2}, p_{t2}, h_{to2} - flow rate, pressure and enthalpy of the lower heating extraction; $\vartheta_{pov}, \vartheta_{1w}, \vartheta_{2w}$ - temperatures of the returned system water, and after the lower and upper heating extractions

At transition from one-stage on two-stage heating of district heating system water, with unchanged heating load, the additional production of electricity ΔP is

$$\Delta P = D_{to2}\left[(h_{to1} - h_{to2})\eta_{g.m} + \dot{E}_1(h_{zvv2} - h_{zvv1})\right] \quad (5)$$

and the additional specific production of electricity $\Delta\dot{E}_2$ by means of the heating steam

$$\Delta \dot{E}_2 = \frac{D_{to2}}{Q_{to}^{TE}}\left[(h_{to1} - h_{to2})\eta_{g.m} + \dot{E}_1(h_{zvv2} - h_{zvv1})\right] \tag{6}$$

At a two-stage heating of district heating system water by scheme shown in Fig. 2 the optimum increase of water enthalpy is equal in both stages of heating [3-4].

4. Heat-supply operating regime of T-100-110/130-3 CHP turbine: two-stage heating of district heating system water

For T-100-110/130-3 CHP turbine on t he basis of theoretical principles, the design data obtained from the manufacturer of the UTMZ-Russia turbine, the data of normative and remaining measurements performed in the Cogeneration Plant Zagreb and on the basis of data obtained during exploitation, the uniform operating regime diagram has been designed in the graphical form in which all turbine working regimes are presented [3]. After that, the obtained operating regime diagram in graphical form is completely translated into the analytic form, i.e. described by analytic dependences in the form of energy characteristics. The energy characteristics are built into the algorithm of original computer program, by means of which it is possible to calculate all the operating regimes of T-100-110/130-3 CHP turbine [3]. These are the condensing operating regime and the heat-supply regimes with one-stage, two-stage and three-stage heating of district heating system water.

As in this paper the object of investigation is stage-wise heating of district heating system water, only the results for the heat-supply operating regimes with two-stage heating will be presented: both in analytic form (by equations) and by means of diagrams [3]. The heat-supply regime with two-stage heating is used when the need for heat is minimally 120 MW, and when the daily temperature is below 5^0C. The functional dependences are obtained on the basis of results from the region of CHP turbine heat-supply operating regimes with two-stage heating [3].

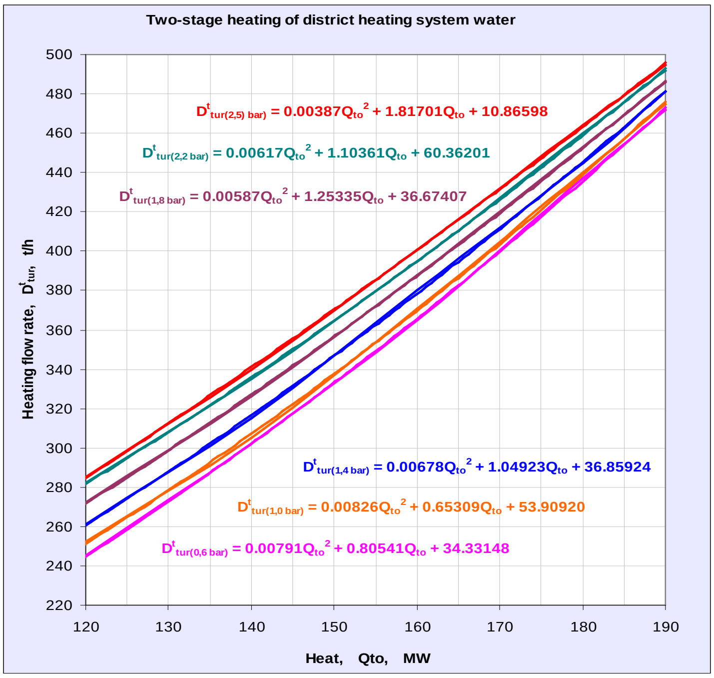

Fig. 3. Heat-supply operating regime of the T-100-110/130-3 CHP turbine - dependence of heat-supply flow rate on heat and on the pressure in the upper heating extraction at two-stage heating of system water [3]

The dependence of heat-supply flow rate $D^t_{tur_{dvo}}$ on heat Q^{dvo}_{to} and on the pressure in the upper heating extraction at two-stage heating (index *dvo* in the following equations) of system water is presented in Fig. 3, and can be described by the following equation

$$D^t_{tur_{dvo}} = a^{dvo}_D (Q^{dvo}_{to})^2 + b^{dvo}_D Q^{dvo}_{to} + c^{dvo}_D \tag{7}$$

The dependences of increasing parameters of the heat-supply flow rate $a^{dvo}_D, b^{dvo}_D, c^{dvo}_D$ on the pressure in the upper heating extraction p_{t1} at two-stage heating of the system water can be described by the following equations [3]

$$a^{dvo}_D = -0.004119 p^5_{t1} + 0.025966 p^4_{t1} - 0.05743 p^3_{t1} + 0.051103 p^2_{t1} - -0.015333 p_{t1} + 0.008073 \tag{7.a}$$

$$b^{dvo}_D = 1.259133 p^5_{t1} - 7.872131 p^4_{t1} + +17.222733 p^3_{t1} - 15.060567 p^2_{t1} + 4.186251 p_{t1} + 0.917671 \tag{7.b}$$

$$c^{dvo}_D = -92.54839 p^5_{t1} + 572.1809 p^4_{t1} - 1237.44892 p^3_{t1} + 1072.77346 p^2_{t1} - 273.77944 p_{t1} + 12.73158 \tag{7.c}$$

The dependence of electricity produced by heat-supply flow $P^t_{e_{dvo}}$ on the heat Q^{dvo}_{to} and on the pressure in the upper heating extraction at two-stage heating of the system water is presented in Fig. 4, and can be described by the following equation

$$P^t_{e_{dvo}} = a^{dvo}_P (Q^{dvo}_{to})^2 + b^{dvo}_P Q^{dvo}_{to} + c^{dvo}_P \tag{8}$$

The dependences of increasing parameters of the electricity produced by heat-supply flow rate $a^{dvo}_P, b^{dvo}_P, c^{dvo}_P$ on the pressure in the upper heating extraction p_{t1} at two-stage heating of the system water can be described by the following equations for the pressure range 0.6-1.4 bar [3]

$$a^{dvo}_P = 0.000428 p^2_{t1} - 0.001145 p_{t1} + 0.001499 \tag{8.a}$$

$$b^{dvo}_P = 0.100437 p^2_{t1} + 0.212762 p_{t1} + 0.386902 \tag{8.b}$$

$$c^{dvo}_P = 4.4641 p^2_{t1} - 8.9851 p_{t1} - 7.5197 \tag{8.c}$$

and for the pressure range 1.4-2.5 bar by the following equations [3]

$$a^{dvo}_P = 0.01746 p^5_{t1} - 0.172862 p^4_{t1} + 0.673167 p^3_{t1} - 1.287444 p^2_{t1} + 1.208139 p_{t1} - 0.444287 \tag{8.d}$$

$$b^{dvo}_P = -6.03471 p^5_{t1} + 59.848 p^4_{t1} - 233.57253 p^3_{t1} + 448.01589 p^2_{t1} - 422.14618 p_{t1} + 156.85117 \tag{8.e}$$

$$c^{dvo}_P = 402.1153 p^5_{t1} - 4006.05631 p^4_{t1} + 15686.88113 p^3_{t1} - 30157.54742 p^2_{t1} + 28457.0162 p_{t1} - 10560.43274 \tag{8.f}$$

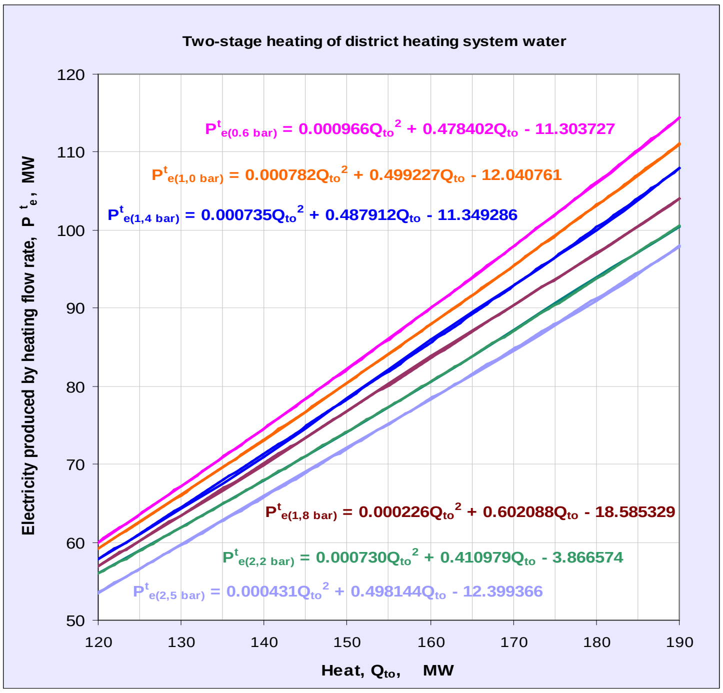

Fig. 4. Heat-supply operating regime of the T-100-110/130-3 CHP turbine - dependence of electricity produced by heat-supply flow on heat and on the pressure in the upper heating extraction at two-stage heating of system water [3]

5. The equations reliability

Equations given in the paper are checked by comparing the results of the calculation obtained by the program using the measured data obtained on the actual turbine during operation for the same ambient air temperatures. The results of comparisons for the regime with two-stage heating of the returned system water are given in Table 1.

Table 1. Comparison of the calculation results obtained by the program with the measured data obtained on the actual turbine during operation for the same ambient air temperatures for the regime with two-stage heating of the district heating system water [3]

Ambient air temperature,	Program			Measured data obtained during operation			Electricity deviation
$\vartheta_{v.z.}$	$(P_e)_{prog}$	$(D^t_{tur\,dvo})_{prog}$	$(D^t_{kon_{dvo}})_{prog}$	$(D_{tur})_m$	$(p_{t1})_m$	$(P_e)_m$	ΔP_e
4^0C	84 MW	278 t/h	62 t/h	340 t/h	1.0 bar	82 MW	+2.4%
2^0C	92 MW	317 t/h	83 t/h	400 t/h	1.4 bar	91 MW	+1.1%
0^0C	94 MW	352 t/h	68 t/h	420 t/h	1.6 bar	93 MW	+1.1%
-2^0C	96 MW	387 t/h	53 t/h	440 t/h	1.8 bar	95 MW	+1.0%
-4^0C	98 MW	423 t/h	37 t/h	460 t/h	2.0 bar	97 MW	+1.0%
-6^0C	101 MW	458 t/h	32 t/h	490 t/h	2.2 bar	99 MW	+2.0%
-8^0C	100 MW	461 t/h	29 t/h	490 t/h	2.4 bar	98 MW	+2.0%
-10^0C	99 MW	472 t/h	18 t/h	490 t/h	2.4 bar	97 MW	+2.0%
-12^0C	99 MW	472 t/h	18 t/h	490 t/h	2.4 bar	97 MW	+2.0%
-14^0C	99 MW	472 t/h	18 t/h	490 t/h	2.4 bar	97 MW	+2.0%

Since in case of heat-supply operation regime on the turbine it is not possible to measure only the electricity obtained on the basis of heat-supply steam extractions but rather the total electricity, in this case the electricity obtained on the basis of the total steam flow through a turbine is compared with total electricity that is given by the program. As can be seen from

Table 1, t he results obtained by using the program provide a good match with the measurement data obtained on the actual turbine: the deviation is in the range of +1.0% to +2.4%. It can also be seen that the sum of computed steam flow of heat extraction and computed steam flow to the condenser fully agree with the measured steam flow at the entry into the turbine. Therefore, it can be concluded that the results of the calculations provided by the program are reliable, including therefore also the equations based on these results.

Single equations are valid only for a specific turbine, but by taking into consideration single specific characteristics similar equations can be obtained for different CHP turbines.

6. Conclusion

The paper presents some results of the original computational program by means of which it is possible to calculate all the operating regimes of T-100-110/130-3 CHP turbine. The energy characteristics, which are obtained by translating the previously designed uniform operating regime diagram from graphical to analytic form, are built in the algorithm of the program. The computational program is successfully used in the Cogeneration Plant Zagreb (TE-TO Zagreb) for the prediction of the relevant parameters of single operating regimes with the aim of work optimization of the CHP turbine. Simultaneously it makes possible to investigate the different operating regimes with the aim of improving their economy (e.g. the introduction of stage-wise heating of system water of district heating). The algorithm is also applicable for other types of CHP turbines, and by taking into consideration single specific characteristics, a program for calculating the operating regimes of the concrete turbine is obtained (condensing turbines with one or two controlled steam extractions; turbines with back-pressure, including the turbines with back-pressure and controlled steam extraction). The comparison of the results of the calculations provided by the program with the measured data obtained on the actual turbine during operation indicates that the equations presented in the paper are reliable, i.e. their accuracy is acceptable for the engineering application.

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Potential for low-temperature energy usage at power plant's cold end in order to increase energy efficiency

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Abstract: Thermal power plant (TPP) 'Bitola' is the largest electricity producer in the Republic of Macedonia with installed capacity of 3x225 MW. It is a lignite fired power plant, in operation since 1982. Most of the installed equipment is of Russian (former Soviet) origin. Power plant's cold end consists of a condenser, pump station and cooling tower. The power plant was built without considerations regarding energy efficiency and usage of waste heat energy.
A possibility to increase energy efficiency through low-temperature heat usage from the power plant's cold end is shown in this work. The system includes connection of heat pump to the power plant's cold end for heating of greenhouse (orangery) complex located close to power plant's cooling towers. An analysis presenting economic feasibility of the concept for two different refrigerants used in the heat pump is also presented.
Comparison between separate production of heat energy in a boiler - house and combined – merged system consisting of three heat pumps working in parallel proves the applicability of the heat pumps concept in terms of increased energy efficiency and pay-back period of investment.

Keywords: *Power plant, Heat pump, Energy efficiency*

1. Introduction

Orangery or greenhouse is a building with microclimate quite different from the external, meaning its internal temperature is substantially different from the external air temperature. Part of the solar energy is absorbed by plants and soil, part is transformed to heat energy, hence heating up the internal air. That is the reason, depending on local climate conditions, heat radiation covers 30 to 60 % of the total heat energy needs of the orangery.

Greenhouse complexes built so far in Macedonia are supplied with heat mainly by boilers using heavy oil as a fuel. At the moment, price of oil on the world market has negative impact on the price of end product. Price of the fuel, for some products, contributes to as much as 70% in the total price of the product, [1]. That does not mean that the rate of growth of orangeries should decrease. It is necessary to substitute the oil with fuel available in the country, especially in the Bitola region.

2. Low temperature heat energy from the cooling towers

One of the possible ways to raise the efficiency of orangery production is by using part of the low temperature waste heat from cooling towers of lignite fired power plant "Bitola".
A complex (combined) system is proposed, comprised of low temperature system (heat pumps) and system with boilers.

One, two or more (up to 10) parallel systems can be located next to the cooling tower of TPP "Bitola". Each system should consist of 21 module, each with 1,5 ha of greenhouses with dimensions: length 21x35 = 735 m and width of 428,6 m. Total area covered by one system is 21x15 000 = 315 000 m^2 or 31,5 ha.

Techno economic analysis presented in the article refers to one orangery complex comprised of 21 module with an area of 1,5 ha in each module. Creation of other parallel systems results in equal economic results.

According to [2], the required installed heat energy for heating of the complex, (for 1,5 ha, required heat energy is 3 457 kW), for total area of 31,5 ha are:

$$Q_{OC} = A_{OC} \cdot q_{OC} = 31{,}5 \cdot 2\ 305 = 72\ 600 \text{ kW} \qquad (1)$$

Two systems, with three heat pumps in each system, should be installed in combination with boiler house for back-up heating of the medium (running on hot water 75/35 °C).
Cooling tower of one of the blocks of thermal power plant "Bitola" works with following design parameters of cooling water:

- volume flow of water through cooling tower q_w = 30 000 m^3/h;
- temperature of hot water entering cooling tower t_{w1} = 33 °C;
- temperature of cold water exiting cooling tower t_{w2} = 25 °C.

Low temperature system of heat pumps is supplied with water from the cooling tower's basin, e.g. Fig. 1. Basin has a volume of 10 100 m^3, [3]. Water with temperature of 33 °C enters in parallel in every evaporator of the heat pumps where it is cooled down to a temperature of 25 °C and through a common pipeline brought back into cooling tower's basin.

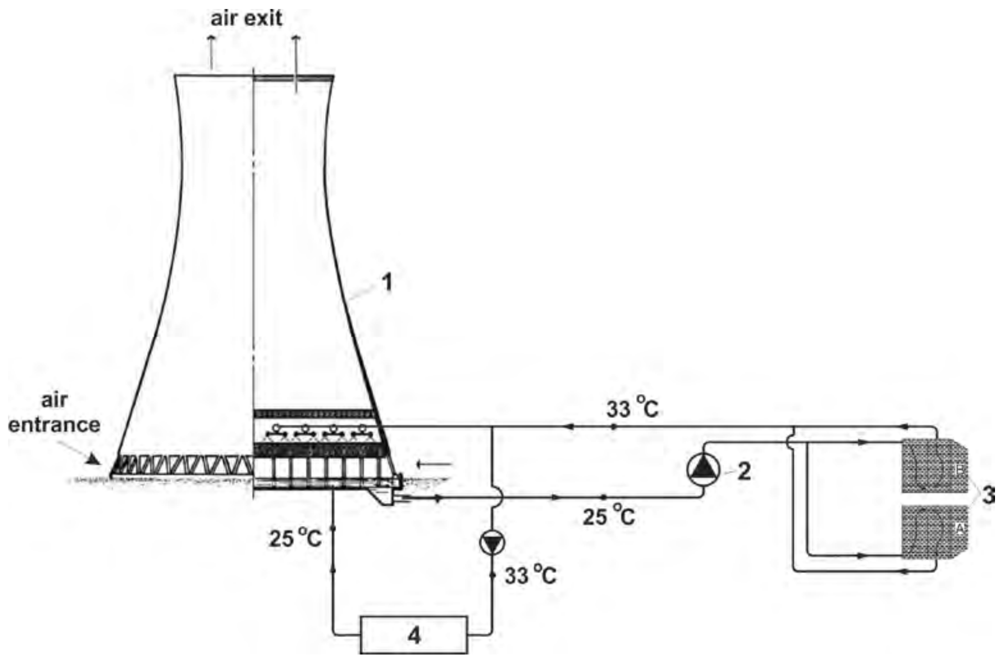

Fig. 1. Heat pumps connected to Thermal Power Plant's cold-end; 1 – cooling tower; 2 – circulation pump station; 3 – condenser; 4 – heat pumps

Mass flow of water from the cooling tower to the heat pumps is 3x359 = 1 077 kg/s, or 12,9% of designed flow of water in the system cooling tower – condenser.

In evaporator of every heat pump, the quantity of heat transferred from the water to the refrigerant is:

$$Q_1 = \dot{m}_{w1} \cdot c_p \cdot (t_{w1} - t_{w2}) = 359 \cdot 4{,}186 \cdot (33\text{-}25) = 12\ 022{,}192 \text{ kW}$$

Total transferred heat for one system (made of 3 heat pumps):

$$Q_{total} = 3 \cdot Q_1 = 3 \cdot 12\ 022{,}192 = 36\ 066{,}576 \text{ kW} \qquad (2)$$

Evaporators of all three heat pumps are connected in parallel (in respect to circulating water from cooling towers), while corresponding condenser units are connected in series (in respect to orangery's' heating medium 75/35 °C), e.g. Fig. 2.

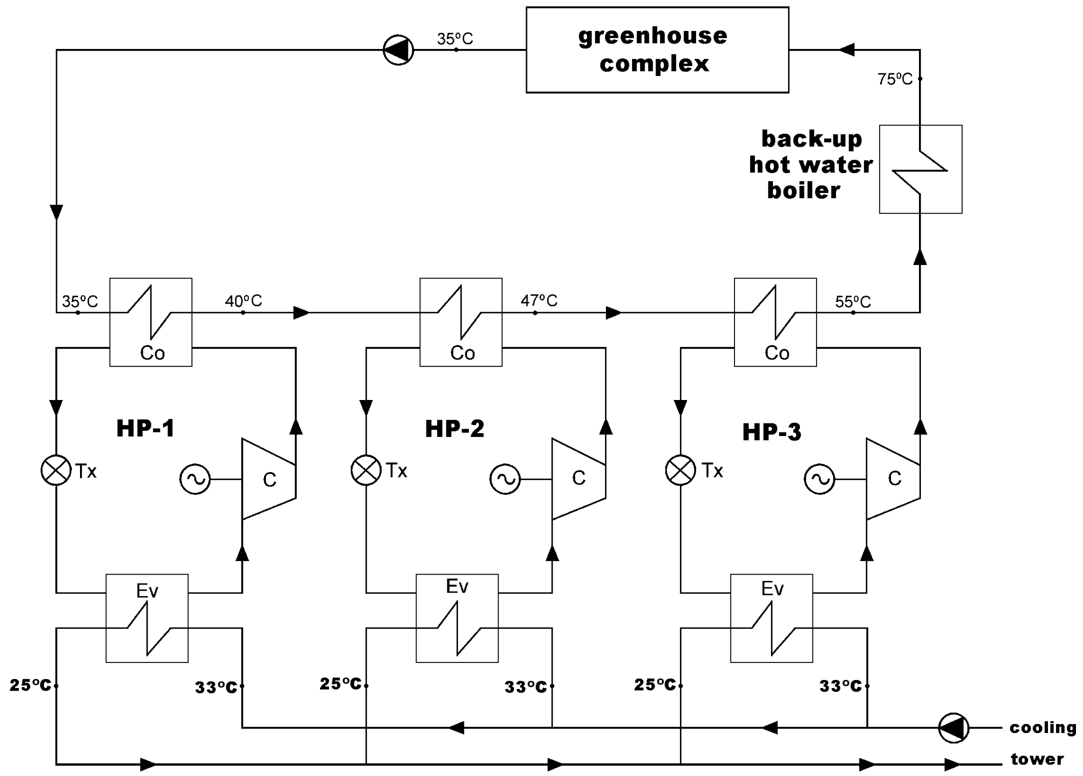

Fig. 2. Combined heating system: heat pumps and back-up boiler house

Although calculations for two refrigerants (HFC-134a and R410A) and two different condensation temperatures (3 K and 5 K) were performed, due to limited space for the article only an example of calculation for one medium and one condensation temperature will be presented completely. Results from other calculations, a review of the operating characteristics of heat pumps for different working fluids, [4], [5] and [6], and condensation temperature of $\Delta t_c = 3$ K, is given on Table 1.

Parameters from techno-economic analysis are shown hereafter, [7].

Total annual consumption of fuel for separate production of heat energy (boilers running on lignite with efficiency 90%) is:

$$Q_{tot,yr} = 132{,}5 \text{ GWh/year} \ ; \ B_{yr} = 69\ 920{,}844 \text{ tons of lignite/year} \qquad (3)$$

where $Q_{tot,yr}$ is the total demand for heat energy per year and B_{yr} is the total annual consumption of fuel if separated system is used.

Table 1. Review of operating characteristics of heat pumps for different cooling fluids

Refrigerant	HP No.	Δt_c , K	l_i , kJ/kg	q_c , kJ/kg	m_f , kg/s	N_e , kW	COP_{avg}
HFC-134a	1	5	21,91	168,27	53,93	1 312,84	6,220
HFC-134a	2	5	29,82	164,68	77,15	2 501,76	4,565
HFC-134a	3	5	31,39	154,05	94,25	3 287,23	3,975
HFC-134a	1	3	22,36	171,82	52,82	1 341,63	6,088
HFC-134a	2	3	27,44	166,10	76,49	2 332,10	4,903
HFC-134a	3	3	35,49	161,45	89,93	3 546,24	3,685
R410A	1	5	24,01	178,63	50,80	1 355,23	6,026
R410A	2	5	32,46	184,08	69,02	2 489,31	4,593
R410A	3	5	47,06	168,08	86,38	4 516,70	3,900
R410A	1	3	27,41	185,93	48,81	1 486,53	5,494
R410A	2	3	28,64	173,06	73,41	2 336,10	4,895
R410A	3	3	36,56	162,78	89,20	3 623,50	3,606

Combined system (comparison for heat pumps with HFC-134a and R-410A and Δt_c = 5 K):

HFC-134a ; Δt_c = 5 K	R-410A ; Δt_c = 5 K
$Q_{BH,yr}$ =33,13 GWh/year	
$Q_{TOT,HP}$ = 99,37 GWh/year	
$B_{TOT,yr}$ = 17 482,85 t /year	
COP_{avg} = 4,92	COP_{avg} = 4,84
E_{COMP} = 20,197 GWh/year	E_{COMP} = 20,531 GWh/year
$B_{COMP,yr}$ = 12 150,17 t/year	$B_{COMP,yr}$=12 351,10 t/year
B = 29 633,02 t/year	B = 29 833,95 t/year
ΔB = 40 287,82 t/year	ΔB = 40 086,89 t/year

where $Q_{BH,yr}$ is the total annual production of heat energy of the boiler house, $Q_{TOT,yr}$ is the total annual production of heat from heat pumps, $B_{TOT,yr}$ is the total annual consumption of fuel of the boilers, COP_{avg} is the average value of the coefficient of performance for a heat pump system, E_{COMP} is the total annual energy consumed by heat pump's compressors, $B_{COMP,yr}$ is the total annual consumption of lignite for heat pump's compressors, B is the total consumption of fuel of a combined system and ΔB is the annual savings of fuel if a combined system instead of separated system is used.

3. Economic efficiency

Values for specific investment costs, maintenance costs and average price of coal for year 2006, [8] and [9]:

- Lignite price 0,0556 EUR/kg
- Heat pump investment 142 907,5 EUR/1 MW
- Hot water boiler house investment 43 125 EUR/1 MW

3.1. Investment costs

A. For separate production of heat in a boiler-house:

$$72{,}6\cdot 43\ 125 = 3{,}130875\cdot 10^6 \ \text{EUR}$$

B. Combined system

- heat pumps: $36{,}3\cdot 142\ 907{,}5 = 5{,}187542\cdot 10^6 \ \text{EUR}$

- hot water boiler house: $36{,}3 \cdot 43\ 125 = 1{,}565437 \cdot 10^6$ EUR

3.2. Exploatation costs

3.2.1. Cooling fluid HFC-134a and $\Delta t_c = 5\,°C$

- Fuel
  A. $69\ 920\ 844 \cdot 0{,}0556 = 3{,}8876 \cdot 10^6$ EUR/year
  B. $(17\ 482\ 850 + 12\ 150\ 174) \cdot 0{,}0556 = 1{,}647596 \cdot 10^6$ EUR/year
- Maintenance costs
  A. $0{,}06 \cdot 3{,}8876 \cdot 10^6 = 0{,}233256 \cdot 10^6$ EUR/year
  B. $0{,}06 \cdot 1{,}6476 \cdot 10^6 = 0{,}100476 \cdot 10^6$ EUR/year

3.3. Total annual costs

3.3.1. Cooling fluid HFC-134a and $\Delta t_c = 5\,°C$

A. Total annual costs for purely boiler system are equal regardless of the cooling medium used,

$$\Sigma T_A = \left(\frac{3{,}130875 \cdot 10^6}{8} + 3{,}8876 + 0{,}233276\right) \cdot 10^6 = 4{,}512216 \cdot 10^6 \quad \text{EUR/year}$$

B. Investment costs $\dfrac{(5{,}187542 + 1{,}674596) \cdot 10^6}{8} = 0{,}\ 8577673 \cdot 10^6$ EUR/year

- Fuel $(17\ 482\ 850 + 12\ 150\ 174) \cdot 0{,}0556 = 1{,}674596 \cdot 10^6$ EUR/year
- Maintenance costs $0{,}06 \cdot 1{,}674596 \cdot 10^6 = 0{,}100476 \cdot 10^6$ EUR/year

Total annual costs for the combined system are:

$$\Sigma T_{B,com} = (0{,}8577673 + 1{,}674596 + 0{,}100476) \cdot 10^6 = 2{,}632839 \cdot 10^6 \quad \text{EUR/year}$$

Energy unit (specific) price:

$$C_A = \frac{4{,}512216 \cdot 10^6}{132{,}5 \cdot 10^3} = 34{,}055 \quad \text{EUR/MWh}$$

$$C_B = \frac{2{,}632839 \cdot 10^6}{132{,}5 \cdot 10^3} = 19{,}87 \quad \text{EUR/MWh}$$

The rest or 'the savings' are:

$$\Sigma T_A - \Sigma T_{B,com} = (4{,}512216 - 2{,}632839) \cdot 10^6 = 1{,}879377 \cdot 10^6 \quad \text{EUR/year}$$

Investment payback period:

$$\tau = \frac{(5{,}187542 + 1{,}565437) \cdot 10^6}{1{,}879377 \cdot 10^6} = \frac{6{,}752979 \cdot 10^6}{1{,}879377 \cdot 10^6} = 3{,}59 \text{ years}$$

4. Conclusion

For the defined optimal orangerie's complex comprised of 21 modules, each having 1,5 ha or 31,5 ha in total, and needed heat energy of 72,6 MW for heating up the complex, two systems are proposed:
A. Separate system, comprised of boilerhouse for production of hot water which meets the total requirements for heating of the complex (72,6 MW, system 75/35 °C), and
B. Combined (merged) system, comprised of low-temperature system with heat pumps (capacity of the pumps 36,3 MW) that will cover around 75% of the total annual heat energy requirements, and boilerhouse with capacity of 36,3 MW that will cover the remaining 25% of the annual heat energy needs. Calculations are done for two cooling fluids, HFC-134a and R410A and at two condensation temperatures (Δt_c = 3 K and Δt_c = 5 K).

Fuel used in the boilerhouse is lignite from the "Suvodol" basin (fuel used by the TPP) with lower calorific value of H_d = 7 580 kJ/kg.

Techno economic analysis is performed under equal energetic efficiencies of both systems. Total annual costs for both systems are compared and results are shown on Table 2:

Table 2. Comparison table for total annual costs for both systems

System type	Energy unit price (EUR/MWh)	Total annual costs (EUR/year) (in millions)	Savings (EUR/year) (in millions)	Investment return period (in years)
System A	34,055	4 512 216	/	/
System B HFC-134a;Δt_c=5K	19,87	2 632 839	1 879 377	3,59
System B HFC-134a;Δt_c=3K	19,90	2 636 624	1 875 592	3,60
System B R410A ; Δt_c=5K	20,33	2 693 458	1 818 758	3,70
System B R410A ; Δt_c=3K	20,88	2 766 522	1 745 694	3,84

From the analysis presented in the article, one can conclude that the combined (merged) system, that is the system that uses HFC-134a as a cooling fluid and Δt_c = 5 K is the most applicable in the turns of savings and investment payback period.

Despite all the benefits of such a system, only basic structure for one greenhouse module was built near one of the cooling towers of above mentioned power plant. Unfortunately, neither pipelines nor other elements of the proposed system were ever built or installed.

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An Evaluation of Internal Combustion Engines as the Prime Movers in CHP Systems

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Abstract: Optimum selection of prime movers in combined heat and power (CHP) systems is of crucial importance due to the fact that inappropriate choices reduce the benefits of CHP systems considerably. In the selection procedure the performance characteristics of prime movers as well as economic parameters should be considered. The aim of this paper is to present a thermo-economic approach to selecting the optimum nominal power and planning the operational strategy of internal combustion engines in a medium scale combined heat and power system is presented using the Net Annual Cost (NAC) criterion. Three modes of operation have been considered, namely one-way connection (OWC) mode, two-way connection (TWC) mode, and heat demand following (HDF) mode. The proposed method has been used for a case study. It has been observed that the optimum nominal powers in the case of using gas engines are 3.3 MW, 3.2 MW, and 1.2 MW and in the case of using diesel engines are 3.4 MW, 3.4 MW, and 1.4 MW for TWC, OWC, and HDF modes respectively. The proposed method may be also used for other types of prime movers as well as various sizes of combined heat and power systems.

Keywords: *Combined Heat and Power System, Internal Combustion Engines.*

Nomenclature

ACT	*annual carbon tax*	*\$/year*
C	*cost*	*\$/kWh*
CC	*capital cost*	*\$*
COF	*cost of fuel per hour*	*\$/hr*
$\dot{H}$	*heat rate*	*kW*
HRB	*heat recovery boiler*	
i	*interest rate*	*%*
k	*number of equipment*	
LT	*lifetime*	*year*
MC	*maintenance cost per hour*	*\$/hr*
N	*number of time intervals*	
NAC	*Net Annual Cost*	*\$/year*
P	*electric power*	*kW*
SV	*salvage value*	*\$*
τ_m	*time interval of demand profile*	*h*

Subscripts

b	*buying electricity*
el	*electricity*
f	*fuel*
h	*heat*
r	*required*
s	*selling electricity*

1. Introduction

Combined heat and power (CHP) systems are considered to be one of the most important ways to consume the fossil fuels efficiently. These systems emit less pollution compared to the separate production of the same amount of electricity and heat. This paper presents a thermo-economic method for optimum sizing of internal combustion engines to serve as the prime movers of medium scale (500 kW-5,000 kW) combined heat and power systems. Three modes of operation: one-way connection (OWC) mode, two-way connection (TWC) mode, and heat demand following (HDF) mode are examined. In all three modes, buying electricity from the grid is possible while selling electricity to the grid is allowable in TWC and HDF modes. The objective of HDF mode is to minimize the waste of energy; therefore the engines work in a condition at which the excess generated heat is minimal. A backup boiler can be installed to supply heat in all three modes.

2. Methodology

The applied method is one of the standard engineering economy approaches which is called annual cash flow (ACF) analysis. In ACF method, all costs and benefits are converted to equivalent uniform annual cost (EUAC) and equivalent uniform annual benefit (EUAB). To compare the various options, the difference of EUAC and EUAB (EUAC-EUAB) is calculated and the one which results in the minimum value is the most economical choice [1]. Based on the annual cash flow method, the proposed objective function (Net Annual Cost (NAC) \$/year) is defined as:

$$\mathrm{NAC}=\left[\sum_{j=1}^{k}\left(CC_j - SV_j\left(\frac{1}{(1+i)^{LT}}\right)\right)\right]\left(\frac{i(1+i)^{LT}}{(1+i)^{LT}-1}\right)+\mathrm{ACT}+\sum_{m=1}^{N}\left[\sum_{j=1}^{k}\left(MC_j + COF_j\right) + P_b \times C_{el,b} - P_{CHP,r} \times C_{el} - \dot{H}_{CHP,r} \times C_h - P_{CHP,s} \times C_{el,s}\right]_m \times \tau_m \quad (1)$$

2.1. Selection and planning of operational strategy

To determine the optimum nominal power and the operational strategy of internal combustion engines as prime movers of CHP systems based on the specific electricity and heat demand profile, the following procedure is adopted:

- For nominal powers from 500 kW to 5,000 kW and for each time interval of demand profile (τ_m) with changing of partial load from 20% to 100%.
- Calculating NAC for a given partial load (this is represented by NAC_m).
- Comparing the calculated NAC_m values and choosing and saving the minimum value ($NAC_{m,\,min}$) and its associated partial load.
- Calculating NAC by adding up the $NAC_{m,\,min}$ values for all time intervals.
- Choosing the nominal power which results in the minimum NAC as the prime mover's nominal power of the CHP system.
- For the selected nominal power and for each time interval the partial load at which the $NAC_{m,\,min}$ is obtained is the operational strategy of CHP system.

3. Results

To illustrate the Net Annual Cost method, we have chosen a case study. It is noted that adoption of the specific operational mode directly depends on the method of connection to the grid which determines the possibility of selling electricity. Fig. 1 shows the electricity and heat demand profile for the case study based on operational data of a local educational institute [2].

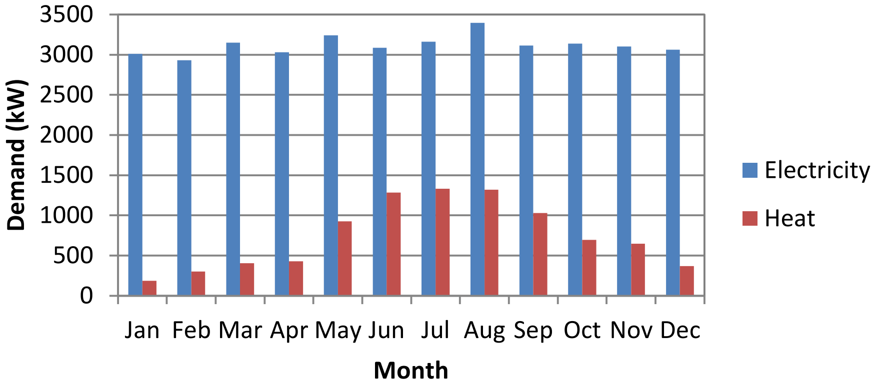

Fig 1. Demand profile for the case study

Table 1 lists the costs of natural gas, diesel fuel, and electricity as well as the value of generated electricity and heat [3-5]. A nominal Carbon tax of $30 per emitted tonne of CO_2 equivalent is assumed [6].

Table 1. Price list

Items	Price ($/kWh)
Buying electricity ($C_{el,b}$)	0.18
Natural gas	0.045
Diesel fuel	0.117
Selling electricity ($C_{el,s}$)	0.15
Generated electricity (C_{el})	0.18
Generated heat (gas engine) (C_h)	0.05
Generated heat (diesel engine) (C_h)	0.138

Figs. 2-4 illustrate the variation of Net Annual Cost versus nominal power of gas engine in three modes of operation. In TWC mode a 3.3 MW gas engine, in OWC mode a 3.2 MW gas engine, and in HDF mode a 1.2 MW gas engine have resulted in the minimum NAC values.

Fig. 2 Variation of Net Annual Cost versus gas engine nominal power in TWC mode

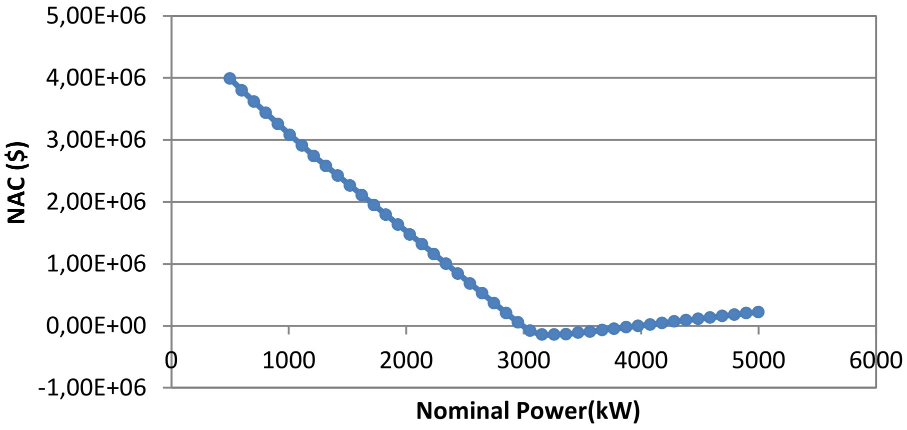

Fig. 3 Variation of Net Annual Cost versus gas engine nominal power in OWC mode

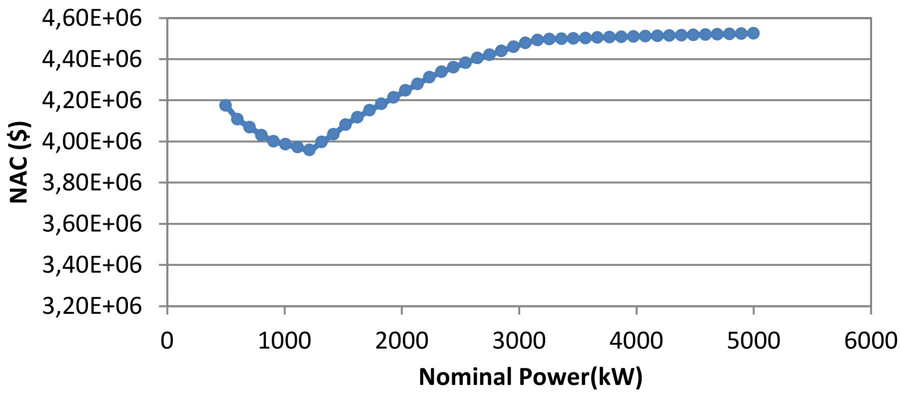

Fig. 4 Variation of Net Annual Cost versus gas engine nominal power in HDF mode

The variation of NAC with nominal power of diesel engine for three modes of operation is shown in Figs. 5-7. The optimum nominal powers in TWC, OWC, and HDF modes are 3.4 MW, 3.4 MW, and 1.4 MW, respectively.

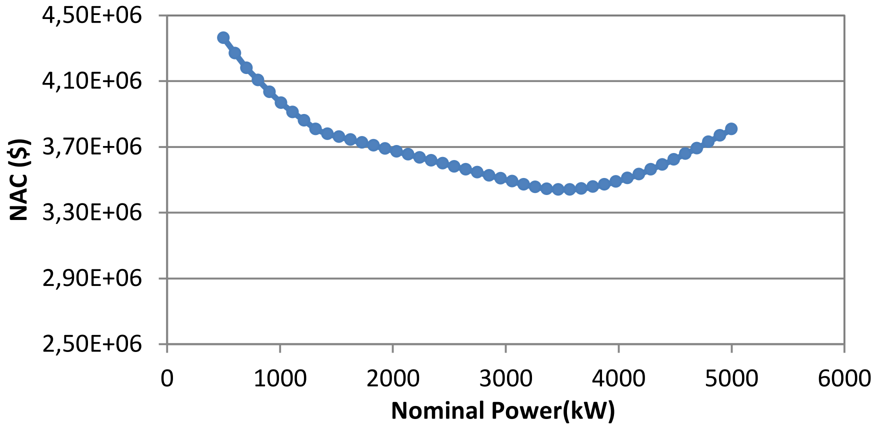

Fig. 5 Variation of Net Annual Cost versus diesel engine nominal power in TWC mode

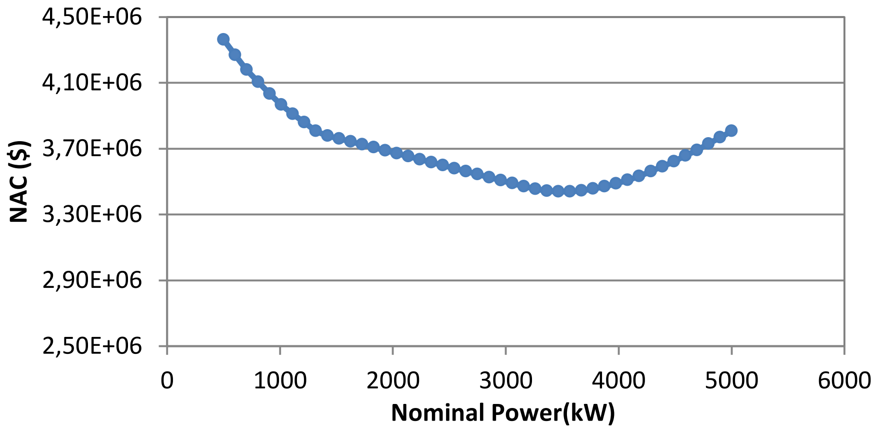

Fig. 6 Variation of Net Annual Cost versus diesel engine nominal power in OWC mode

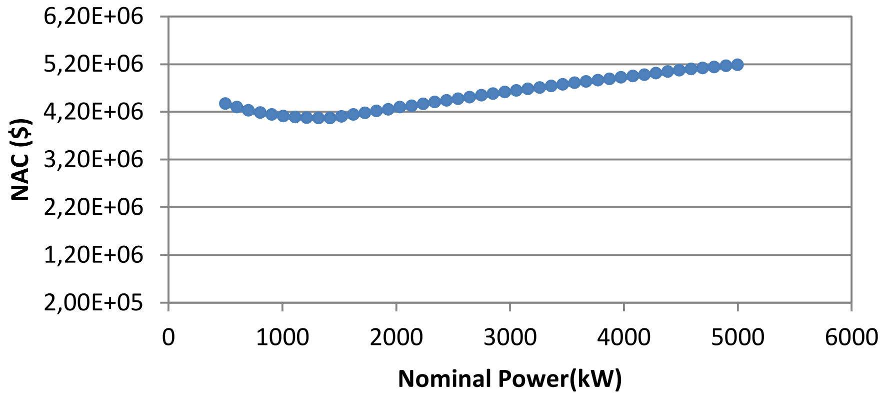

Fig. 7 Variation of Net Annual Cost versus diesel engine nominal power in HDF mode

The operational strategy of selected gas engines and diesel engines in the three modes of operation is shown in Figs. 8-13.

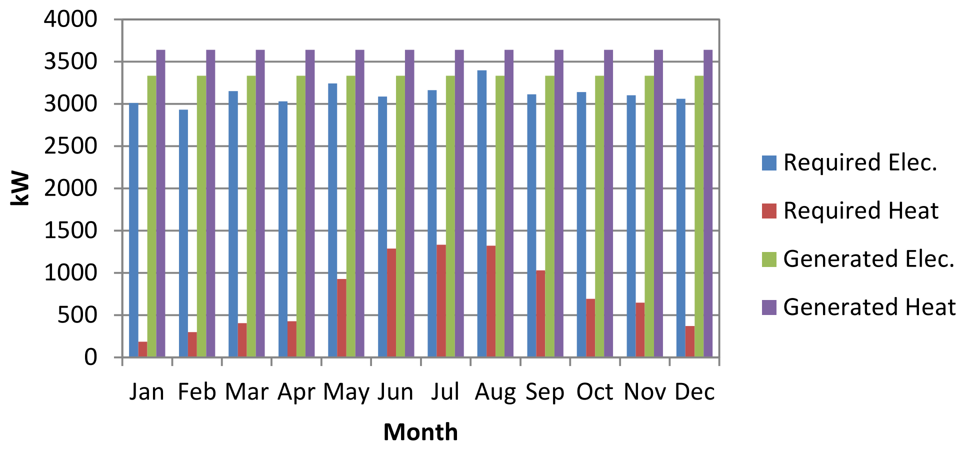

Fig. 8 The operational strategy of selected gas engine in TWC mode of operation

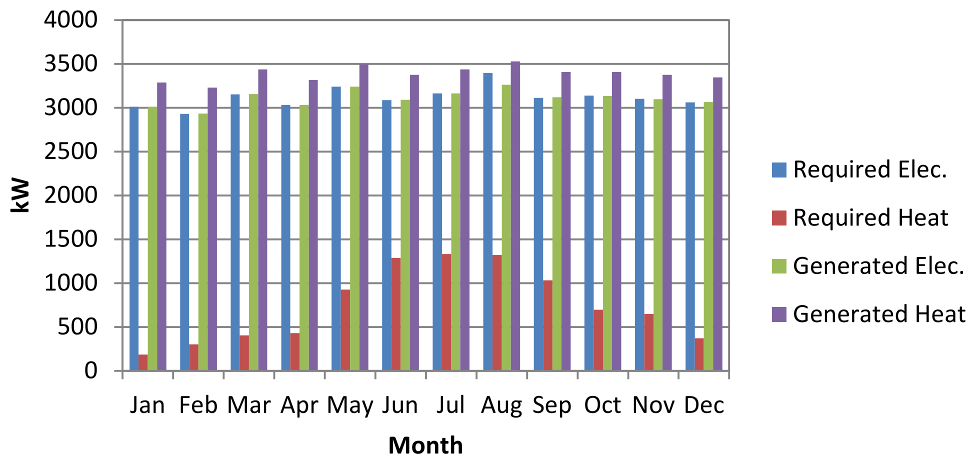

Fig. 9 The operational strategy of selected gas engine in OWC mode of operation

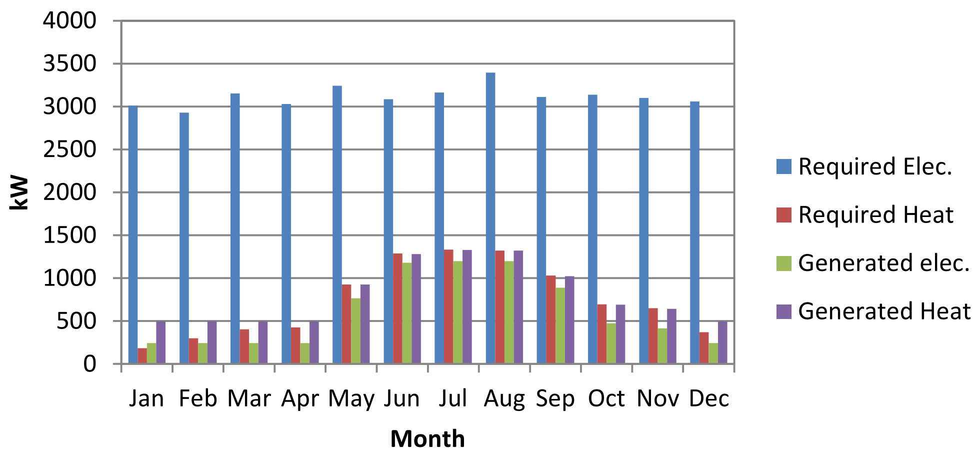

Fig. 10 The operational strategy of selected gas engine in HDF mode of operation

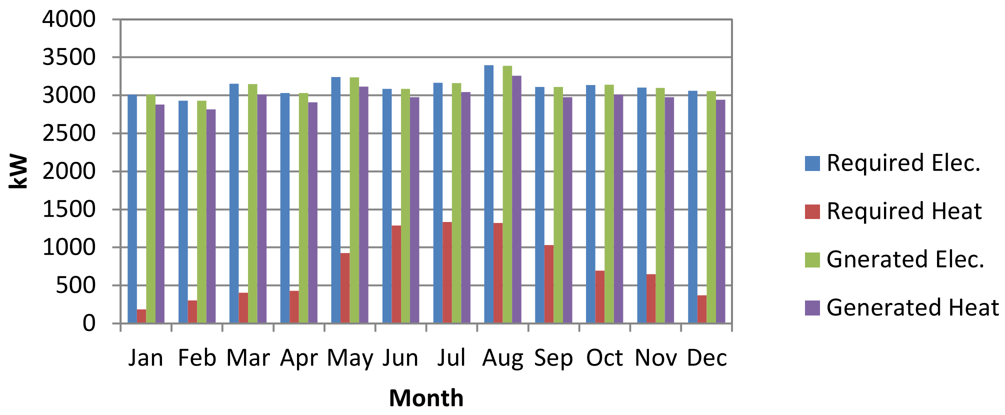

Fig. 11 The operational strategy of selected diesel engine in TWC mode of operation

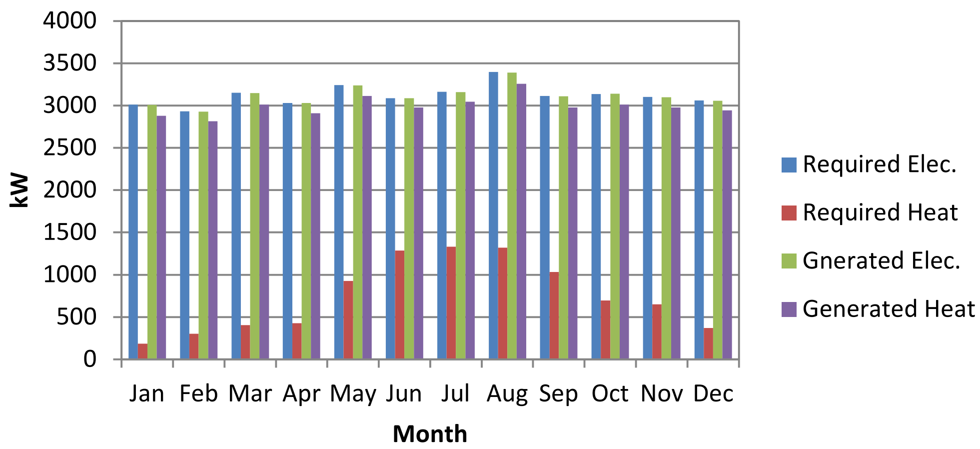

Fig. 12 The operational strategy of selected diesel engine in OWC mode of operation

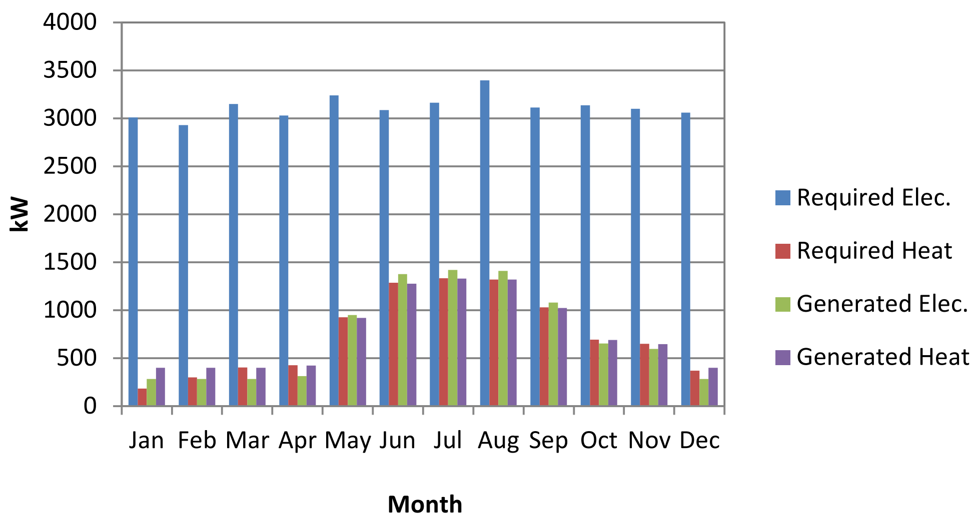

Fig. 13 The operational strategy of selected diesel engine in HDF mode of operation

4. Discussion

The figures for the operational strategy of selected gas engines show that in TWC mode, in which selling the excess electricity is allowed, the prime mover works at full load condition during the year. In OWC mode, the prime mover follows the electricity demand profile and produces as much electricity as required. In HDF mode, a large amount of electricity should be bought due to the fact that to produce as much less heat as possible the prime mover works in low load conditions.

It is noted that because of high price of diesel fuel, in TWC mode of operation the diesel engine follows the electricity demand profile and there is no excess electricity to be sold. Therefore, the values of NAC and consequently the operational strategy results are the same for TWC and OWC modes. Similar to gas engine, the prime mover works in low load condition in HDF mode.

5. Concluding remarks

In this paper, a thermo-economic method for the optimum sizing and planning the operational strategy of internal combustion engines in a medium scale combined heat and power system is presented introducing the Net Annual Cost (NAC) criterion. The methodology has been adopted for an operational case study and the proposed method can be used for all types of prime movers as well as various sizes of the system.

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Air gasification of palm empty fruit bunch in a fluidized bed gasifier using various bed materials

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Abstract: Use of lignocellulosic biomass as an alternative, renewable and sustainable source of energy has fulfilled part of the growing demand for energy in developed countries. Amongst various technologies applied to convert biomass wastes to biofuel and bioenergy, biomass gasification has attracted considerable attention. In this work, gasification of palm empty fruit bunch as a potential lignocellulosic waste was investigated in a pilot scale air-blown fluidized bed. Silica sand and dolomite were used as bed material. The bed temperature was varied in the range of 650 to 1050 ^oC. The quality of the producer gas (H_2, CO, CO_2 and CH_4) and gasification performance was assessed in terms of heating value, carbon conversion efficiency, dry gas yield and cold gas efficiency. It was concluded that high temperatures improved the quality of producer gas; maximum heating value of 5.3 and 5.5 MJ/Nm^3 were achieved using silica sand and dolomite. Maximum dry gas yield of 1.84 and 1.79 (Nm^3gas/kg biomass), carbon conversion of 91 and 85% and cold gas efficiency of 69 and 65% were obtained for silica sand and dolomite, respectively. Although the quality of the produced gas was considerably improved at high temperatures, however formation of the bed agglomerates was the major concern at temperatures above 800 and 850 ^oC for silica sand and sawdust.

Keywords: *Biomass gasification, Fluidized bed, Gas producer, Palm empty fruit bunch*

1. Introduction

In recent years, rapid development of modern industry has greatly increased the demand for energy. Today, fossil fuels are the most common energy sources in the world. Most countries which use such conventional fuels are facing major air pollution problems as it has been estimated that the world's oil reserves will get depleted by 2050 [1]. Besides, significant amount of pollutants including CO_2, NO_x and SO_x are emitted from fossil fuels into the atmosphere. Meanwhile, the cost of fossil fuel is globally increasing [1, 2]. Considering theses issues, boosts the importance of finding and exploring alternative, renewable and sustainable energy resources.

Lignocellulosic biomass is one of the potential renewable energy resources which is receiving great worldwide attentions. Malaysia as the largest producer of palm oil generates a large amount of lignocellulosic residues including palm empty fruit bunch (EFB), palm shell and mesocarp [3]. These lignocellulosic biomass feedstocks can be efficiently utilized in various thermo-chemical conversion processes to yield energy and fuels. Among various biomass conversion technologies, special attention has been paid to biomass gasification due to its high conversion efficiency [4-6].

A survey of literature reveals successful application of lignocellulosic biomass in various types of gasifiers including fixed beds [7], entrained flow [8] and fluidized beds [9-13]. However, amongst different categories of gasifiers, fluidized beds have offered advantages such as efficient mixing of gas and solid, improved reaction rate and conversion, and low tar content of the producer gas. Various gasifying agents including air, steam, oxygen-steam, air-steam, O_2-enriched air and oxygen-air-steam have been utilized in fluidized beds [6, 8, 14, 15]. Although a very high quality producer gas is not attainable through air gasification, however is boosts the feasibility of the biomass gasification for industrial application.

Although various biomass feedstocks have been gasified in fluidized beds, little data has been published on g asification of EFB in catalytic fluidized beds. Current research aims to investigate the gasification of EFB in a pilot-scale air blown bubbling fluidized bed. Calcined dolomite and silica sand were used as bed material and their effect on the quality of the producer gas was investigated.

2. Methodology

2.1. Biomass feedstock and its characterization

The biomass used in the current study was palm empty fruit bunch which was obtained from a local palm oil mill factory. The raw feed containing high amount of moisture was air dried for 2 days. The dried feed was then crashed and ground to the fibers with the mean length of 2-6 mm.

Ultimate and proximate analysis was conducted on a sample of EFB to determine the elemental composition of the biomass. The heating value of EFB was measured by a bomb calorimeter. The obtained results and data analysis are presented in Table 1.

Table 1. Ultimate and proximate analysis of EFB

Ultimate analysis (wt %)	
Carbon	43.52
Hydrogen	5.72
Oxygen	48.90
Nitrogen	1.20
Sulfur	0.66
Proximate analysis (wt %)	
Moisture	7.80
Volatiles	79.34
Ash	4.50
Fixed carbon	8.36
HHV, MJ/kg (dry basis)	15.22

2.2. System description and operation

An air blown bubbling fluidized bed gasifier with the height of 1050 mm and internal diameter of 150 mm was operated for EFB gasification. Air was introduced into the gasifier using a 0.75kW blower. Silica sand and calcined dolomite with mean size of 600 µm were used as bed material. The biomass was continuously fed into the reactor through a screw feeder conveyer equipped with an inverter. The temperature of different operating zones of the gasifier was monitored by several type K thermocouples. The operated experimental setup is represented in Fig. 1.

At start up, the system was heated up to the desired temperature of 500 ^{o}C. There was a heating chamber supplied by LPG below the distributer plate to provide the necessary heat. As the temperature of reactor reached to 500 ^{o}C, air was introduced and the biomass feeding was started. To avoid the pyrolysis of biomass inside the screw feeder, there was a cooling jacket surrounding the conveyor and cooling water always passed during the process.

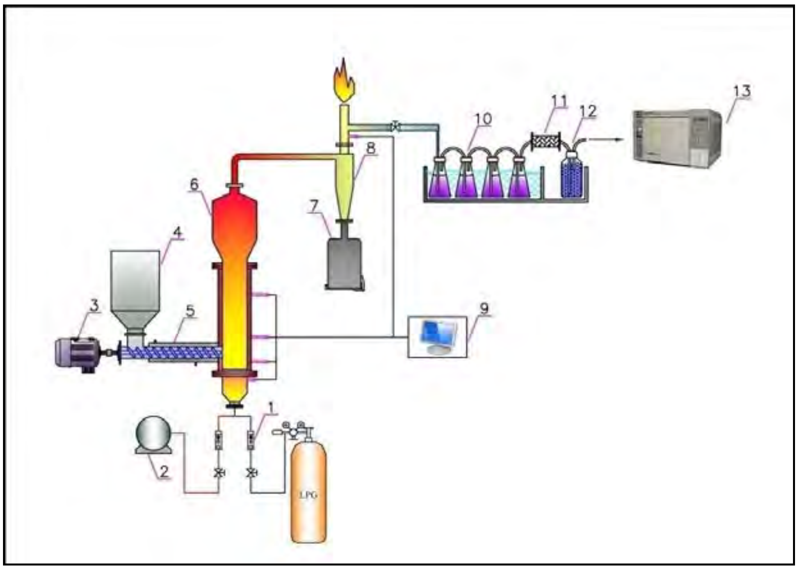


Fig. 1. Schematic representation of the pilot-scale BFB gasifier:
1. Mass flow controller; 2. Blower; 3. Variable frequency driver; 4. Feeding hopper; 5. Water cooled screw feeding system; 6. Fluidized bed reactor; 7. Particle holder; 8. Cyclone; 9. Temperature monitoring unit; 10. Condensers; 11. Fiber filter; 12. Silica gel; 13. Gas chromatograph

2.3. Gas sampling and analysis

The gasifier was operated at atmospheric pressure. The gasifier was equipped with a cyclone and the dirty outlet gas containing ash, char, tar and dust particles entered the cyclone separator. The cyclone removed ash and chars from the hot gas and derived them into the bin connected to the cyclone. Producer gas was exited from the cyclone to the incinerating device while a part of it was sent to the gas sampling unit. The gas samples were collected in several gas sampling Tedlar bags for further analysis using Gas Chromatograph (GC). The GC (Agilent Technology, 4890) was equipped with a thermal conductivity detector (TCD). A packed Carboxene 1000 (Supelco, USA) column (15 ft × 1/8 in, 80/100 mesh) was used to measure the mole fraction of permanent gases. External standard method obtained from 6 tanks of simulation gas was used to calculate the composition of the producer gas. Temperature programmed GC analysis was carried out with initial oven temperature set at 35 °C, then it was gradually increased to 210 °C at a rate of 20 °C/min. The injector and detector temperatures were 150 and 220 °C, respectively. Helium was applied as carrier gas at a rate of 35 ml/min.

3. Results and Discussions

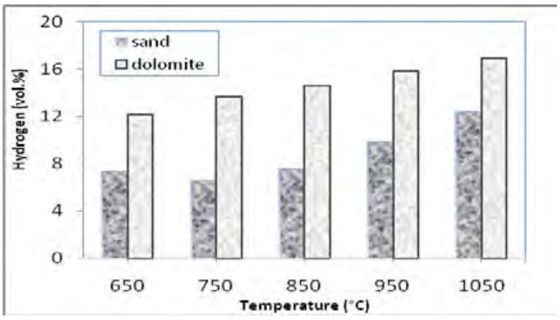
3.1. Producer gas composition

In order to investigate the effect of temperature and bed material on the composition of producer gas, the bed temperature was varied in the range of 650 to1050 ^{o}C. The results are depicted in Fig. 2 (a) to (d). As observed in Fig. 2 (a) increasing the bed temperature from 650 to 1050 ^{o}C improved the H_2 content of the producer gas from 7.3 to 12.4% and 11.1 to 16.8% for silica sand and dolomite, respectively. Such increase in the H_2 level of the producer gas was due to the improvement of the endothermic reactions (1-3) involved in the gasification process:

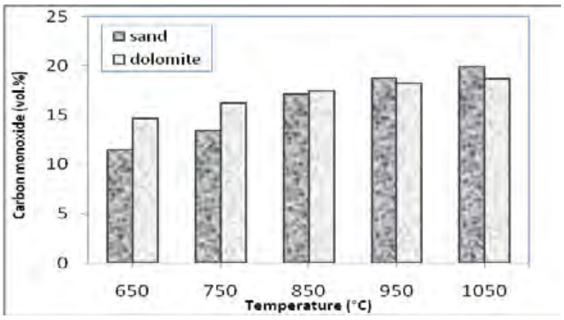
$$CH_4 + H_2O \leftrightarrow CO + 3H_2 \qquad \Delta H = +206 \text{ kJ/mol} \qquad (1)$$

$$CH_4 + 2H_2O \leftrightarrow CO_2 + 4H_2 \qquad \Delta H = +165 \text{ kJ/mol} \qquad (2)$$

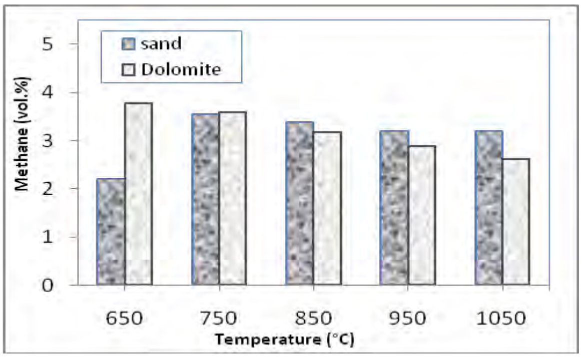
$$CH_4 + CO_2 \leftrightarrow 2CO + 2H_2 \qquad \Delta H = +247 \text{ kJ/mol} \qquad (3)$$



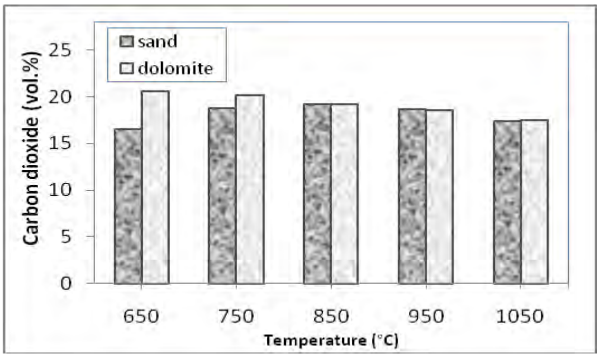
(a)



(b)



(c)



(d)

Fig 2. Effect of bed temperature and bed material on producer gas composition

Beside the contribution of the endothermic reforming reactions in increasing the H_2 concentration, the remarkable higher H_2 concentration obtained using dolomite in comparison to sand was confidently related to the improved tar cracking reactions (4-6):

C_nH_m (tar) + $nH_2O \leftrightarrow (n + m/2) H_2 + nCO$ $\Delta H > 0$ (4)

C_nH_m (tar) + $nCO_2 \leftrightarrow (m/2) H_2 + 2nCO$ $\Delta H > 0$ (5)

C_nH_m (tar) $\leftrightarrow (m/2) H_2 + nC$ $\Delta H > 0$ (6)

The variation of CO level of the producer gas with respect to the bed temperature is presented in Fig. 2 (b). The obtained result revealed the positive effect of the bed temperature on CO content. As the bed temperature was raised from 650 to 1050 ^oC, the CO level increased from 11.5 to 19.8% and 16.2 to 18.7 for silica sand and dolomite, respectively. It was inferred that improved char gasification reactions (7 and 8) as well as methane reforming reactions (1-3) were the main cause of such increase at high temperatures [12]:

$C + H_2O \leftrightarrow CO + H_2$ $\Delta H= +131$ kJ/mol (7)

$C + CO_2 \leftrightarrow 2CO$ $\Delta H= +172$ kJ/mol (8)

Fig. 2 (C) shows the CH_4 level of the producer gas at various applied bed temperatures. The maximum CH_4 level of 3.8 and 3.6% was obtained at 750 ^oC for silica sand and 650 ^oC for dolomite, respectively. The results showed that the CH_4 content of the producer gas follows a reducing trend for both silica sand and dolomite at high gasification temperatures. High temperature favors endothermic methane reforming reactions, thus reducing the CH_4 content of the producer gas.

The variation of CO_2 level of the producer gas with respect to the bed temperature is presented in Fig. 2 (d).The high concentration of CO_2 was observed at low temperatures and then a drastic decrease at temperatures above 850 ^oC was experienced for both sand and dolomite. At low temperatures, CO_2 is produced through water-gas shift reaction (9) but high temperature promoted its evolution via methane reforming (2). However, the generated CO_2 was consumed through methane dry reforming (3), tar cracking (5) and Boudouard reaction (8) to yield more H_2 and CO and lead to a decrease in CO_2 level at temperatures above 850 ^oC. The lowest CO_2 content of 17.4 was achieved at 1050 ^oC for both sand and dolomite.

$CO + H_2O \leftrightarrow CO_2 + H_2$ $\Delta H= - 41.98$ kJ/mol (9)

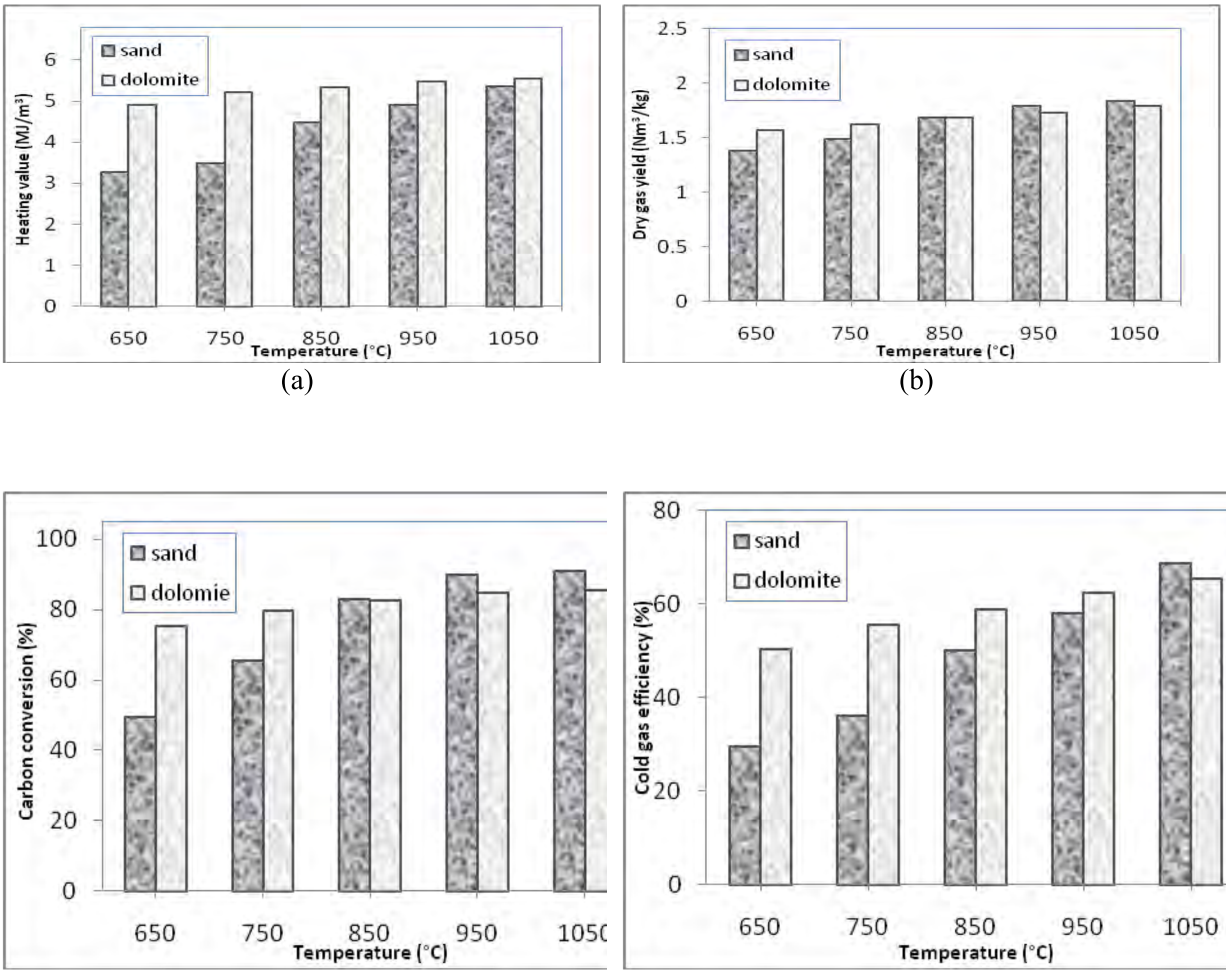
3.2. Gasification performance

Fig. 3 (a) illustrates the effect of bed temperature on high heating value (HHV) of the producer gas for sand and dolomite. As explained earlier, high temperatures enhanced the evolution of combustible gases especially H_2 and CO which in turn resulted in an increase in HHV of the producer gas. The HHV of the producer gas increased from 3.3 to 5.3 MJ/Nm^3 and 4.9 to 5.5 MJ/Nm^3 for silica sand and dolomite, as the bed temperature was increased from 650 to 1050 ^oC.

Variations of dry gas yield with respect to bed temperature are shown in Fig. 3 (b) for silica sand and dolomite. Increase of the bed temperature improved the dry gas yield from 1.3 to 1.8 Nm^3/kg and 1.5 to 1.8 Nm^3/kg for dolomite, respectively. Increase in dry gas yield may be originated from the promotion of initial pyrolysis rate at high temperatures which increased the gas production as well as steam cracking and reforming of tars at high temperatures. In addition, endothermic reactions of char gasification at elevated temperature (7 and 8) improved the dry gas yield [11].

The result of carbon conversion calculation is presented in Fig. 3(c) for sand and dolomite. As expected, high temperatures enhanced carbon conversion efficiency due to the improvement of water-gas and Boudouard reactions (7 and 8) through which more carbon is converted to gaseous products. However, increase of the bed temperature beyond to 850 °C did not enhance carbon conversion due to the reduction of CO_2 content despite CO production.

Improvement of cold gas efficiency with increasing the bed temperature for EFB and sawdust is depicted in Fig. 4 (d). The highest cold gas efficiency of 69 and 65% was achieved at 1050 °C for sand and dolomite due to the high dry gas yield and heating value.



(a) (b)

(c) (d)

Fig 3. Effect of bed temperature and bed material on gasification performance

Agglomeration of the bed material was observed as the major concern in EFB fluidized bed gasification, especially at high temperatures. Such undesired phenomenon originated from the high K_2O content of EFB (44%) which deteriorates the sintering and agglomeration tendency of the bed materials to form low melting eutectics [16]. Increase of the bed temperature beyond to 800 and 850 ^oC for silica sand and dolomite, resulted in the growth of bed particle. However, agglomeration with dolomite was not severe and the size of agglomerates was not considerable in comparison to silica sand agglomerates.

4. Conclusions

Gasification of EFB as an abundant lignocellulosic waste was studied in an air blown pilot-scale bubbling fluidized bed gasifier. The effect of bed temperature and catalytic bed material on the quality of the producer gas was assessed. The achieved results proved the potential of this biomass to generate energy as the HHV of 5.5 M J/Nm^3 was obtained with dolomite. However, the agglomeration evolved at high temperatures was the main concern in EFB gasification. Thus, the EFB gasification experiments should be performed at temperatures below 850 ^oC to ensure the avoidance of any agglomeration.

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Future-Proofed Design for Sustainable Urban Settlements: Integrating Futures Thinking into the Energy Performance of Housing Developments

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Abstract: This paper investigates sustainable building and low energy housing at a neighbourhood or city district scale. In particular, it examines how futures thinking on the energy performance can be integrated into the selection of building components, materials and low or zero carbon technologies. A multiple case study is undertaken in European housing developments that represent sustainable communities of 'best practice'. A literature review on the need for long-term thinking in the built environment research is followed by the definition of 'future-proofed design' and its application to the energy performance of housing developments. The extent to which building strategies in selected urban settlements have been 'future-proofed' is assessed. The analysis of the case studies includes a set of identified trends and drivers affecting the energy performance of buildings by 2050. The building strategies that explicitly accommodate these future aspects in these projects are also examined. Results suggest that the vast majority of building decisions focus predominantly on cost-effective solutions, such as energy efficiency measures. The use of renewable energy technologies, low embodied energy components, and new methods of construction relate to a demonstration project or any specific regulatory requirements. It is shown that 'best practices' accommodate predictable trends and drivers rather than exploring a wider spectrum of plausible futures. This reveals the tendency to neglect long-term thinking due to the complexity of dealing with uncertainty and the short-term mindset of the building industry. It is concluded that building strategies need to be more flexible to adapt to climate change, accommodate future changes and follow the increasingly stringent building regulations. A new generation of decision-support tools that combine futures techniques with mainstream sustainability assessment methods should also be developed.

Keywords: *Sustainability, Housing developments, Energy performance, Future-proofing, Building strategies.*

1. Introduction

The building sector has the greatest potential to deliver long-term, significant and cost-effective Greenhouse Gas (GHG) emissions compared to other major emitting sectors, such as transport and industry [1]. It is estimated that 64% of the world's economic production, consumption and environmental pollution is associated with the urban built environment in developed countries, where people spend around 80-90% of their time indoors [2-3]. At present, the building sector accounts for around 40% of total energy consumption worldwide, which translates to about 30% of global carbon dioxide emissions [4].

Sustainable development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' [5]. Sustainable building has emerged as an integrated approach to urban design with the evaluation of social, economic and environmental aspects surrounding the use of natural resources, energy consumption, environmental performance, functional quality, and the consideration of future values [6]. The latter entails the concept of 'future-proofing', which refers to an explicit and systematic appraisal of future possible options. In practice, however, little research has been conducted into the issue of how to design and construct buildings considering long-term implications of the energy performance and carbon footprint, due to the dominant short-term mindset that prevails in much of the property and construction sectors [7].

This paper introduces the concept of 'future-proofed design' and presents its application to the energy performance of European housing developments of 'best practice'. It seeks to assess the extent to which exemplary projects integrate futures thinking into the selection of materials, building components and low or zero carbon technologies. The objective is to uncover building strategies that can 'future-proof' the energy performance of residential buildings against long-term impacts of climate change, technological innovation, demographics, energy behaviours and market forces. The term 'energy performance' refers to energy efficiency, on-site renewable energy generation, and the embodied energy[1] of materials and building components. There is a growing trend towards 'sustainable communities', which refer to eco-developments of various scales, such as eco-neighbourhoods, eco-towns or eco-cities. In this paper, the term relates to urban settlements at the neighbourhood or city district scales that demonstrate pioneer thinking, political leadership, a whole systems approach, innovative financial solutions, low carbon innovation, multi-stakeholder collaboration, and community engagement [8]. Unlike individual buildings, community-led processes offer greater opportunities for a step change in sustainability through the integration of community energy networks and better economies-of-scale for novel Renewable Energy Technologies (RET) [9].

2. Methodology: Case study approach

The research adopts a 'real-life' perspective to understand the opportunities, practical constraints, and trade-offs in the selection of materials, building components and RET. The literature review focuses on the justification and conceptualisation of 'future-proofing'. A multiple case study method is employed in turn and 'best practice' European housing developments from 200 to 11,000 residences are selected. Table 1 provides a list of the case studies, along with a short project description. These projects are expected to provide the best platform for planning and design techniques from which to develop any improvements with regard to 'future-proofing'. Case studies entail both desk-based research and fieldwork. An ongoing survey via a structured questionnaire in parallel to expert interviews and focus groups via a semi-structured questionnaire are carried out since October 2010. The target audience includes planners, developers and local authorities involved in these projects.

3. The concept of future-proofed design in urban settlements

3.1. The need for futures thinking

An underlying reason to 'future-proof' buildings is that design choices cannot be easily revised and that the cost of inaction significantly outweighs the cost of timely action [14-15]. Futures thinking should be systematically integrated into the early planning and design stages, thus avoiding social, economic, and environmental costs associated with modifying settlements once they have been built. 'Although upfront design and construction costs may represent only a fraction of the lifecycle costs, when just 1% of a project's upfront costs are spent, up to 70% of its lifecycle costs may already be committed […] that first 1% is critical because, as the design adage has it, all the really important mistakes are made on the first day' [16].

[1] Embodied energy is the energy used to extract, process, manufacture and transport building materials and components.

Table 1: Selected 'Best-Practice' Housing Developments in Europe.

Project	Description
Hammarby Sjöstad, Stockholm, Sweden [8]	The 2010 European Green Capital. A mixed-use development of 11,000 apartments with energy, waste, and water following a unique eco-cycle. The City's long-term goal is to be fossil fuel-free by 2050.
Malmö, Sweden [10]	Bo01 and Västra Hamnen are two 'green' neighbourhoods (around 600 homes). By 2020, the City aims to be climate neutral and by 2030 the whole municipality will run on 100% renewable energy.
Freiburg, Germany [8]	Vauban (5,000 homes) and Rieselfield (4,200) homes are two district demonstrating pioneer thinking in solar energy.
Hanham Hall, Bristol, UK [9]	The first development of around 185 homes to meet zero carbon standards (Code for Sustainable Homes Level 6) in the UK.
Northstowe, Cambridgeshire, UK [11]	A new carbon neutral town of approximately 9,500 new homes, a town centre, offices and schools at a pre-design stage.
First wave of the Eco-town Programme UK [9,12]	Four new mixed-use developments of around 5,500 zero carbon homes and 40% of affordable housing at a pre-design stage: - Whitehill Bordon, East Hampshire - China Clay Country, St.Austell, Cornwall - Rackheath, Norfolk - Northwest Bicester, Oxfordshire
One Planet Communities UK [13]	- BedZED, London Borough of Sutton: around 100 zero carbon homes and 50% affordable housing. - One Brighton: a new mixed-use development of around 175 zero carbon apartments, office units and community facilities.

Another key motivation for future-proofing is the slow turnover of the stock. Buildings have generally an economic life of 50 to 60 years and a design life of 40 to 100 years [17-18]. Long lifecycles are due to high upfront costs of retrofitting, practical difficulties associated with deconstruction or demolition, and social attachments due to historical or cultural reasons, even if this was not explicitly the intention [19]. However, change is inevitable and caused by operational and maintenance processes, which determine refurbishment, deconstruction or demolition. It is estimated that 70% of the existing stock will be standing in 2050, thus each new building constructed in an energy-wasting manner or retrofitted to a suboptimal level will lock us into a high carbon-footprint future.

3.2. Definition of future-proofed design

Future-proofing is defined as 'designing something that can be resilient to future developments including both mitigation of negative impacts and taking advantage of future opportunities' [20]. This concept is promoted implicitly within the increasingly stringent environmental legislation, building standards and regulations at European and national levels, such as the recast of the European Performance Building Directive and the UK Climate Change Bill [21-22]. When applied to the context of energy and buildings, future-proofing refers to building strategies made at early stages which can be connected to long-term energy solutions, such as ability to accommodate new technologies or space for energy storage, thus achieving optimum energy performance throughout the lifecycle [23].

A future-proofed design strategy entails ‘stress-testing’ against a range of possible futures to ensure that building decision remain robust of the lifecycle and simultaneously ensuring effective management of future energy requirements. There are two key characteristics that underline this concept:
- The level of uncertainty surrounding the trends and drivers that could influence the energy performance of buildings, which can vary between predictable trends and unknown aspects that cannot be anticipated based on present forecasts.
- The level of availability in product and process innovation; i.e. technical solutions and decision processes to accommodate future aspects of the energy performance.

Future-proofed building strategies should manage both uncertainty and the need for innovation. This will aid the selection of materials, building components and low or zero carbon technologies that will be cost-effective and flexible in accommodating future changes or requirements. The benefits of sustainable building can only be realised over the long-term and, therefore, failure to incorporate futures thinking may result in poor levels of energy performance for decades.

4. Results

A review of policy documents and consultation reports for the identified case studies, along with data gathered via the ongoing survey and interviews, have revealed the extent to which ‘best practice’ urban settlements accommodate futures thinking in energy-related decisions.

4.1. Trends and drivers affecting the energy performance of urban settlements

Figure 1 reveals that the investigated housing developments acknowledge predominantly four trends and drivers from a broad spectrum of issues affecting buildings by 2050. These include: i) demographic changes due to increase in urban populations and social changes in housing unit and tenure types, ii) the increasingly stringent environmental legislation, building standards and regulations, iii) innovative economic incentives and funding mechanisms for energy efficiency, RET, and community energy networks, and iv) the launch of new technical solutions.

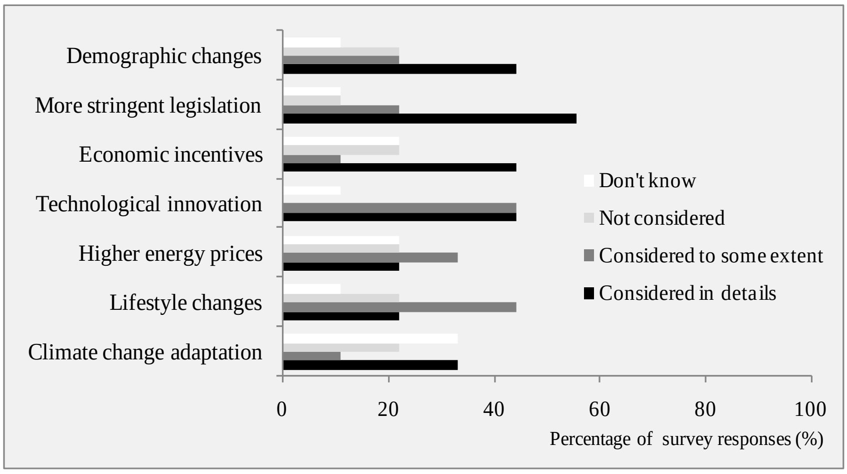

Fig.1. Trends and drivers affecting the energy performance of urban settlements by 2050.

Higher energy prices and lifestyle changes are considered to some extent. The latter refers to the energy-intensive behaviours associated with higher energy consumption, such as the purchase of more appliances, higher preferred lighting levels or room temperatures, and the occupancy of larger living spaces per person. Nonetheless, it is shown that 'best practices' do not fully consider adaptation to a changing climate change, as this trend is not considered or even overlooked in about two thirds of the survey data. Many future impacts of the energy performance of housing developments are already 'locked-in', as result of past GHG emissions. Figure 1 shows that adaptation to a changing climate is not yet a priority at the design stage, as building strategies have mainly focused on mitigation; i.e. reducing GHG emissions via energy efficiency measures and the use of RET.

4.2. Future-proofed building strategies

This section includes a list of building strategies adopted in the selected case studies as shown in Table 2, along with observed limitations and directions for future research. These future-proofed building strategies aim to accommodate the trends and drivers affecting the energy performance of buildings by 2050 (see Figure 1). In addition, Table 2 provides an understanding of the decision-making process behind them. Survey data reveals that the majority of the building strategies are selected due to the commonly used and cost-effective environmental design techniques; i.e. strategies to mitigate GHG emissions with energy efficiency measures.

Table 2: Future-proofed building strategies used in the case studies.

Building strategies	Main reason for selection
Energy efficiency of the building fabric: • Passive systems: location and orientation, natural daylighting, external shading, natural ventilation • Active systems: optimum insulation, thermal mass, and advanced glazing • Low energy lighting • Low energy appliances • Control systems: building management systems and smart metering	Standard practice, cost-effective
Low and zero carbon technologies: • Individual buildings: solar thermal panels, photovoltaic (PV) panels, micro-wind, heat pumps • Local energy networks - Gas-fired and biomass-fuelled Combined Heat and Power (CHP) plants - District heating and/or cooling systems - Large wind turbines outside built-up areas	Demonstration project
Low embodied energy materials and building components	Demonstration project, regulatory requirement
New methods of construction (e.g. prefabricated solutions, green roofs and walls, cool roofs, phase change materials, smart facades)	Demonstration project, regulatory requirement, marketing or 'green' image

Apart from the abovementioned environmental design features, the analysis of the case studies shows that 'best practices' integrate economic aspects of sustainability to enhance long-term affordability in the building layouts, functions, materials, building components and energy systems. This is achieved by process innovation in business models for the commercialisation of new technologies or the establishment of energy partnerships and community trusts. An example can be the establishment of an Energy Service Company (ESCO), which engages in a long-term arrangement with a developer to cover both the financing and management of the energy-related costs over the development's upfront and running costs. Furthermore, 'best practices' demonstrate social aspects of sustainability, by ensuring buildings for all types of occupants with a variety in housing unit and tenure types and by enhancing health and well-being. Social acceptability of low or zero carbon technologies is also achieved via community engagement and public participation.

Nevertheless, Table 2 reveals a lack of adaptation strategies that could bring flexibility into the building design and enhance the ability to undergo the impacts of future changes. The case studies do not fully demonstrate a diversified mix of energy sources and the ability to accommodate future changes or mandatory requirements regarding new technologies, such as PV-ready roofs or space for energy storage. Adaptable building strategies that address socioeconomic issues, such as internal space flexibility to support new behavioural patterns (e.g. home-based working) should also be incorporated in the building design. Another issue that is not considered in detail is a specific strategy for the decommissioning stages at the early lifecycle stages. Demolition should be avoided and designers should opt for materials and building components that can be disassembled for re-use and recycling. Improvements in energy efficiency have led in reduced energy consumption at the operational stage, and therefore the relative significance of embodied energy has increased, as it forms a higher proportion of the total amount of energy used during the lifecycle [24]. The findings, however, reveal that embodied energy is not integrated systematically, as this choice is related to a demonstration project and the establishment of any mandatory or prescriptive requirements for such calculations.

5. Concluding discussion

Future-proofed building strategies aim to ensure the delivery of resilient and flexible buildings that foster low carbon development and have potential for cost savings, lower running costs, and added-value in the future. To date, the case study research demonstrates that a starting point to future-proof a housing development is to be one step ahead of the building regulations with high energy efficiency measures and installation of cost-effective RET. It also highlights the importance of stakeholder engagement and the need for a step change from short-term mindsets to long-term strategic thinking and full lifecycle considerations, since it is the early decisions that determine whether a project will be sustainable and future-oriented or not. Nonetheless, when 'best practices' think about future-proofing, they focus predominantly on mainstream and cost-effective building strategies, such as energy efficiency, low energy lighting, and control systems. More innovative features, such as novel RET, local energy networks, embodied energy considerations, and new methods of construction, are still not mainstream solutions and are mainly considered due to a demonstration character, regulatory requirements, marketing or 'green' image purposes of a project, when testing novel energy solutions.

At present, it is challenging to deal with uncertainty and long-term decision-making on the building design. Interviewees agree that there is still no single, truly holistic sustainability assessment method that can integrate futures thinking into the evaluation of the energy performance, thus bringing flexibility to the building design. The case studies reveal that futures techniques have only been applied to a limited fashion in urban settlements. Futures techniques can help identify both anticipated and uncertain outcomes, bring together different perspectives, challenge current thinking, and aid robust decision-making. They are a family of tools that have not been developed with sustainability in mind but their orientation is of direct relevance to future-proofing. For instance, Scenario Planning is one commonly used technique, which has become increasingly dominant in business strategy and long-term planning of products, processes and industrial sectors [25].

The case studies have revealed the lack of a comprehensive technique to integrate futures thinking into *ex ante* sustainability assessment methods. At present, mainstream techniques and tools, such as Environmental Impact Assessment (EIA) or building rating tools (e.g. BREEAM, Code for Sustainable Homes, LEED, etc.), give emphasis to particular environmental themes rather than social and economic and focus predominantly on predictable energy trends and drivers. Therefore, they tend to overlook reasonably foreseeable or unknown dimensions of the energy outlook. A new generation of decision-support tools should be developed, which will adopt a hybrid approach combining mainstream sustainability assessment methods (e.g. EIA) with futures techniques (e.g. Scenario Planning) for the appraisal of the energy performance of housing developments.

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Space-time of solar radiation as guiding principle for energy and materials choices

Embodied Land instead of primary energy as universal performance indicator

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Abstract: Renewable energy is based on using a direct route from solar radiation to consumption, as an efficiency improvement from a long term route via fossils. However, both routes put a claim on space/land and the time of use of that land/space to intercept and convert it to useful forms. However, the same solar radiation is needed, to produce materials in a similar change from fossil materials to renewable materials, and materials are needed as well to produce the conversion devices for renewable energy. Similar processes take place in the realizing sustainable buildings, especially 0-energy buildings: : there is space time involved to generate the renewable energy, but also to generate for instance the renewable material based insulation materials, or the wooden construction.
These insights lead to the notion that looking to production of renewable energy only is sub- optimization of systems, and could in fact be counterproductive. This has defined our research to explore new ways of evaluation of activities, and in our case buildings. We have developed a indicator called Embodied Land, to evaluate the time and space occupied by generating both renewable energy and renewable materials. This has been tested in two cases, and runs out to be a interesting approach, showing clearly how the optimization of land and space use over a certain time period relates to choices in materials and energy together, and makes it possible to optimise from both resources together, using an minimum of land occupation.

Keywords: *Exergy , Exergetic space, Embodied land, Primary energy, Maxergy, Space time evaulation, Building assessment,*

1. Introduction and research questions

In reducing the impact of Buildings and built environments, what we want in the end is to measure whether we are really moving towards a more balanced use of materials and energy at a fundamental level and to see whether this can provide a approach and strategy that will transform the activities in a way to be maintained for many generations to come. It is however not the absolute use or burden we are interested in but whether the use within a certain space (system) and time (frame) can be continuous , with regeneration of quality instead of net depletion of systems potentials over the time of use. Studying the different possibilities of such a approach creates an inconvenient feeling with current calculation methods, performance indicators and assessment Tools . These exist in many forms however seldom measure real improvement of the global impact or resource situation. Nearly all tools use relative or subjective weighting, historic benchmarks and more, including even LCA (Life Cycle Assessment) tools . Other studies have provided similar conclusions: “Many research studies show the vulnerability of tools when accumulating indicators are used to reach a sole value”. [1] [2] Lowe has attempted to see if we could define absolute environmental limits for the built environment. Lowe concluded that there are also many uncertainties and problems when applying. [3] Another issue is that, for practical use, most tools and assessment methods are not very convenient, and provide too much detail according to the influences of the specific stakeholders’ position as has also been experienced in practice and concluded in research: “the non-transparency of tools for use in practice”. [1,2]
We will have to see if we can find new ways of calculating and accompanying tools and approaches that overcome these disadvantages..

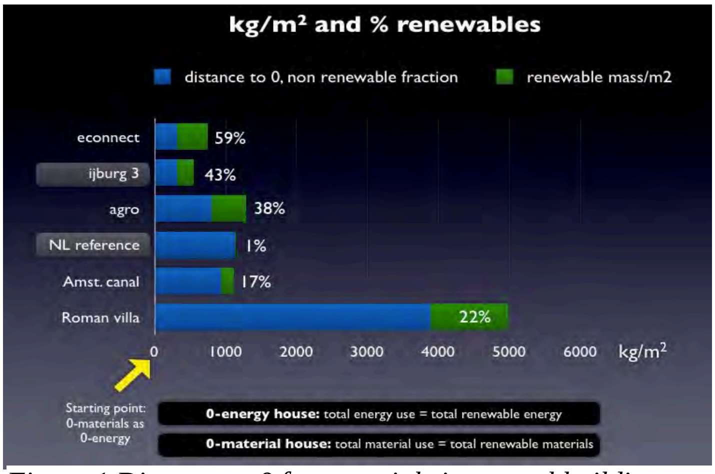

Figure 1 Distance to 0 for materials in several buildings

A first step to improve from looking at energy alone has been made in research on how to define a closing cycles approach, firstly focussing at materials. [4,5,6] . Materials are under threats of scarcity as well, and are a m ain cause of CO2 emissions in production. Materials should therefore , similar to energy, after centuries of growing depletion, start to fit in to a closed cycle approach. The logic step is to define a material neutral building as one that is been made of renewable materials. There are still resources involved, but only ones that ca be regenerated over the time of their use. It's a similar approach as for E nergy, when applying solar radiation . The difference is that the renewable energy is i nstantaneously regenerated, for renewable materials the time span is much longer. (but so is their application)

At that point a few questions were phrased:

A) If a 0-energy building is created, (fossil-) energy for operations and CO2 emissions are no issue anymore (besides in production of devices)[7] However, the embodied (fossil) energy of construction materials have become the major cause of the resource depletion and CO2 emissions related to erect and construct a building…! This poses questions like: Should we add more insulation (with still energy and CO2 impacts) or remain a higher heating load (requiring more –renewable-energy), what is best? [8] In other w ords: looking only into operational energy has become obsolete and is sub-optimisation, . But and how to combine both energy and materials in a evaluation? [1]

B) renewable materials are only renewable if they are renewed, and how would that work out in defining a 0-materials building, one that regenerates the resources on site?

C) both energy approach and materials approach , be fore de scribed, is still a quantitative approach. How would this change if we look at specific qualities needed? (heat, structural materials etc).

This paper further explores answers to these questions, introduces a approach and a exploration of two cases to test the approach.

2. MAXergy

One of the main question to address, in order to get answers, is to explore how energy and materials can be combined in a closed cycle approach , what would be a common denominator, one that automatically requires that different qualities are integrative addressed[2].

This forces us to look more in-depth at an overarching approach, that of exergy, which explores the quality potentials in a system. Energy can not be depleted, however its exergy ,

[1] The production of materials requires enormous amounts of energy, (cement production alone is responsible for 7 pct of all worldwide CO2 emissions, and growing [9] the total burden on fossil fuels is due to materials use! [10]

[2] This link between materials and energy has been explored in research on exergy, among others in The SREX programme in The Netherlands {http://www.exergieplanning.nl/} [11]

the qualities of energy (to provide work) that can get lost . The approach is mainly to see how decrease of the quality can be reduced. The usual approach is that a system is trying to be optimised from the inside: re-use of waste heat for instance (get more out of the same energy flow). More important however, the analyses is usually based on a "fossil" notion of exergy: that of oil and gas of high exergetic quality , available in a system. These however have only a high exergy/quality, since they are 'available'. It is seldom asked how they *became* available… These notions require a redefinition of quality in a system and how to maintain it. The following observations and arguing help redefine this.

2.1. Ecosystems, quality and humans

Natural ecosystems generate the highest quality. However one can argue if the word quality is the right word to use. Nature in fact has no q uality, nature just is. Physically its about thermodynamic stored potential, however only quality in terms of human use if made available *to do "work*". Its humans that value qualities since they make use of it. To explore the *human valued* quality, in different forms, we will explore in how far humans can make a potential available , and to have maximum use of it, maximum in the sense of lowest exergy loss (or better: to balance exergy *consumption* with exergy *growth* in time and space in a human managed system.)

2.2. Systems

the system addressed is usually limited ie a part of the earth. If quality is a main evaluating criterion for mankind's inhabiting of the earth, then its no use looking at a limited system: the largest system that is bordering human influence is the earth. There is no neighbouring system that can provide resources[3]. There is only one connection outside that system: that of solar radiation, the driver of our whole system, and the only source capable of preventing equilibrium(total decrease of quality). (besides a little gravity)

2.3. Redefining the oil route: solar radiation

Following this argument, the origin of Oil in fact is solar radiation (from outside the largest human addressed system) , converted to biomass, ending up as sediments and under heat and pressure changed in Oil (or gas or coal) This reveals that oil is in fact not the ultimate source for (100%) exergy calculations but just a specific state into a process of using/decreasing quality in the system as a w hole. . If we calculate this, (total known oil stocks, 65 m illion years process, over total earth surface) , w e can find that oil is renewably generated at a speed of approximately 14000 liter per day globally!. One step further we can derive the relation of oil gas and coal with space and time: the speed of generation and the earth surface use over time (for the biomass involved) . In fact electricity via the fossil fuel route (average of oil gas and coal) comes out at ~0,0017 kWh per ha per year. As comparison : el ectricity from solar panels provides ~1.000.000 kWh per ha per year . Its two different routes from solar radiation to electricity, with different impacts in land use and time. This creates a direct link to the use of a source and the space- time involved. And directly from that, the space time occupied by the use of it. Or in other words: if we do not use more oil as regenerated it's a lasting process, a sustainable operation. Based on the input of land and time to convert solar radiation. Via a different route Tran and Vale come to the same question of involving land in measuring sustainability and renewable energy production.. [12]

[3] Many of our system analyses are based on looking at a limited system, with imported resources un quantified, however having a burden on a neighbouring system loosing quality. This is only acceptable is the neighbouring system is also a well managed system. In the end its at the scale of the earth it all comes together, and no neighbouring system is available anymore.

2.4. And what about mass?

Energy and mass are two of the same, as Einstein already concluded and both share thermodynamic laws. In modern ecosystem approach its even mainly mass recognised as the main potential and process for capturing quality (as was biomass for oil…) [13, 14] Connect this to the fact that a shift to a *renewable* materials approach is based on solar energy as well, for materials to be (re-)generated on land, in a certain time period, and we have our first direct relation to evaluate energy and materials in one assessment. : the land use over time to produce the (human valued) quality. For food and water similar approaches apply.

Ultimately it is the solar radiation that decides on the quality in a system that directly translates into forming of mass and energy out of solar radiation, and both have direct effect on the land-use to make these conversions take place. In a change for a renewable sources based society- (closed cycles) there is in fact 1 principle basic to both, which is the ability to convert solar radiation into useful forms of exergy: quality in the form of mass and/or energy. (and food and water, however is not the scope of this paper)

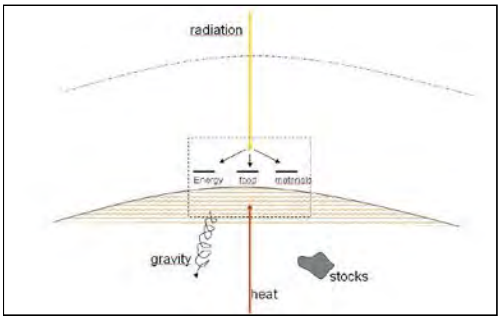

Figure 2 solar radiation access as the main structuring value

Important aspect of this approach is the relation with space needed to produce these resources and the time aspect in which they will regrow.

The questions we posed before can now be answered .
Ad A1 how can energy and materials be evaluated in a common system, is to explore the time space use that is involved in maintaining a closed cycle management, based on renewable resources. the question on energy and materials sub optimisation can be answered by using a common nominator for their impact: m2 solar radiation access over time to (re-)generate the demand (and the different qualities).:(or restore quality)

Ad B What is a 0-materials building, can be answered as one that re-generates the resources *on site*: it has to include space over a certain time to be able to regrow the resources used to construct the building, and the time relates to do so before their end of use.: In other words: the land to be appointed for their regrow should be included in the building site (similar to roof surface for PV for example)

Ad C The issue of qualities in stead of quantities has become obsolete in this approach: Its not an issue, it's the production potential to fulfil a function, with least time space occupation that is decisive for our possibilities , staying within closed cycle limits. Its all a matter of m2 solar access, which helps makes choices, also in qualities.

3. The Exergetic Space approach

Mass and energy , in a closed cycle operated society, have become one and the same, and can be only optimised in a combined way, in relation to their claim on solar radiation access via land/space over time. This can be phrased as The Exergetic Space , required for some function: The space-time needed to produces certain qualities over the time of use of a function fulfilled.

And the only real value to address this quality, or better the prevention of decrease in potential quality, is the m2, and our capability to create quality (convert solar radiation into human valued resources) in (at least) the same pace as it is consumed.

Or to turn it around: any system, no matter what size defined, has a maximum capacity to generate quality. If activities inside the system uses more quality then generated, it depletes resources and will face collapse in the end. Or in other words: one can determine the maximum activities in a system, to be maintained for ever by incoming potential and converted to useful forms.
Optimising for space-time, on the basis of converting energy/mass into useful carriers for human used value, leads to a complete different approach as so far. It requires reserving areas of space for generating a meaningful volume of the the most wanted quality.
And preserving the highest quality in a system, is not established by starting from cascading inside sources, but by starting from the system entering solar radiation and capture and convert in the highest valued mix of needed qualities

3.1. New indicator: Embodied land

Going back to our fist exploration into kg's of material involved in construction - the distance to 0 where all materials required were provided on a renewable basis - we can now quantify the impacts of the need to regrow these resources, without depleting a system: it's the land over a certain time involved : or the Embodied Land (EL).

4. Pilot cases

The approach developed can be used in two different ways. One is to evaluate the performance of different buildings ("the exergetic space need" or Embodied Land, for providing the building m2's) .

The other way is to explore in how far an existing and consuming urban environment can be re-developed into a 0-impact area, using the time space need as structuring element. This has been explored in a parallel case in which we develop the Urban Harvest + approach, and tested in a pilot Kerkrade West, a district in the south of The Netherlands. Its described in detail in other papers { 15}

4.1. The methodology

The methodology is structured as in the illustration (fig 3): first to explore the space need involved with generating the renewable materials. A database has to be developed to record yields for different resources. The results will be part of another publication, the illustration shows some basic findings (these are climate related of course). Next step is to include the embodied energy of the materials, and translate this into Embodied land.

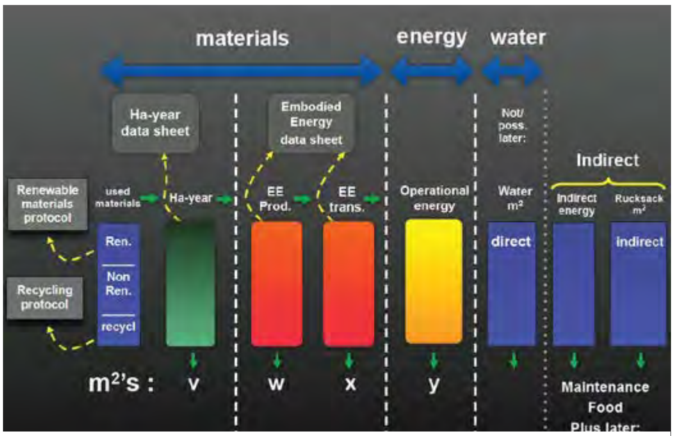

Figure 3 the methodology

For Embodied Energy figures, this research bases itself on the Inventory of Carbon & Energy (ICE) from the University of Bath version 1.6a .
As an example we both re-calculated the land use for fossil energy as well as with renewable energy. The third step is to add the operational energy to the calculation, giving a total land

need over a certain period of time to compensate for the exergy load/ quality loss in the system. In a further research also water will be added as well as secondary resource use and maybe food.

4.2. The cases and results

One case was a 5 level prefab Timber frame and straw bale house, designed for Amsterdam's new canal house district Ijburg.. Its based on 43 % of renewable materials
The materials use and energy related data were brought together and the embodied land was calculated for the above mentioned fractions.

Materials embodied land
In the case of Ijburg , the production of (43% renewable) materials require 916 m 2-year to produce , per m2 of living area. This can be produced in 1 year on 916 m2, or , if we take the lifecycle of a house as 50 years, on 18.3 m2 for the continuous period of 50 years. The space time occupation of embodied land significantly drops when lifetime of the house increases.

Energy embodied land
This has been recalculated for both fossil based energy and renewable based energy. To produce the energy for materials production by fossils, a land use of 43 million m2 per m2 of living area is involved (on a 50 year regeneration basis…!) . A huge amount, of course. To do so with modern biomass energy generation 2,16 m2 is needed, and via PV panels 0,06 m2.(both in 50 years) (only direct energy, not including yet indirect energy, for storage for instance) But it shows already the immense difference in effectivity whether fossils or renewables are used. For operational energy similar calculations are made: for Ijburg-3 0,08 m2 per m2 living area is needed. (solar generated, or 57 million m2 when fossils are used)

	Ijburg 3 50 years lifetime 1 m2 living area 550 kg/m² 43% renewables			Dutch Ref House 50 years lifetime 1 m2 living area 1145 kg/m² 1% renewables		
EL	18,33 m² - year			0,24 m² - year		
	PV	biomass	fossil	PV	biomass	fossil
EE	0,06	2,16	43.527.315	0,07	2,24	45.209.601
OE	0,08	2,83	57.013.505	0,49	16,51	332.914.466

Figuur 4: Embodied land for reference house and house from Straw and wood: for materials generation(EL) and for three energy sources providing Operational energy (OE) and embodied energy (EE)

From this point on its already clear that in the case of a ch ange to renewable materials , with still using fossil fuels as energy source, the last one is by far the most devastating to our land use : A 100 m illion m2 for EE and OE per m2 living area, compared to 18.33 m2 for materials (t he 43%, maybe twice as much for a 100 pct renewable materials house). However, if we include the fact that we have to change for 100% renewable energy, the picture is completely turned upside down: 0,14 m2 for EE and OE compared to 18,33 m2 for the materials fraction (on a 50 year calculation, but the relation remains the same) This already shows that decisions regarding materials have far more impact then those related to energy, in a renewable resources based world. As we will see later more in detail. In a second case study we started at the other side: that of an existing district which consumes more energy and mass as is produced in the area, or in other words, has huge embodied land occupied outside its own "jurisdiction", providing its own water and materials as well. This will require strong reduction of demand, and maximise production. This has been done following a 5 step model (the Urban Harvest plus approach [Rovers 2010] .For example: The energy plan assumes all houses are renovated towards passive house standards, requiring large amounts of insulation materials and a new structural façade. However from materials point of view these are not available, and require a large extra amount of land. A calculation shows that there is need for 135 ha of extra land to supply all materials for the whole district over a period of 20 years. On the other side it only requires 17 ha of Solar collector "land" to supply the heat for un-insulated houses. The choice is clear: no insulation and extra heating is the most effective choice. The finding were surprising even for the researchers, and even when expecting that materials might be more important then energy in a closed cycle and renewable source based society. It should be noted that only direct energy and mass has been calculated: materials for collectors, or process energy for materials have not been included yet. A follow up study should detail this issue, and probably find an optimum between insulation and heating. Both examples show that it is possible to combine energy and mass in one objective approach and relate directly to the sole sources for both qualities in the earthen system: m2 access to solar radiation, or "Embodied Land" . The model developed proved useful, and shows no un beatable barriers. Nevertheless some issues still have to be specified: The land relation for non renewable materials, as far as they are still used, the valuing of recycled materials (16), the detailing of choices, using indirect energy and materials, and other issues.

5. Conclusions and Consequences:

First of all the attempt to combine both energy and materials in one objective calculation has been proven possible though details still have to be settled. It turns out that direct solar access and the space time involved is the real value to relate decisions of environmental effectively and operation within a closed cycle process. Even food can be included in this evaluation (though not explored here) since it is in the same way depending on solar access. A second conclusion is that materials are as expected more influential in the environmental performance as (renewable) energy , though even far more as expected by the researchers.
Further findings and conclusions are:

- Quality is not a direct issue anymore: Since the evaluation starts from the potential available(in a given district) or the potential needed and the land to be included, in case of a new development qualities are to a certain extent given facts, and not directly structuring.
- Embodied Land seems a very good and understandable indicator to judge the impact of any activity .
- Optimising space and time in capturing the needed qualities, is what has to be valued , in order to establish a highest level of materialised welfare . How high is depending on our pattern of consumption of qualities, and the amount of individuals striving for that level of welfare, ie acquiring the useful functionalities.
- Optimising for space time, on the basis of converting energy/mass into useful carriers for human use, leads to a complete different approach as so far. It requires reserving areas of space for generating a meaningful volume of the most wanted quality.
- Preserving the highest quality in a system, is not established by starting from cascading inside sources, but by starting from the system entering energy and capture and convert in the highest valued mix of needed qualities

There is a few consequences to this approach. First of all: The notion " primary Energy " has become a historic artefact and thrown in the rubbish bin, since a historic relic from a fossil fuel driven society. When real values and impacts are calculated, the reference has become the sun, and the time space involved to generate quality from its radiation, and the capability to convert that in useful forms for humanity[4]. It also shows that trying to optimise the energy cycle, looking at (renewable) energy alone, , is sub optimising. The role of materials is far more important . So far the exploration has only involved a 2 D approach, in m2 land available for a specific amount in time. However in fact we face a 3D problem: How to deal with shading, how to deal with excavations, quarries in this approach? Think of a troglodyte house: The underground houses found in dry climates, like Tunisia, and including some underground villas by the Romans. They in fact produce materials, in stead of consuming by way of excavating soil to create living space. Or to include height in the form of hydropower potential . A more general approach for this has to be explored, in relation to the study of the use of non renewable materials .

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[4] Nature has no qualities. It is however thermodynamic stored potential, however only quality in terms of human use if made available to do “work”) . To explore the human related quality, it is explored in how far humans can make a potential available , and to have maximum use of it, maximum in the sense of lowest exergy loss (or better: to balance exergy consumption with exergy growth in time and space in the addressed system. (from the SREX research)

Energy Efficient Building in Third Climatic Region of Turkey

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Abstract: Residential and commercial buildings consume a considerable amount of the energy produced in Turkey. 82% of that consumed energy is heating related. A reduction to 25% to 50% of energy consumption is possible with only proper insulation of these buildings. Fossil fuels such as coal and petroleum produce CO_2. Tests have shown that CO_2 levels have reached 360 ppm in Turkey. In this context, buildings that are efficiently designed and configured will provide energy savings. Energy efficiency in buildings in Turkey, has gained prominence recently with the adoption of the Directive on Energy Performance of Buildings in 2008. The object of this study is to convert a building, located in the 3rd climatic region in Turkey, to an energy efficient one. Analysis of the building has revealed that it does not accommodate the TS 825 s tandards. New thermal insulation design has cut energy consumption estimates to 37,09 kWh/m^3, which is within the limits of regulation codes.

Keywords: *Energy Efficient Building, TS 825, Energy Performance of Building.*

1. Introduction

Fossil fuel reserves that provide a significant amount of world's energy requirement are rapidly coming to an end. Using energy resources efficiently is significant. It has been emphasized in several studies that only by using energy efficiently provide savings on energy consumption at the rate of 30% annually.

In Turkey, 82% of energy is used for heating. It is possible to provide 25% to 50% fuel savings only by building insulation. It is seen that the released CO_2 level as a result of fosil fuel burning is 360 ppm nowadays. Carbondioxyde is relatively 55% more efficient than other greenhouse gas on c ausing global warming. Therefore it is required that the living environments must be designed and configured to provide energy savings and efficient energy usage. In this study, by taking into consideration the requirements mentioned above, it has been intended to turn a building which is in Ankara, Gölbaşı in the third region, on the lakeside of Lake Mogan, away from the tall buildings, frontal to highway, having its own garden, independently oriented; consisted of a ground floor, one normal floor and a penthouse to an "Energy Efficient Building".

2. Heat insulation project

2.1. Heat insulation project for the current building

Considering the indoor temperature as 19°C in accordance with TS 825 Heat Insulation Regulations, conformity to standard has been reviewed by designing heat insulation project for the current non-insulated building. In the analysis for the current building, while the limited energy requirement is 33,77 kWh/m^3, calculated energy requirement for the building was 86,40 kW h/m^3. As it stands the building is not confirmed to TS Standard no 825 on Rules of Heat Insulation in Buildings in Turkey.

2.2. Variations on the architectural project and insulation application

To provide the building's conformity to TS 825 and reduce the energy consumption, various variations on external structure and roof has been proposed. Changes has been occured on the walls, windows and roof of the building as a result of the reconsiderations mentioned below and the analysis has been repeated in accordance with TS 825. Reconsiderations for the building were:

Window space has been increased on the south frontage of the building. 62% of window space increase on south frontage and 45% on total has been provided.

Roof gardening has been applied on the South and North frontages of the roof.

As a result of roof gardening application, the South frontage space of the building and the penthouse window space have been increased.

As a result of roof gardening application, “open air roof space” has been emerged.

Shadowing has been done on the North side of the building by planning evergreen plantation.

As a result of the studies made to provide conformity to TS 825 for the building, rockwool of 6 cm thickness for outdoor air contacted areas and 8 cm thickness for unheated inside walls have been used. 12 cm thick glaswool on the roof areas of the ceiling and 10 cm foamboard on open air roof because of the roof gardening application have been used in accordance with the fire code. Thickness of insulating material on flor has been calculated, considering the energy balance of the building, as 10 cm of foamboard. 10 cm floating floor boards have been used on floors next to unheated areas.

Instead of double-glass used in current situation, Low-E plated heat insulation bridged aluminum windows which has an Up value of 2,4 W/m^2K have been used. 3 cm thick cement mortar has been used on the external wall in current situation. In the new insulated condition of the building; 7 mm thick anorganic based palstering made of lightweight aggregates has been applied on insulation instead of cement mortar because of the nonconformity to structure physics.

2.3. Heat insulation project for the new condition

As the heat insulation done in accordance with TS 825 Heat Insulation Regulations energy requirement for the building has been reduced from 86,35 kWh/m^3 for current condition to 37,09 kWh/m^3. Therefore energy requirement for the building has been reduced from 37,12 kWh/m^3 as presented in the standard and confirmed to TS 825 standard. Annual energy requirement of non-insulated building has been reduced from 71544 kWh to 28572 kWh, provided energy savings of 60% and reduced CO_2 release with the insulation.

The comparison of heat loss values for construction element before and after insulation can be seen in Figure 1.

3. Alternate energy sources

Troubles, affecting whole world such as global warming, climate change and greenhouse effect caused by the usage of increasing amount of fossil fuel and so energy usage, prompts communities to develop new and clean alternate energy sources. Accordingly, new solution offers for active and passive systems to reduce the energy consumption in the current building are as follows.

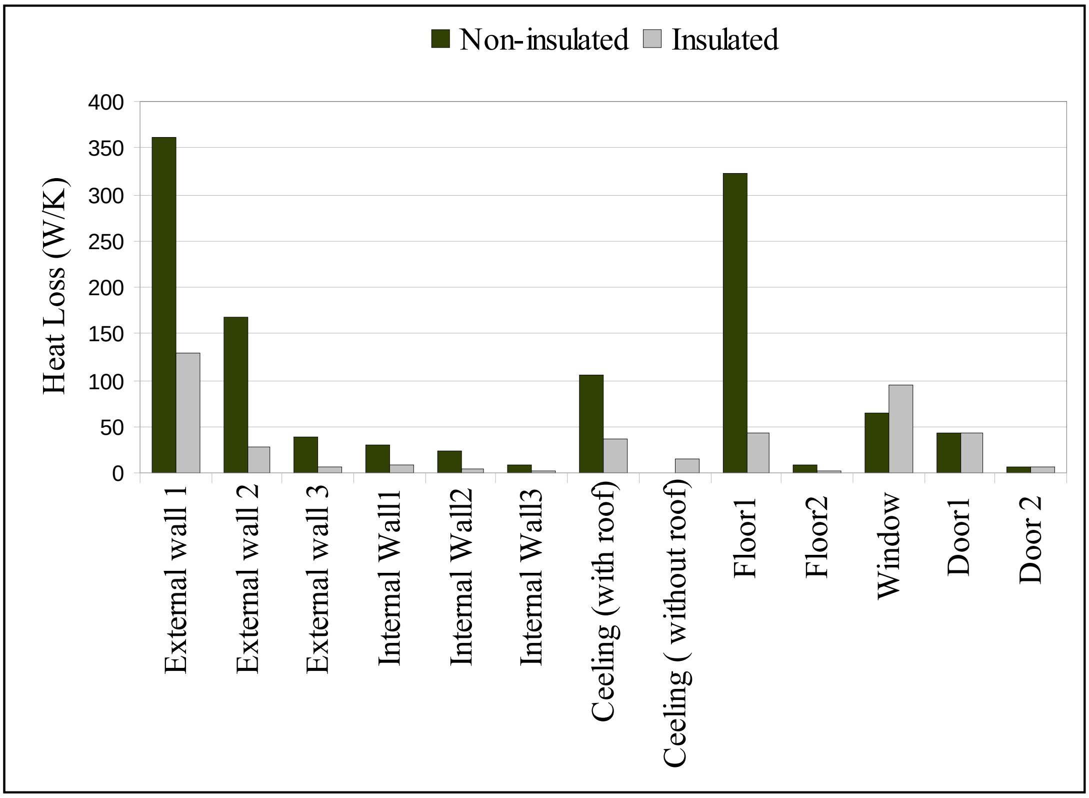

Fig.1. Heat loss for insulated and non-insulated conditions

3.1. Ground source heat pump application

To do heat insulation in accordance with TS 825 standard and to provide the annual building heating and cooling requirements which are reduced to minimum in virtue of passive methods applied, vertical type ground source heat pump application has been approved.

Energy requirement for the building has been calculated in accordance with TS 825 as mentioned above and distributions by months have been determined. As this distribution is reviewed it is seen that in January at the value of 20.497.178 kJ (7,9 kW) maximum energy requirement is occurred. Heat pump with 14,6 k W heating and 2,4 kW (EER=5,1) cooling capacity has been selected according to heating load. By calculating the cooling load of the building, solar collector has not been applied because in the system designed to be used both in heating and cooling seasons the heat pump will provide the required energy for both heating and cooling water usage. Analysis results for this design are presented in Table 1. Payback period for the planned system has been calculated as 11 years and 11 months.

When geological structure in Lake Mogan surrounding in Ankara-Gölbaşı region has been investigated, it has been understood that after a significant boring depth underground water is reachable [1]. Accordingly, specific thermal contraction capacity of stratas with underground water has been determined as 70-90 W/m [2]. It has been seen that 102 m borehole is required as a r esult of calculations below based on the peak load a h eat contraction capacity. Investment cost (device, pipe, boring and labor cost included) for this system is determined as 8472 TL. Fuel requirement is removed the heat pump will completely provide the energy needed for heating the house and generating hot water.

3.1.1. Economic analysis of active systems

Investment calculations, fuel savings and other additional cost (electricity consumption) belong to above mentioned active systems have been calculated and economically reviewed. Interest rate for the economic analysis has been considered 10% and "payback period" of the system has been calculated also considering the time value of Money.

The results obtained are presented below on Table 1. By considering interest rate as i = 10% and also considering the time value of Money, it has been seen that the system will return to profitability in 11 years and 11 months.

Table 1. Energy audit of the new investment and monetary values

	Heating (m^3 N.Gas)	Domestic Hot Water (m^3 N.Gas)	Cooling (kW)	Cooling (TL)	Investment (TL)	Saving (TL)	Additiona l Cost (TL)
Current situation	7647	340	12,3	1004			
Insulation	-4592				13722	2572	
Heat pump (heating)	-3395				10500	1901	-1356
Heat Pump (cooling)			-12,4	-393			+611
PV					1090		
TOTAL	0		0	+611	25312		-745
						Net Utility (NU) =	3728

Payback period (PP) is calculated according the equation below:

$$PP = \frac{\ln\left(\frac{\text{NetUtility}}{\text{NetUtility} - i * \text{Investment}}\right)}{\ln(1+i)} \quad (1)$$

$$PP = \frac{\ln\left(\frac{3728}{3728 - 0.10 * 25312}\right)}{\ln(1+0.10)} = 11 \text{ years } 11 \text{ months}$$

3.2. Heat storage in greenhouse, water wall and bedrock

Thermal storage is significant in direct solar energy recovery systems. Thermal masses allow storage and later usage of solar energy.

3.2.1. Greenhouse application

As one of passive heating systems greenhouse application has been applied on the building (Fig.1, Fig.2). Greenhouse is a structure which is on the South frontage, adjacent to the building. It has one-way inclined roof and its all areas are consisted of glass. Roof pitch is designed as 50° in accordance with incidence angle of sun beams for Ankara in winter. Therefore heat gain occurs in the areas next to the greenhouse. Glass used on greenhouse is a Standard insulation glass with a U value of 2,6 W/m^{2}K. By using this glass sun radiation has been utilized more effectively. At the same time heat loss from the glass has been tried to minimize. In virtue of the vents that positioned on the upside and underside of the greenhouse, it has been targeted to reduce the negative contribution to cooling load of the greenhouse by providing an air stream in hot summer days. Also with the help of shadowing components (jalousie) that will be placed on glass surface of the greenhouse and deciduous trees, it has been provided to reduce sun radiation that affect the greenhouse surface. As a result of thermal analysis of the design the total heat gain provided from the greenhouse has been calculated as 17,444 kW.

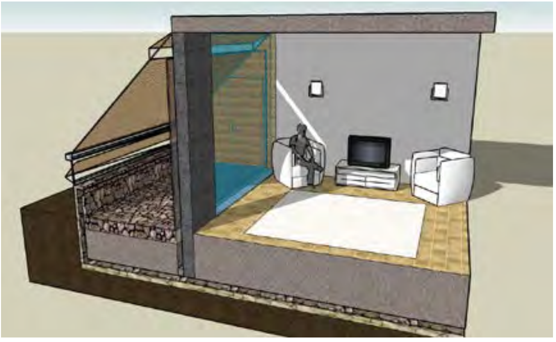

Fig. 1. Greenhouse, summer application (jalousie closed, went open)

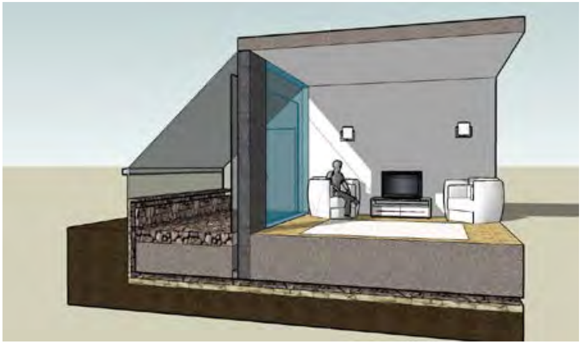

Fig. 2. Greenhouse, winter application (jalousie open, went closed)

3.2.2. Water wall application

Both to store thermal energy and to reduce light transmittance the wall that separates the greenhouse from the site has been transformed to a thermal mass by using two plane plexiglas board. In this application, by using water, which is a supply that has one of the highest thermal capacity (4160.103 kJ/m^{3}K), more heat has been stored and also it has been provided to increase the amount of sun beams entering the site because of the transparent surface [3]. With this thermal mass that is placed on south frontage sun radiation affecting the surface will be stored to able to be used in hours that we can not utilize the sun enough or none.

3.2.3. Heat storage application on bedrock

Bedrock has been formed as a thermal mass on the greenhouse or house floor to support passive heating of the house. It has been anticipated that by means of this thermal mass storing of excess heat accumulates in the greenhouse during the insulation and utilizing this energy when insulation is not enough [4,5,6].

It is provided to transform heat to rocks by sending the hot air which is drafted from between the water columns with a glass panel placed on front side of water columns, by means of the fan that is placed on the intersection point of the greenhouse floor and water columns. In virtue of two sensors, one is placed inside the greenhouse and the other on rock surface, fan only will work when the temperature in greenhouse is higher than rock heat. By this means, it is provided to prevent this cool air to reduce the heat of the bedrock. It has been targeted to rise apparent ambient temperature in virtue of the heat stored on rocks which cause a temperature rise on floor heat.

3.3. Other passive system applications

Window spaces on the south frontage of the building have been increased to utilize incident rays in winter. Window space increase has been provided at the rate of 62% on south frontage and a total of 45%.

To prevent living spaces from extreme heating in summer because of new windows which have been placed to utilize the sun beams more effectively in winter, window shades in specific sizes have been placed on top of the windows. These components let the light in which comes with oblique angle in winter but reflect the light out which comes with right angle in summer.

Two lines forestation has been done on north to protect the building from north winds. No forestation has been done on South frontage of the building.

Natural air conditioning – vents have been place on North frontage to provide natural air conditioning in the building. These vents have been placed on stairs column, penthouse bedroom and living room walls. Pressure difference required for these vents to work will be occurred when the Windows on South frontage are open and by that air circulation will be provided.

Light shelf systems – Light shelf is a component which is designed to prevent the sun light entering and direct it to the ceiling and placed horizontal or almost horizontal on inner surface or exterior surface of the window. These components will be added to top sides of the windows afterwards.

Two-leaf glass frontage application – Glass frontage cladding has been applied on first floor bedroom and first floor living room to utilize the sun beams on south frontage and two vents are used on the walls. These vents have been placed on top corners and bottom corners of the wall as enter and exit.

Power generation with Photovoltaic panels (PV) – It has been seen that payback period for the system will be too long as a result of feasibility study on whether all energy requirement of the building that becomes independent on heating and providing hot water can be provided with renewable energy or not. In that case, it has been designed to provide electricity requirement for fire exit way illumination and smoke sensors with PV panels instead of entire energy requirement of the house. For this purpose a package unit that consists of 180 W solar battery, 1 charge regulator and control unit, 1 solar accumulator and 4 light bulbs (11 W, 12 V) has been selected to be placed on roof. Investment cost for this unit is 1090 TL and it is presented in economical analysis tables mentioned above.

Heat insulated garden roof terrace – Besides looking beautiful, roof gardening, which is very common in western Europe, also provides substantial economical and ecological benefits if it is applied with a safe water insulation and well planning [7,8,9]. Considering the draught in Ankara, water has become significant and roof gardening application has been decided.
Water saving and recycling – To reduce the utility water usage in the house it has been suggested to use type-A water saving sinks and double stage reservoir in bathrooms and to store the rain water handled in gutter and roof gardening to use in both toilet flush tank and watering the garden.

Chimney flue – No change has been made in the chimney which is on the North side of the current house. It has been thought that using the chimney in winter will provide heat gain on the colder north side of the house and also to utilize flue gas heat. Discharge shaft has been designed as a heat transformer to do that. In that design, by placing a second layer on flue gas brick it is targeted to heat the flowing air in between and return it to the environment. Therefore reduced heat requirement for the environment has been provided.

Phototubes (Cold light in hot day) – Sun light has the top quality light among lighting devices. Day light for first floor North bathroom, garage, mechanical room and the penthouse which has been made by roof gardening application has been provided by this system. Therefore there will be electricity saving at the rate of 30%-70%.

4. Conclusion

It is a fact that a significant part of energy consumption is occurred at our living environments, houses and working places. Therefore designing and configuring the living environments to provide energy saving and efficient energy use is a necessity.

In this study in virtue of heat insulation, active and passive methods applied to the building both energy saving and economical benefits has been provided. Energy generated, transmissioned and commercialized in our country has been used without squandering. When the applied methods are considered as a whole, 7987 m^3 natural gas and 10320 kg CO_2 release saving has been provided. In the second system that also the cooling load of the building is considered as well as the heating requirement 7987 m^3 natural gas saving and reduced electricity consumption has been provided. In that case CO_2 release saving has been 11847 kg.

Current building has been transformed into an "Energy Efficient Building" by applying heat insulation as well as other several active and passive systems and its ecological footprint has been reduced.

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Urban materials for comfortable open spaces

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Abstract: All the elements present in open areas contribute to define the microclimate and they have to be designed to mitigate the microclimate. In particular urban materials have to be selected on the basis of the urban space use and its thermal behavior.
This paper shows the influence of urban pavements and building facades materials on the open spaces environmental performance and on thermal comfort conditions. In order to evaluate the contribution of the materials thermal simulations in dynamic regime were carried out of simplified configurations (corner of squares and streets. The paper shows how the urban space thermal performances change when only one or two walls are considered and if differences occur when the analyzed area is near or far from the wall, as well as when building height changes. This first part of analysis considers the open space as reference case and evaluates how the thermal performances change according to the changing context (from open space to the corner of the square). The second part points out the differences among the materials due to the physical properties, like albedo, thermal capacity and density. The last analysis concerns the evaluation of these configurations in terms of thermal comfort.

Keywords: *Microclimate mitigation, urban materials, thermal comfort, open spaces.*

1. Introduction

Pavement and building facades represent the recognizable support of urban space, i.e. the scenario of collective memory and social life built by movements, trading, meetings and communication. These spaces should represent more than the possibility to cross or reach destinations: they should satisfy the users need dealing with the perception of the space [1] [2]. Pavements and facades have another role. Urban space materials, as well as urban morphology, define the urban heat island. Nowadays the insufficient attention to physical properties of materials and the free development of the built environment induce to increase this phenomenon. It affects the unpleasant microclimate in contemporary cities, especially during the summer. It is important to know natural materials properties in order to classify them on the basis of energy performances.

To understand the energy behaviour of materials in urban space an analysis was done comparing energy performance of some urban configurations by changing pavements and facades materials. Thermal simulations in dynamic regime were carried out with the software Solene [3] in order to define the role of materials and observe their behaviour in particular urban contexts. Simulations were done for a latitude of 45° (Milan, Italy) in a sunny day (clear sky). The microclimate is determined also by the materials' thermal properties and can be evaluated in order to foresee suitable environmental performance and acceptable thermal comfort conditions of urban space, in case of new project or urban renewal.

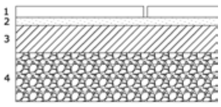
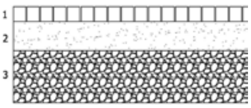
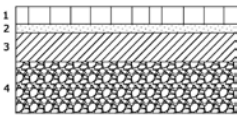
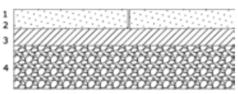
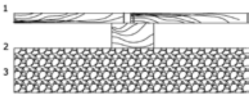
2. Methodology

Thermal simulations in dynamic regime have the advantage of highlighting each element contribute one by one. For this reason it is possible to evaluate the pavement colour impact on energy performance of the urban space as well as the heat capacity. In other words it allows to understand if it is better to pave a square with red granite or wood, with clear or dark stone.

Cases simulated with Solene and reported in the paper describe the thermal behaviour of specific locations in a urban space (centre of a square, the corner or areas differently oriented) by varying paving and facades materials.

Nevertheless before analysing thermal performance of materials in specific urban configurations, the most common paving materials should be analyzed to better understand differences [4]. To reach this goal we use a urban space not surrounded by buildings. This situation will be next considered as reference case.

Table. 1. Pavements materials used for the simulations. (A is albedo)

	N^o	Material	cm	Conductivity (W/m°C)	Specific heat (J/kg°C)	Density (Kg/m^3)
ASPHALT A= 0.2 	1	Wear layer - asphalt	2.5	0.7	920	2100
	2	Tout venant – (gravel)	7	1.2	840	1700
STONE A= 0.5 	1	Red granite slab A= 0.5*	≥3	4.1	840	3000
	2	Mortar	3-4	0,58	840	1200
	3	Hot flush	15	0.94	880	1800
	4	Road-metal	20/40	0.6	840	1700
* alternative coating	1	Marble A= 0.8	≥3	3	840	2700
	1	Lime A= 0.7	≥3	1.5	840	1900
PORPHYRY A= 0.3 	1	Cubes of porphyry	5	2.9	880	2200
	2	Sand and concrete layer	10	0,35	840	1800
	3	Road-metal	20/40	0.6	840	1700
BRICK A= 0.4 	1	Sestini di laterizio	6	1.7	840	2400
	2	Mortar	2,5	0,58	840	1200
	3	Hot flush	15	0.94	880	1800
	4	Road-metal	20/40	0.6	840	1700
COLORED CLS A= 0.5 	1	Slurry	8	1.2	880	1800
	3	Hot flush	7	0.94	880	1800
	4	Road-metal	20-40	0.6	840	1700
WOOD (LARIX) A= 0.6 	1	Larix stave*	4/5	0.12	2700	550
	2	Joist transverse				
	4	Road-metal				
* alternative coating		Cedrum stave	4/5	0.19	2390	700

It's important to keep in mind that with solar radiation, the characteristic with highest impact on thermal behavior is the solar reflection coefficient, the albedo (A), which depends on color and texture [5] . Material surface temperatures on horizontal plan are more close to the solar radiation trend then the air temperature.

A first assessment was done on several stone materials – granite, porphyry, lime stone and marble. Specific heat in stone materials is quite similar, while conductivity and density can be quite different. A second study was done on other urban materials (asphalt, concrete, wood).
The analysis will be completed after evaluating the previous simulations into a urban context. Each urban space, i.e. a square, a road or a courtyard is a distinct system that should be analyzed every time. In this work just parts of urban spaces were considered, like a position close to a w all (dihedral) or the niche (trihedral) representing the corner in a s quare. Simulation results were compared with the reference case (pavement in open space, i.e. without facing buildings).

In order to include geometrical and material aspects in the same analysis the mean radiant temperature MRT was considered, i.e. the all surfaces temperature multiplied by the view factors of buildings and pavement.

The urban space is usually considered "closed", i.e. the sum of view factors is equal to 1. In this analysis only pavement and facades were considered, (dihedral and trihedral configuration) (fig.1).

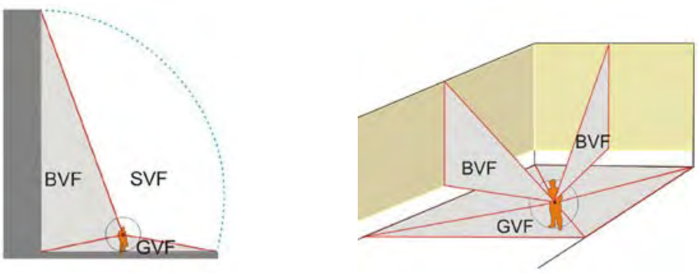


Fig.1: Dihedral and trihedral sections with angles representation for view factors calculations. BVF= building view factor; GVF= ground view factor; SVF= sky view factor (1- BVF-GVF).

Table. 2. Physical characteristics of façade materials used for the simulation

	N°	**Material**	**cm**	**Conductivity (W/m°C)**	**Specific heat (J/kg°C)**	**Density (Kg/m^3)**
"LIGHT"	1	wooden floor	2	0.15	2500	560
	2	polystyrene	20	0.04	1000	25
	3	wooden floor	2	0.15	2500	560
MASSIVE	1	plaster	1.5	0.9	840	1800
	2	bricks	20	0.8	840	2000
	3	plaster	1.5	0.9	840	1800
GLASS WALL	1	Double glass	2.2	1	837	3500

The two configurations in the four orientations were analysed and observations were made to understand what happens when the point is near or far from the wall and what happens if the wall is 4 or 20 metres high. It is possible to investigate the role of vertical surfaces, it means to understand what happens when the wall is a glass' one, brickwork (heavy) or highly insulated (light) one, associate to a paving with albedo A = 0.5.

3. Results

3.1. Materials' energy behaviour in open space

The comparison among stone materials shows that the porphyry is the stone with the worst environmental performance because of the high conductivity and relative low density. If we consider only density and conductivity e not the albedo parameter, marble and granite would be quite similar and with best environmental performance (fig.2). During the day surface temperatures would arise over the air temperature (>10°C) while in the night it would go under air temperature, to about 4-5 °C.

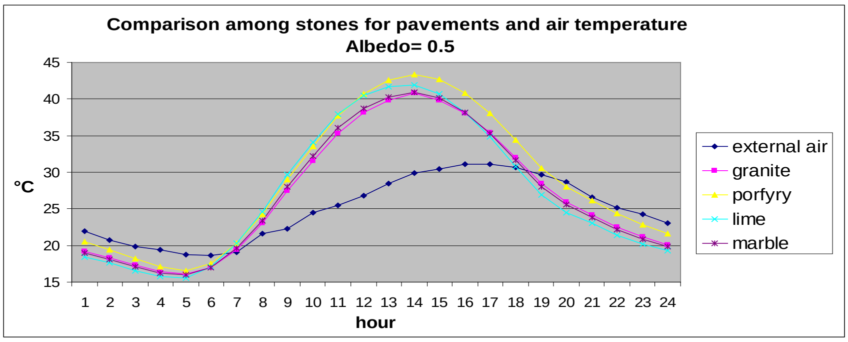


Fig.2: air temperature and stone pavements surface temperature. All stone materials are considered with the same albedo

Lime stone with relative low density and low conductivity has the surface temperature higher than the marble's and granite's ones and during the night it is the coolest material.
Regarding the other materials, wood has the worst performance, few differences if it is citron or larch. The asphalt is similar to the concrete and it isn't the worst material as usual (fig.3).

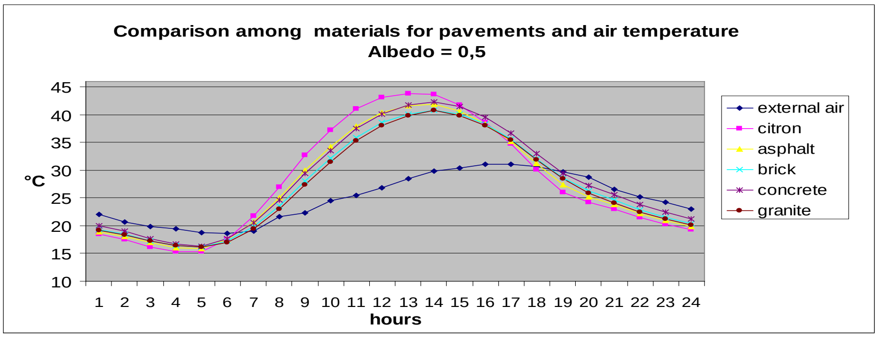


Fig.3: air temperature and surface temperature. All materials are considered with the same albedo

Considering realistic albedo values the red granite temperature is between porphyry and lime stone's ones (fig.4), quite higher than the marbles one (>10°C). According to [7], it is evident that higher is the albedo, lower is the surface temperature, in spite of the other physical characteristics of the materials. The white marble for instance has the albedo value close to 0.8 and his surface temperature is lower than the air temperature. On the other hand asphalt is absolutely the worst, due to the low albedo. With a simple observation we can confirm that asphalt should be avoided in pedestrian areas.

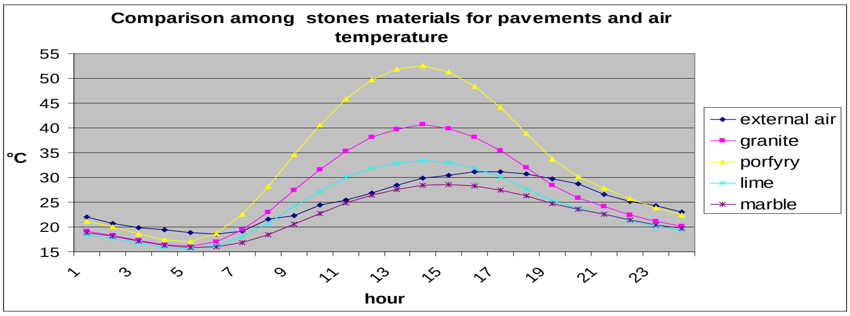


Fig.4: air temperature and stone pavements surface temperature

Wood hasn't good performance as well and if we want to use it, it would be better to paint it otherwise to use it with water as for cool pavements.

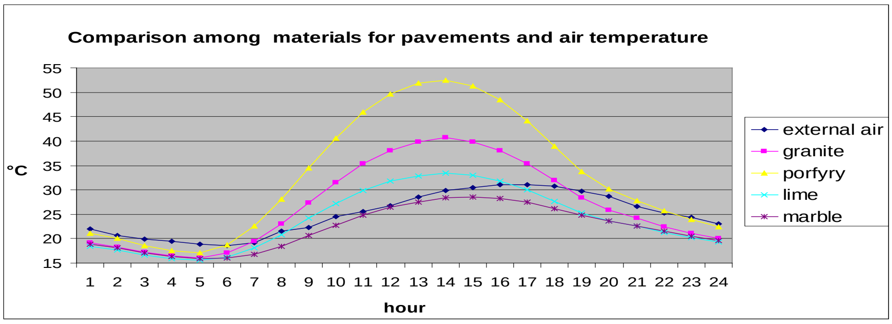


Fig.5: air temperature and pavements surface temperature

In general we can see that during the day the difference between materials and air temperatures could be also about 23°C (the higher difference at 2 p.m., in fig.5), but in the night the air temperature is always higher than the pavements materials' one. Figure 5 also shows that even in this case there are significant differences during the day when a big amount of solar radiation is present. In these hours the albedo influence is evident. During the night differences are due to density and conductivity (specific heat is similar for them).

3.2. *Materials' energy behaviour in simplified urban configurations*

The graphs display air and mean radiant temperature in a dihedral and trihedral shape.

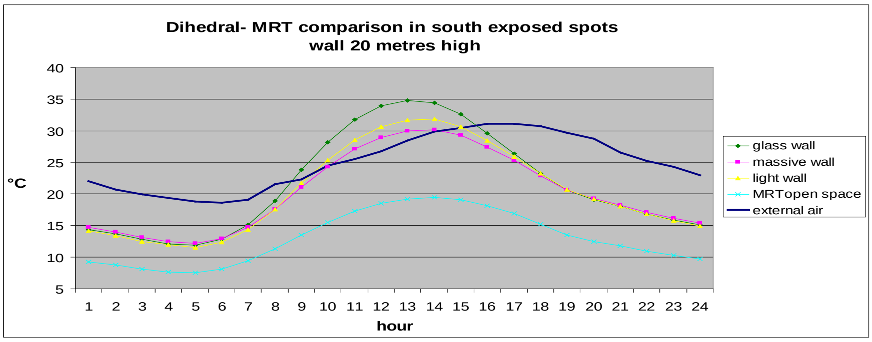


Fig.6: air temperature and mean radiant temperature (MRT) in an open space and dihedrals shape with massive light and glass wall. The point is south exposed 10 metres far from the wall 20 m high

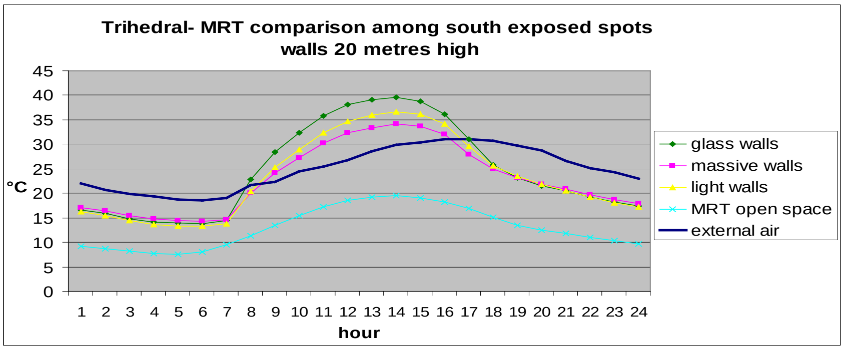


Fig.7: air temperature and mean radiant temperature (MRT) in an open space and trihedrals shape with massive light and glass wall. The point is south exposed 10 metres far from the wall 20 m high

Both in the dihedral and the trihedral with a glass wall the MRT is higher than in massive and light walls During the day, especially between 8 a.m. and 5 p.m. the MRT with glass wall is maximum 3 °C higher than in the light wall and till 5 °C than in the massive wall(fig.6, fig.7).. The farther we move from the wall the lower the surface difference will be; this is due to different wall materials. 10 metres far from the wall the differences are insignificant.

When the wall height decreases also the surface temperature decreases and consequently the MRT too. Differences of temperature between a wall 4 metres high and another one 20 metres high are about 4-5°C for every orientation (fig.8, fig.9). By comparing MRT of dihedral and trihedral with MRT in open field – with only pavement- the contribution is clearly evident. For instance at 2 p.m. a south oriented dihedral with the glass wall 20 metres high has the MRT 20°C higher than MRT in open field as the MRT in the configuration with glass wall 4 metres high is 7°C higher than one in open field.

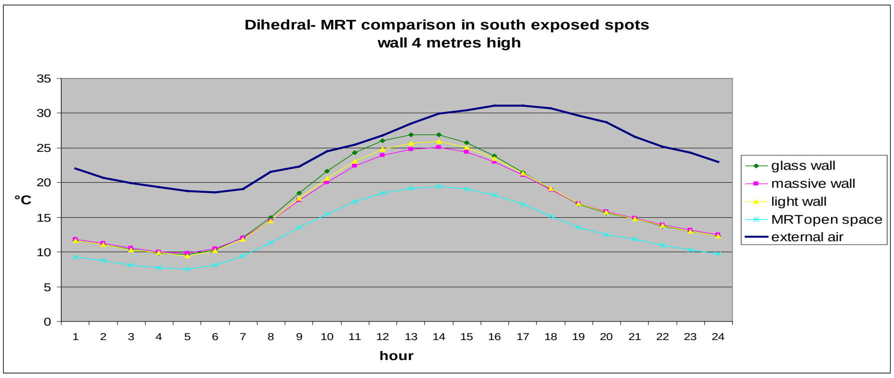


Fig.8: air temperature and mean radiant temperature (MRT) in an open space and dihedrals shape with massive light and glass wall. The point is south exposed 10 metres far from the wall 4 m high

It is possible to observe same differences in the other orientations even though temperature trends are different.

The MRT in the dihedral with the north oriented wall is always under the air temperature because it isn't never reached by solar radiation. The one with west oriented wall is the worst because of the large amount of solar radiation that reach the wall.

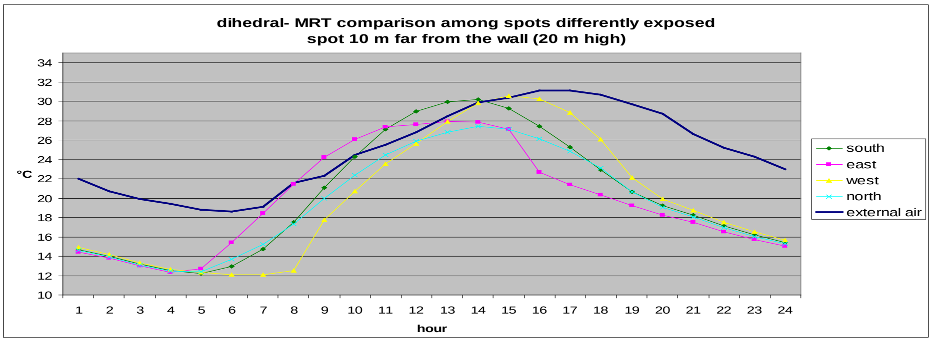


Fig.9: air temperature and mean radiant temperature (MRT) in an open space and dihedrals shape with massive wall. The points are south east and west exposed 10 metres far from the wall 20 m high

3.3. Thermal comfort

Finally a thermal comfort analysis was carried out to define configurations environmental performance in terms of people well-being. Surface temperature and MRT parameters are only a part of urban space configurations used to evaluate environmental performance. In order to evaluate thermal comfort we need to "close" this configuration by considering the sky view factor and the sky temperature. Thermal comfort was considered in terms of PET. With this evaluation it is possible to see any changing in people behaviour when they walk on a street like a "belvedere", for instance, or when getting close to a square corner. Graph reported below considers the dihedral and trihedral with facing walls 20 metres high and the analysed position 10 metres far from the wall.

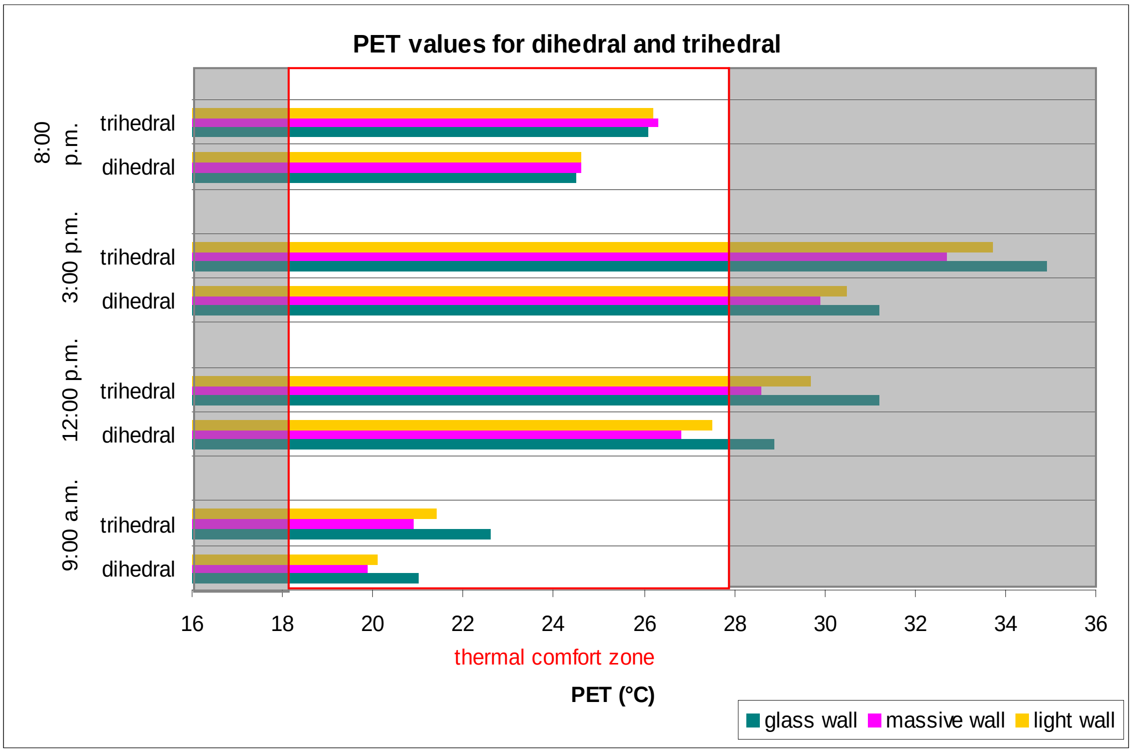


Fig.10: PET of the south exposed dihedral and trihedral with glass, massive and light wall.

For the trihedral we have the same trends of the dihedral but at mid-day and early in the afternoon PET is about 4°C higher then in dihedral. It is strongly recommended not to use glass wall and to be careful with the light wall too. Massive structures should be preferred.

According with the previous analysis west oriented configurations have the worst comfort conditions due to the incident radiation on the facades in the hottest hours of the day.

4. Discussion and conclusion

Lot of investigation have been done considering performance of materials in terms of surface temperature. The target of these researches are mainly focused on the heat island effect [6] [7]. According to this it would be easy to have simple conclusions on the choice of the best performing urban material. Nevertheless we need to clarify possible misunderstandings.

As we have seen, during a sunny day the surface temperature increases as the albedo decreases; in other words dark colours correspond to higher temperature and vice versa.

Clear and smooth materials like the marble have surface temperature are similar to the air temperature thus they behave as they are in shadow. One of the most popular strategies to reduce the heat island effects consists of using clear materials because they don't heat and reflect solar radiation. Nevertheless some problems are faced by using clear materials and when considering the idea to white as much as possible the urban surface. Problems can be the dazzling and the visual discomfort in addition to problems related to the urban traffic.

The other issue is related to the thermal comfort. The solar radiation reflected from a clear surface, like the marble, can be easily redirect to a space user. In the heat balance we have the surface temperature (as MRT) with the whole radiation including the reflected one. It's true that the marble absorbs 20% of radiation and its surface temperature is always quite low, but we cannot ignore that the 80% go back to the environment and can hit other urban surface on the space users. Material choice has to be done by keeping in mind all the elements trying to combine the "bad" material in terms of thermal comfort, with cooling strategies, like shading devices or water cooling system. A Thermally positive material surfaces temperature should be close to the air temperature during the day, with surfaces temperature similar to the surfaces temperature of materials always shaded.

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The Franklin district of Mulhouse: first French experience of low energy building renovation in a historic area of the city centre

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Summary: The project for the Franklin district of Mulhouse is the first French experiment in the renovation of old buildings in the context of a deteriorating urban area with a historic character to preserve incorporating firm energy objectives. Its first phase has just been completed with the publication of a feedback report [1] regarding its energy concept, large parts of this paper are based on these findings. The latter is in line with the Annex 51 programme of the International Energy Agency, *Energy Efficient Communities: Case Studies and Strategic Guidance for Urban Decision Makers*. The aim of this paper is to clarify the main elements enabling this project and to present the first results after two years of monitoring.

Keywords: *Urban Renovation, planning instruments, financing schemes, historical area*

In the European context a large part of the activities in urban development planning focus on the rehabilitation of existing areas. Today's approaches for rehabilitation schemes have to address the urgent environmental questions by increasing the energy efficiency of our cities but at the same time have to find answers to social difficulties and in many cases respect historic characteristics of the city. These were the main objectives for the City of Mulhouse in 2004 when it began to renovate a large part of its city centre and simultaneously intensify its sustainable development policy, especially focusing on climate change. Much of the city centre at that time was experiencing social difficulties and the inhabitants saw their everyday surroundings deteriorate. For this reason, the city chose to combine urban renovation and low energy use concepts by launching out one of the first projects in France regarding renewable energy in a historic city area formed by the legacy of the city's working-class past. The Franklin scheme is in line with the definition and the set-up of sustainable development policies at the national and European level. The aims at the outset were high and the conditions for getting there were difficult. This paper will discuss the first results and show that the project succeeded to nut just conduct a renovation programme but to fit and interlock with a policy and city planning logic on the agglomeration scale. Energy efficiency is thus closely linked with social and economic considerations. First results from the time span between 2004 to 2010 are discussed here based on a follow up report published in May 2010 [1], first of all by presenting the contextual specifics on which the operation depends; by focusing on the elements necessary for setting it up and finally, by presenting the necessary determining factors in the success of low energy building renovation measures that this experiment produced.

1. Context and energy targets

1.1. Operational Context

The district of Mulhouse (112 000 inhabitants) and its metropolitan area m2A (Mulhouse Alsace agglomeration - 255 000 inhabitants) occupies a unique geographic position in close proximity to Switzerland (Basel) and Germany (Freiburg). In the early 20th century it was one of the biggest European industrial centres. After de-industrialisation and the sweeping economic changes which followed this age, the town experienced harder times which it has been trying to overcome for many years. In order to achieve this, it can count on a young population and recognised technological know how mainly in the automobile industry.

Having something of an image problem, and looking to make the area more attractive, the Mulhouse agglomeration was one of the first actively to embark on sustainable city planning. Its climate plan, drawn up in accordance with the National Climate Plan, is one of the first in France (2007). This first step also includes the hope to revitalise the agglomeration's centre and to slow migration of commercial activity and the middle classes towards the periphery. To this end, work was undertaken in 2001 as part of a vast programme to renovate the city centre which included public spaces, economic activity and housing. It is within this framework that the local authority decided to renovate a number of particularly run-down buildings in line with low energy use targets. Thus first and foremost it is an approach linked to city policy, within which an environmental and energy aspect is formulated.

1.2. Energy Objectives

The Franklin district was built by the leaders of the Mulhouse textile industry between 1880 and 1910 to house their workers. It was very run-down and heading towards abject poverty, which resulted in a sizeable lack of renovation of buildings, some of these becoming outdated without a corresponding fall in housing costs falling behind in terms of comfort and basic facilities as well as security problems. In 2004, the city therefore launched a consultation process as part of the city centre's renovation. The local authority wanted to preserve the strong working-class identity of the area while implementing a thorough renovation which could have a practical impact on the urban environment and on the inhabitants' quality of life. Eventually the low energy building standard (BBC[1]) was set as target. Back then, and still today, renovating buildings according to the BBC standard is regarded ambitious in the French context, with energy use twice as low as the requirement of new buildings at that time. This level was set by the ALME (Agence locale de la maîtrise de l'énergie – Local Energy Agency) one of the very first French agencies created within the framework of the 1999 European SAVE programme. The ALME was given a mandate by the city of Mulhouse to develop energy optimisation and the use of renewable energies on the buildings to be renovated in Franklin. It also coordinated and led the operation, being responsible for accompanying the contracting authorities and project managers in applying their energy limits.

The neighbourhood consists of 300 buildings of which 106 were identified as not being in an adequate condition. Almost a third of the 106 buildings were potentially involved in the renovation work. Most of the dwellings in question are identical terraced town houses (i.e. adjoining on two sides) which contain 2 to 4 levels. To reduce the primary energy demand from an average of 450 kWh/(m²a) in primary energy to the set target, a modest intervention was not enough. From the outset, ALME, which engaged the services of a specialist energy research department (ENERTECH), decided to develop "standard technical solution" (solution technique universelle - STU) [2] in order to gain simplicity and efficiency in the implementation and also to reduce the costs. An initial comparison based on the dynamic simulation of individual buildings allowed assessing different combinations of existing efficiency technologies in order to define the targets which would be adapted to the Alsace region. To reach the BBC level, several main themes were defined. Insulation was reinforced for the walls and windows (triple glazing), taking summer comfort into account. External insulation was preferred where possible but the historic character of the façades or the encroachment onto the pavements often rendered this solution impossible.

[1] The French BBC standard limits primary energy use to 50 $kWh_{primary}/(m^2a)$. This value includes heating and cooling needs as well as energy for domestic hot water, ventilation and lighting.

The existing distribution system (i.e. radiators) were maintained but supplied by new wall mounted condensing gas boilers. The air exchange was ensured via mechanical ventilation with heat recovery, centralised for each building. From the point of view of electricity consumption, savings were identified in specific uses of electricity (appliances on standby, buying class A appliances or better). Domestic hot water (ECS) was taken care of by solar water heaters, from 5 to 7 m² per building, representing about 40% of the needs. At the same time, devices reducing water consumption were installed (e. g. pressure reducers).

Integrating all these solutions into a renovation project was sometimes complicated. The installation of some particular devices such as the double flux ventilators required ducts inside the dwellings. Alongside these technical problems, complexity also arose around the set-up of the project which had to obtain the maximum amount of financial backing and attain the energy targets.

2. A combination of mechanisms for the renovation scheme

2.1. The process

The city of Mulhouse delegated the project's implementation and management to SERM, a local mixed enterprise for developments in the Mulhouse region. The firm was mandated by the city of Mulhouse to carry out the operation in strict collaboration with ALME.
SERM was in charge of the renovation operation in 2004 for the old historic parts of town. Within this perimeter, some buildings from the Franklin district were particularly run-down, which meant their owners could have been forced to carry out renovations on their property. If they weren't capable to do so, the work would be declared in the public interest for these buildings, which allowed SERM to acquire the buildings. The buildings were then resold at the market rate to private landlords with an obligation to carry out the work according to the low energy standards contained in the conditions of the contract. The resulting incremental costs for investors were compensated by the community authority through subsidies and tax benefits. To support them in the application of the contractual conditions, the investor and his project manager received free assistance from ALME throughout the realisation of the project in order to respond to their enquiries and to ensure conformity for the intended work. The aim was to integrate the energy constraints and to form teams contributing to the installation of the technology. ALME also carried out checks during construction time and was available for the entire operational phase. This monitoring led to an optimisation along the way, following difficulties which arose during the implementation of technology which at that date was not in widespread use. Once the buildings were finished and the inhabitants had taken possession of them, ALME supported the tenants by informing them about the aims of this low energy renovation and by explaining how to operate the devices.

So that these aims and this support would be feasible and financially realistic, the local parties involved sought to take advantage of the financial opportunities the project was able to claim.

2.2. The implementation

In this paper the main focus is put on the implementation process. Therefore technical aspects will be treated in a lesser detail while primarily planning and financial instruments applied in the project will be described. Urban renewal operations as the one described depend on a sizeable number of financial aids to be called upon for the actors within the given area who do not have the necessary funds at their disposal (local authorities as well as private property owners). The necessity as traditional mechanisms to renovate buildings are ineffective (e.g. the property market or economic activity). As a result, the success of a project such as the one in Franklin relies on the ability of the project manager to obtain financial backing and its effective usage. The city of Mulhouse – and indirectly the private investors in the district – managed to do this. In addition to their own funds, they received significant subsidies which the diagram below summarises, indicating the level of origin and whether or not they were transferred directly to the public project manager.

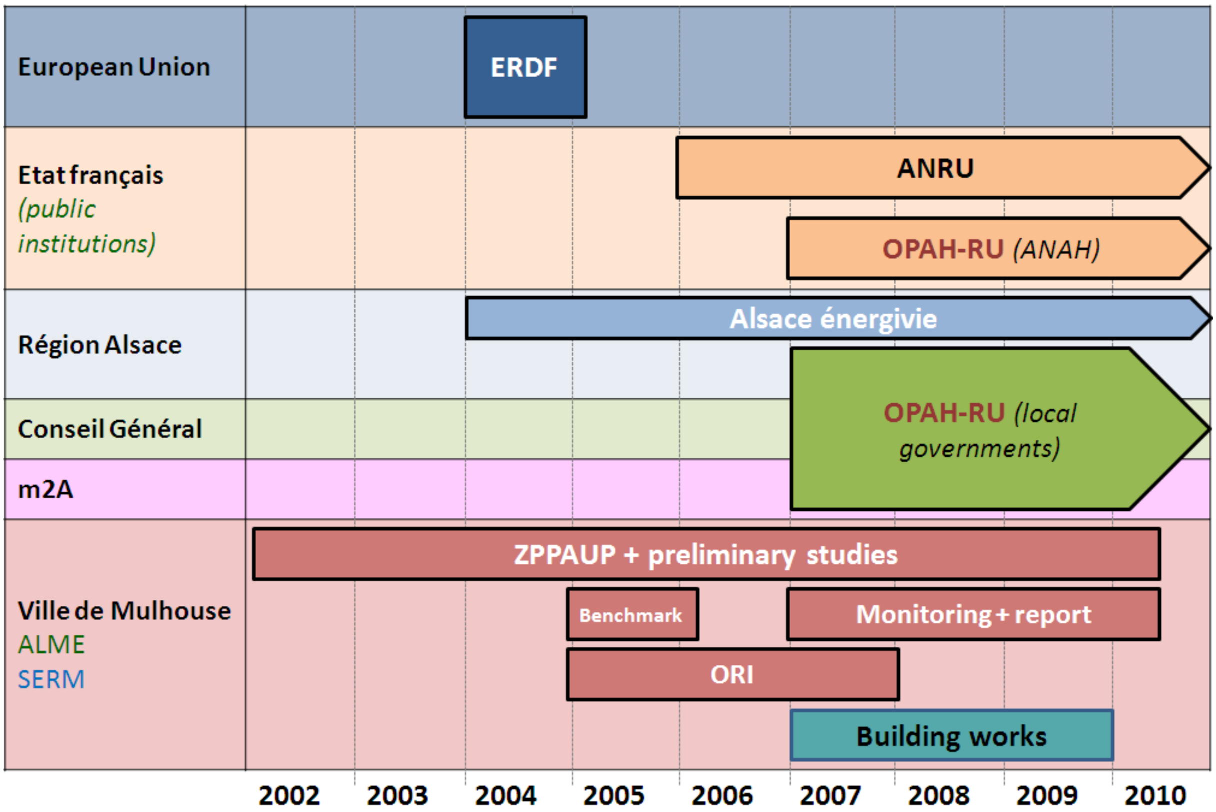

Figure 1 : Summary diagram of programmes and financial schemes in place within the Franklin district project

The European Union contributed via the European Regional Development Fund (FEDER) by financing for two years the preliminary research and the benchmarking. It was also a partner in the programme "*Alsace énergivie*" [4] led by the Region of Alsace in partnership with the ADEME which funded all the organisational engineering and the project's technical support assistance between 2004 and 2010. This programme has been designed since 1998 to promote energy saving and renewable energy by supporting private entities as well as local governments in their projects (awarded the 2008 European Commission Regiostars prize). Alongside this involvement, the state plays a specific role both by contributing direct funds to the local authority, but also by subsidising private entities. The City of Mulhouse came to choose the Franklin district project because it presented an ideal configuration, allowing urban renovation funds set up by the French state to be drawn on as part of the implementation of a city policy. This area is affected by four main mechanisms which are strongly interrelated.

An agreement was signed with the National Agency for Urban Renovation (ANRU) concerning the old city-centre districts such as Franklin (€270m of which 18m were allocated to the programme in 2006). ANRU is a public institute charged with funding and setting up the urban renovation programme across the country in urban zones which have experienced difficulties (lack of social/functional mix, lack of opening up to the rest of the city, etc.). In the Franklin district and the old districts surrounding it, it was expected that the housing on offer would be renewed, and that a series of public places would be rearranged: the Franklin public square, several schools, extracurricular centres, etc. The ANRU funds went directly to the public body charged with carrying out the work.

Furthermore, a scheme designed to improve the housing sector (OPAH) has been launched, dedicated to zones containing a high number of buildings potentially hazardous to health, run down (both internally and externally), empty or subject to social dysfunction. The OPAH-RUs (Urban Renewal, specific to urban zones), solely dedicated to the rehabilitation of urban zones, are organised as a partnership between districts, local authorities and the state. Here, it’s the Alscace regional authority, the agglomeration of Mulhouse m2A and the City of Mulhouse who contributed to the funding. The ANAH subsidies rose to about €350/m² transferred to the new owners of the property for a renovation cost of €1450 /m² (exclusive of tax).

The fourth mechanism is the setting-up of an scheme for property restoration (ORI) for old districts, which can be applied when the building is especially dilapidated and after a public investigation has been carried out. It is applicable within a reduced perimeter and differs from the OPAH-RU operation because of its coercive character. In fact, the owners, once they have been notified of the requirement for work, run the risk of expropriation in the event of non-compliance. This was one of the levers used in order to impose a thorough renovation in the Franklin district.

Finally, tied in with this ORI, the municipality demarcated an architectural and urban heritage protection zone (ZPPAUP) which made it possible for owners to exempt a part of the cost of the renovation work subject to them by renting the building out.

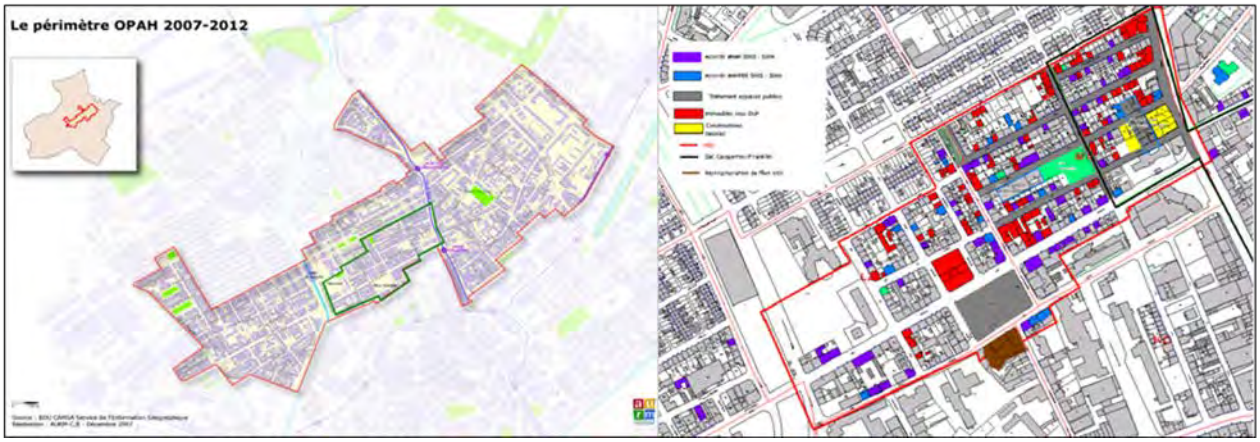

Figure 2 : The boundary of the OPAH and, that of the ORI (Source: ALME, AURM)

Within the framework of the aforementioned financial sources, SERM offered to help the owners for free. Firstly by providing for a dossier allowing all available subsidies to be claimed. Secondly by transferring the part directly subsidised to companies in form of upfront capital fund so that the owner wouldn’t have to pay in advance. It therefore created a one-stop-shop for private entities. This action made the process of distributing subsidies easier, and so increases the attractiveness for private investors.

3. Energy efficiency at the linking technology and behaviour

3.1. The occupant, key element in low energy schemes

From the outset of the project, the Franklin district was intended above all to be a city planning experiment for renovating a city centre, as well as a turning-point taken by the agglomeration in terms of sustainable development. To follow its progress and develop it was therefore the motor for the management of the project. A very unusual approach which could even give rise to disappointment faced with the uncertainty of the results. However, aside from a few pitfalls, the positive outcome of the renovation scheme could clearly be demonstrated.

In financial terms, the additional costs associated with the requirement for low energy renovation ("universal technical solution ", STU) was estimated in 2006, at the start of the project's implementation, at €315/m² (exclusive of tax) relative to usable surface (figure 3). Other costs linked to energy rise to €524/m² (excl. tax) for a total cost for the implemented measures of €1551/m² (excl. tax). The individual measures are described in figure 3 and included the insulation of the roof and the walls, mechanical ventilation and exchange of the boiler.

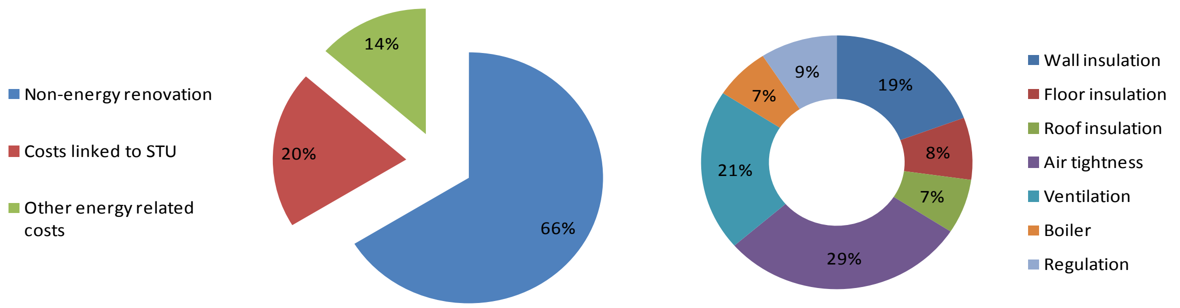

Figure 3: Cost breakdown of the renovation and ventilation of STU average costs in € and € /m² (excluding tax) of liveable surface area [3].

The investment costs, however, have had a tendency to go down since the start of the implementation in 2006 (-20% between 2009 and 2010). In addition, it became desirable to give up on some technical features which remained expensive such as triple glazing, and to develop air tightness in compensation which was found to provide for a higher energy efficiency potential [3] for the same investment. Concerning energy mechanisms, the 12 first buildings were the object of a thermal assessment and 2 years' monitoring. In addition, ALME's presence and its observations identified problems on site which couldn't be measured by instruments.

Yet Franklin is above all a city planning operation which, with or without ambitious energy targets, was a necessity for the neighbourhood. Its primary objective was the renovation of a run-down area improving the quality of life of its residents. The first return of experience on this subject is encouraging. The quality of using the dwellings has been improved: reduction of noise problems thanks to the insulation, greater thermal comfort, etc. This is accompanied by a significant lowering of costs for tenants who today pay rents similar to those in force prior to renovation but with charges considerably reduced (heating costs divided by 8). This advantage is vital because it sizably diminishes the vulnerability to energy price. More generally, the whole set of energy efficiency measures offers an added resale value for investors and increases the maintenance of the buildings over time.

From a specifically energy related perspective, one of the primary factors for success or, alternately, for failure, lies in the residents' acceptance of the systems put in place. An observation which has been highlighted in other analyses already carried out on new construction like in Grenoble's De Bonne district. The first results confirm that technology alone does not reach the full potential of the energy efficiency measures. First of all, the trial of communal areas for washing and drying made up part of the recommendations. However, this solution showed itself to be a failure as the designated spaces were not used very much. Also, some of the residents didn't follow the advice given to them during their moving in and kept the same habits as in a traditional dwelling (e.g. opening windows in winter, high heating temperature). The summer comfort was generally good but the results could have been even better with improved habits (e.g. night time ventilation). As often observed the users regulated the heating system to a higher indoor temperature as was initially assumed - heating to 20°C compared with the recommended 19°C. The final report cites the neutralisation of the thermostatic radiator valves regulated to a maximum of 19°C or the obstruction of the ventilator openings [3]. Besides traditional behavioural problems, one of the factors identified in this misuse lies in the problem of communication with the tenants. Sometimes this was linked to a poor command of the French language (suspicion regarding the measuring devices in the apartments, unworkable advice). In a more general sense sometimes the ALME had difficulties to stay informed of the arrival of new tenants which is due to the magnitude of owners and landlords in the area. However, the options for tackling this area of problems remain few, and their results hypothetical.

3.2. Energy efficiency: know-how and quality of implementation

Another behavioural factor depends on the implementation of the chosen energy efficiency measures. In Franklin, no revolutionary technology was used. On the other hand, in 2004 they were quite unusual compared to those traditionally used in French refurbishment market.
Some of the engineering offices in their approach did not distinguish between low energy buildings and traditional buildings. That notably led to an over sizing of the heating installations and therefore a poor efficiency. Moreover, the monitoring drew attention to the need, from the start up and the receiving of the dwellings, to take particular care of the auxiliary energy as well as ventilation or domestic hot water production.

Moreover some of the building professionals had not been informed about the installation quality required to achieve the low energy objectives. Problem also known in traditional construction yet its consequences become more visible when it comes to achieving this level of performance. Explanatory information had indeed been put together but it didn't work very well, notably because of the fluctuation of involved companies. This lack of care led in some examples to a poor air tightness of the building envelope. After the first applications this point has been added to the contractual conditions. Due to this, energy consumption for heating varied from one building to another partly caused by differences of air tightness. The average energy use is about 70 $kWh_{primary}/m^2$ of usable surface area per year in primary energy. Electricity consumption on the other hand was well managed, excluding that which was consumed by general maintenance services. A malfunction linked to incorrect application of the engineering office's instructions (e.g. continual running of pumps, ventilators) is strongly suspected and will be subject to further investigation. Finally, the thermal solar panels made it possible to attain the domestic hot water objectives.

Monitoring of the construction work will eventually allow the problems to be limited without however managing to avoid them completely. The aim therefore was achieved, which represents a success. Another positive note, the companies involved got used to the specific requirements of low energy buildings and are today more operational than when the project started. Creating a skills centre on low energy building ("pôleBBC") is one of the means by which this is managed today. This centre is in close contact with the previously mentioned Alsace centre for energy [4]. Thus an important aspect of the Franklin district remains its capacity building aspect as a place for the application of energy efficient building techniques. It makes it possible to crystallize experiences, to create a space for discussion and to draw on other similar experiences from professionals. The benefits are threefold: acquire a recognised low-energy skill, bring this economic sector to life and create jobs.

4. Conclusion

The renovation of buildings in the Franklin district contributed a lot to the diffusion of low-energy buildings in Mulhouse and met many of the targets which were originally set. Numerous links have been set up in France and in Europe between Mulhouse and other cities facing similar problems via conferences and visits. The reproducibility of such an operation, which brings together the financial support mechanisms, is however scarcely conceivable in its present state. Some of the funds received were within the framework of promoting renewable energy or energy efficiency. But above all, these were only possible in derelict urban areas. As a result, what made it a success might to a degree be responsible for its non-reproducibility. These measures were chosen partly according to the prerogatives given to the public project manager to impose certain kinds of renovation, and partly according to the subsidies they could obtain with a view to making the project viable and attractive for private investors.

Franklin has become a part of the city's sustainable development policy which now can draw upon a set of good practices and lessons learned. In addition it bears testimony to the synergies between questions of energy efficiency, traditional urban renewal and, to a certain extent, the policy pursued on the scale of an entire agglomeration. Beyond the contribution to improving the urban quality of the city centre and social cohesion, core elements of the project, this experiment focussed above all on energy efficiency in an existing urban area, which remains today the real challenge to which we must respond.

Acknowledgements

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Energy Efficient Communities – A Collaboration Project of the International Energy Agency IEA

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Summary: The background and purpose of a project to evaluate international experiences on planning and implementation of "Energy Efficient Communities" is explained. First results are presented, showing approaches and successes/failures on different levels of "communities", and conclusions to be drawn.

Keywords: *Urban energy planning, energy system models, IEA ECBCS R&D projects*

1. Introduction

Since in general over 40 % of the end energy use in OECD countries is caused by the built environment, an increase of the energy performance in this sector, together with the increased use of renewables for electricity generation, will be the key to a successful energy and climate change policy in the industrialized world. 80 % of our built environment is located in towns and cities. For this reason, it is decisive that cities, small or large, will be able to achieve such ambitious energy goals, and this will entail enormous changes in urban fabric and urban energy use patterns in the future. During recent years, new energy standards like the German "Passivhaus" or the Swiss "Minergie", or even "Net Zero Buildings", have been introduced successfully, which have facilitated a reduction of end energy consumption by a factor of 2 or more compared to conventional new buildings. Is this the solution of the problem? Looking at the existing buildings in our cities and considering the fact, that some 80 % of them will still be there in 2050, and their current primary energy consumption for heating, cooling, hot water and electric appliances is in most cases beyond 300 kWh_{PE}/m^2, a reduction by 80 % would require a primary energy use level of about 60 kWh_{PE}/m^2. While this is technically feasible with today's technologies, there are economic limits due to a non-linear increase of costs. To reduce the economic burden, cost-efficient alternatives must be found to simply decreasing U-values below economic limits.

Due to economies of scale, a number of technologies, like cogeneration or combined heat and power, waste heat recovery, biomass, geothermal energy, solar heating (and cooling), and others, are more efficient – in technical and economic terms – when used in large installations instead of small ones. Taking advantage of these technologies where locally available will enable the primary energy consumption (or GHG emissions) achieved by an optimized system to fall possibly to the best available standards (in terms of kWh/m^2 or kg CO_2/m^2) for new buildings, but with lower cost and with the advantage of a feasibility at community scales. A successful urban climate change policy will only be available if such options can be found and realized; otherwise, it will just be too expensive. Therefore, communities will have an essential role to play in the future to make this happen.

As the number of cities with successful climate change policy is still very low, it is obvious that there are powerful barriers that prevent cities from recognizing and implementing their potentials. A strategy to bypass these barriers is needed, in the form of integrated energy planning for neighbourhoods or energy master plans for whole cities – and the corresponding implementation strategies. Contrary to individual pilot or demonstration buildings, the aim of community-wide energy concepts must be to find an optimized solution *in economic terms* rather than introducing cutting-edge technical innovations, otherwise implementation would not be achievable. This makes a big difference between community projects and projects that are involved just with one single building. This has been recognized in several countries, where national programs for urban energy planning projects have been initiated. To benefit from experiences made by those national Case Studies, an international project (an "Annex") was commenced within the framework of IEA's "Energy Conservation in Buildings and Communities" Implementing Agreement. The title of this ECBCS-Annex 51 is *"Guidelines and Case Studies for Energy Efficient Communities"*. The work has begun in 2009 and will be finished until autumn 2012. 11 countries participate in this Annex.

2. Objectives and Project Structure

In Local or Urban Energy Planning, there are no standard solutions. An optimized design and implementation strategy must be found in every new case. The subject of Annex 51 is to identify methods how to find such solutions and to provide successful examples: Its aim is to provide stakeholders in communities with the necessary information to be able to achieve their local climate policy goals more successfully than in the past. This objective has defined the work plan of Annex 51:

- explore the state-of-the-art of local energy planning with respect to methods, tools and strategies: *Subtask A*
- exchange experiences from projects ("Case Studies") carried out within the ongoing national "city" programs: *Subtask B* for neighborhoods and *Subtask C* for whole cities
- summarize the outcome of this work in the form of a guidebook that serves as a source of methodological knowledge and practical examples for local decision makers and planners, and supply a simplified planning tool for decision makers to be used in the early planning phase: *Subtask D*

3. Annex 51 – Subtasks

3.1 Subtask A: Review on Existing Planning Tools and Implementation Strategies

Subtask A will be finished until summer 2011. The Subtask leader is France, represented by P. Girault and A. Koch from EiFER – European Institute for Energy Research (a research subsidiary of EdF in Karlsruhe). In this Subtask, selected successful Local or Urban Energy Planning projects ("LEP" or "UEP") from the participating countries, and planning methods and tools used in practice are evaluated, but more importantly, implementation strategies and instruments are discussed and conclusions will be drawn.

3.1.1 LEP – Neighbourhood Scale Projects

The LEP projects showed a large variety in terms of size, uses, targets, building constructions and energy systems involved, such as inner city revitalisation projects, as Western Harbour in Malmö or Regent Park, Toronto, or a commercial downtown district in Yokohama, until greenfield residential developments like Burgholzhof in Stuttgart. The number of residents or users is between 1.000 and 10.000 in most cases. While most of the cases have been finished, others are still in some stage of implementation.

The technical descriptions of the LEP projects presented in Subtask A have a big value in itself, because they show the large variety of solutions and approaches that can be used to achieve the energy or GHG goals strived for in the different projects. Due to the fact that in most cases there was no direct access to detailed data in Subtask A (planning data, measured data after completion, cost and price structures etc.), a quantitative evaluation is impossible for the Subtask A cases. In particular, it was not possible in most of the projects to compare the initial targets in terms of energy efficiency or GHG reduction with the reality after project completion. This should be different in Subtasks B and C, because the respective reviewers in most cases are directly involved with the Case Studies considered there. Conclusions to be drawn from Subtask A in terms of planning and implementation processes of LEP projects, show that five major influences seem to be common as success factors:

- a decision maker being directly involved in the specific project and acting as a driver in terms of technical innovations, energy / sustainability targets, feed-back to stakeholders etc.
- bilateral/personal information transfer from comparable other community projects that have been successfully implemented
- a “contract” at the initial phase of the project that is signed by all involved actors in mutual agreement and where the main targets of the LEP project are laid down
- the perspective of grants or allowances for the project according to some public funding program (whereas the absolute amount of money received seems to be less important)
- an “integrated approach”, aiming at a holistic view of the long-term perspective of the neighbourhood or district under consideration in terms of the three components of “sustainability”: social, economic and ecologic development.

In every specific LEP project, there might be other important issues that need proper solutions, but if all these five favourable points as mentioned above are valid in a project, the perspectives for successful implementation seem in general to be good.

3.1.2 UEP - City Scale Projects

A detailed discussion of the conditions and approaches of city Case Studies in terms of energy or GHG policy is being done in Subtask C. In Subtask A, only 2 cities have been presented as cases, Lyon in France, and Freiburg in Germany. While Lyon has began only recently with the establishment of a “climate plan”, in the City of Freiburg a continuous municipal energy policy has taken place since almost 30 years. Four phases can be identified: an initial period of political dispute (1980ies), a phase of first quantification of urban energy saving and renewable potentials and targets (1990 – 1996), a learning phase of practical implementation (until 2003) and a phase of re-adjustment to ensure successful achievement of the energy targets (until 2007). These last two phases may repeat periodically during implementation. The following chart presents wishful and real GHG developments in Freiburg over 20 years of time, showing that successful GHG policies for whole cities need a very long time and continuous adjustments to make sure that there is a move towards the targets set.

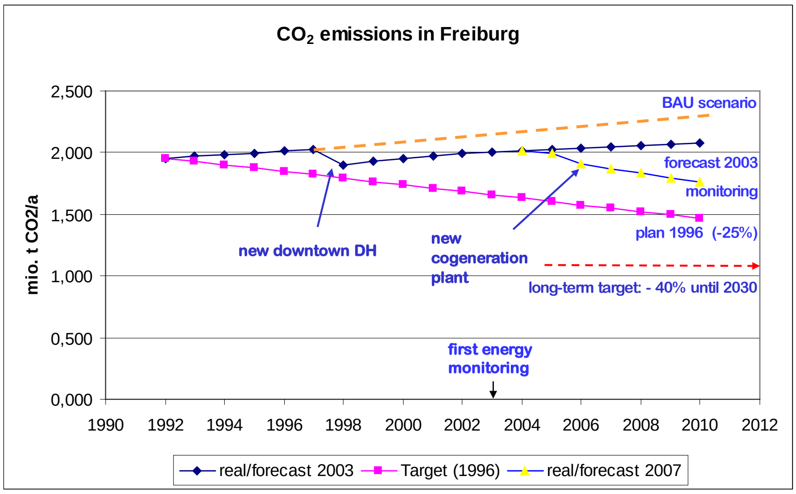

Fig. 1: Projected and real development of CO_2-emissions in Freiburg1992 - 2010

Fig. 1 illustrates the results of these phases in terms of urban GHG emissions in Freiburg, beginning with the first quantification phase in 1995. Based on this, a target of minus 25 % CO_2-emissions until 2010 (compared to 1992) was decided in 1996 by the City Council, while focusing its policy to *solar energy* and on ambitious standards for *new buildings*.

When a first evaluation of this policy, made in 2003, proved that the target until 2010 would be clearly missed, a new phase of analysis of more detailed and realistic energy scenarios was initiated. A first conclusion taken was that it would be necessary to track periodically the effects of measures made in the framework of the municipal energy policy. For that purpose, a tailor-made municipal energy and GHG balancing scheme was developed. However, developing a successful implementation policy based on local energy conservation and renewables potentials was a difficult step, which needed extensive discussions. To enable a detailed discussion of different policies, a spread sheet model with four “scenarios” was developed, which was used to quantify different assumptions or combinations of measures over a given timeline. As a result, in 2008 an almost unanimous decision was taken by the City Council to define a new GHG target of “minus 40 % until 2030” compared to 1992. This decision was combined with the presentation of a “climate change roadmap”. The municipal administration was appointed to be responsible to report periodically on their implementation.

Most important points on the “climate change roadmap” were the support of a retrofit program of the building stock making use of federal building modernisation pro grams, enforcement of neighbourhood scale district-heating schemes using cogeneration, biomass or biogas, substitution of all remaining coal uses, support of electricity saving programs for private households, and a diversity of measures in the mobility sector. Eventually, an ambitious modernization program of the municipal buildings was decided to serve as a model also for other investors in the commercial sector.

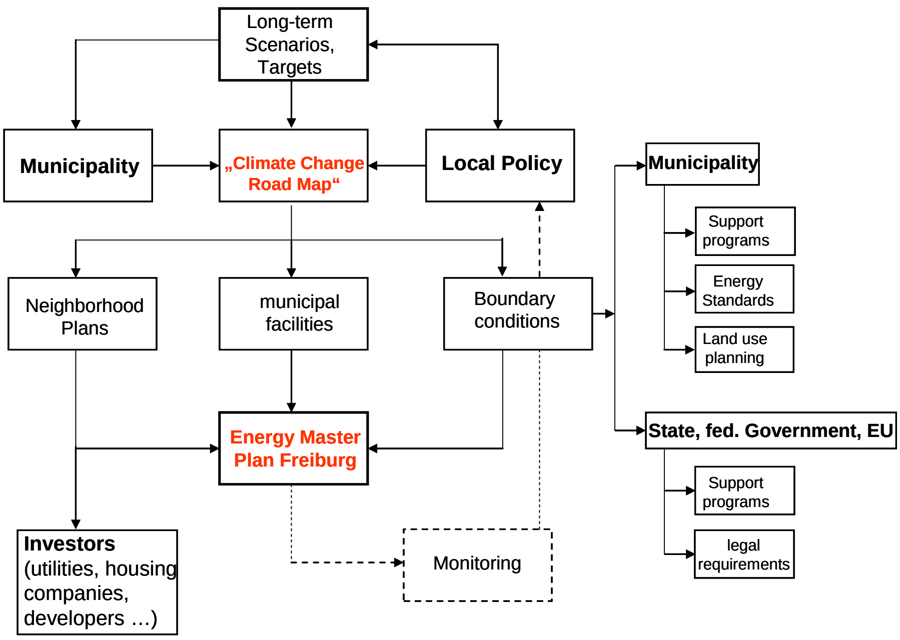

Fig. 2: Climate change policy in Freiburg 2008 - Organisational Structure

Fig. 2 shows a sketch of the decision making structure that can be outlined. The experiences in Freiburg have shown that the pre-requisites of a successful municipal energy and GHG policy will consist of a

- detailed information base on local potentials and options
- realistic target-setting based on achievable results
- detailed delegation of responsibilities and obligations
- continuous monitoring and communication
- installation of a project management (authority, energy agency, …) responsible for work organisation, reporting and feed-back to involved stakeholders.

As can be learned from the experiences in Freiburg, the definition and implementation of a community energy policy is a task, which requires a certain continuity in know-how and management capacities over many years of time. If successful, it will contribute to local economic development and quality of life as well.

3.1.3 Methods and Tools

On the scale of neighbourhoods or cities, different questions are to be answered by the planner compared to the scale of one individual building. While a number of *building planning tools* are available, which have proved their practicability to achieve useful results - examples are the “Passivhaus Planning Package” (PHPP) in Germany, or eQuest in the US, HOT3000 in Canada, Enorm in Sweden etc. – for neighbourhoods or districts, the situation is different. It was one purpose during Subtask A Case Study evaluation to explore, which planning methods and tools are currently in use (or in demand). On the scale of neighbourhoods or districts, the question of energy (and GHG) balances for demand and supply, annual and diurnal variations, economic optimization of both supply and demand measures are relevant for the planner. To be able to include a consideration of energy distribution, an interface with GIS would be useful, such as an energy map. However, on this scale, commercial energy models are not really available so far. Planners often use several different self-made calculation tools, with the disadvantage of intransparent calculation methods and lack of interfaces to existing data bases. As a result, every LEP project is a singular project. However, the situation with energy modelling of neighbourhoods (or cities) is better than currently apparent in planning practice, since several energy system models are “there” and used by academic experts in projects which have often the character of research projects. Two “models” are currently in widespread use, at least in Germany, Austria and Switzerland, one of them “GEMIS”, which is used most often as a reference database for primary energy and GHG factors for a wide range of energy systems, but is also capable to be used to “model” energy systems, including default cost values [2] and the other “model” is ECORegion, a tool primarily intended to make up energy and GHG balances of cities [3]. Two additional balancing tools, BilanCarbon of ADEME (France) and “Energy Balance” in Denmark have been used in Subtask A Case Studies, as well as pure simulation tools of energy supply systems, such as GOMBIS or EISAB, that are applied in Subtask B Case Studies (Germany, Japan) and will be evaluated there. Comprehensive energy system models, such as TIMES, POLIS or PERSEUS, are powerful, but complex optimization models that need skilled users and are in general not used by conventional planners (one application of POLIS is presented in [8]). It would be an important task of the future to develop such tools in a way that they can be used also beyond academic circles of model developers. One different approach has been developed by [4], where a physical model (buildings, spaces between the buildings, orography; climate) is blended with GIS and scanning data to simulate the annual energetic development of a whole neighbourhood including thermal energy demand, solar gains and energy system components and (statistical) user behaviour.

A simplified energy benchmarking approach for neighbourhoods was discussed in Case Studies in Germany [5]. Here, the idea was to extend the existing methods of building energy performance rating, where the specific thermal energy demand of a building, $q_H + q_W$ (q_H = space heating demand, q_W = DHW demand, both in $kWh_{th}/(m^2 \cdot a)$), is covered by an energy system with an end energy use ratio e_{EE} (kWh_{EE}/kWh_{th}). The term $p = (q_H + q_W) \cdot e_{EE}$ ($kWh_{EE}/(m^2 \cdot a)$ is used for the energy performance rating of the building.

Looking at a neighbourhood, typical uses (residential building types, others) have to be identified and the term $p = (q_H + q_W) \cdot e_{EE}$ as mentioned before has to be weighted according to the use areas to calculate an average value of p for the neighbourhood. At this scale, also the quality of the end energy delivered to the neighbourhood has to be considered. This can be thermal energy from a central heating plant, using a biomass boiler in the base load, or a cogeneration plant, a geothermal heat pump, waste heat utilization etc. In every of these cases, the "quality" of the end energy supply process, characterized by f_{EE} (kWh_{PE}/kWh_{EE}), can be described by an appropriate formula. For a central heating station for instance, operated with wood chips in base load and with a gas peak boiler, one may be interested in the "quality" of the end energy supply provided via a neighbourhood heating scheme in terms of fossil energy consumed (kWh_{foss}/kWh_{th}). In this case, f_{EE} is given by $f_{EE} = (1 - f_{ren})$, where f_{ren} is the fraction of renewable energy used in the central station (for instance, f_{ren} = 0,80). The resulting energy performance factor p ($kWh_{PE}/(m^2 \cdot a)$) of the neighbourhood is then given by

$$p = \left(q_H + q_W\right) \cdot e_{EE} \cdot f_{EE} = \left(q_H + q_W\right) \cdot e_{EE} \cdot \left(1 - f_{ren}\right)$$

In the case of a cogeneration plant instead of the wood-chip boiler, f_{EE} (kWh_{PE}/kWh_{th}) would be calculated from

$$f_{EE} = \frac{1+s}{\eta_B} - \frac{s}{\eta_{el}}$$

with

s … ratio of electric to thermal output of the cogeneration plant (kWh_{el}/kWh_{th})

η_B … overall efficiency of the cogeneration system (kWh_{EE}/kWh_{PE})

η_{el} … average electric efficiency of the regional power plant mix.[1]

In other cases, such as a heat pump for instance, different formulae for f_{EE} would have to be used.

One task of Annex 51 is to evaluate the current situation of planning tools and their practical use (or development needs). The basic requirements for such a tool to be applied for LEP projects would be

- description of energy demands (hourly, monthly, annually) and supply systems and their future developments at neighbourhood scale
- balances in terms of costs and GHG on neighbourhood level
- scenario building (business as usual as reference and scenarios using different technical options) for neighbourhoods and cities
- costs and economic assessment (e.g. using LCA) as basis for economic optimization
- continuous monitoring of implementation.

[1] In real applications, the fact that only the base load will be made from cogeneration, and the existence of losses in heat distribution and electric transmission would have to be considered, which makes the formula more complicated.

It remains to be shown if existing tools can be used by conventional planning consultants, perhaps after adequate re-designing of the user interface, or if there is a need for a completely new planning tool still to be developed.

2.2 Subtask B: Case Studies on Energy Planning for Neighbourhoods

This is a continuation of the work carried out in Subtask A, with the difference that in Subtask B the focus is on recent or ongoing Case Studies with explicitly innovative character, be it technically, methodically or with respect to the implementation approach. 14 Case Studies in 11 countries are evaluated, which cover existing neighbourhoods as well as new ones, and residential as well as mixed use neighbourhoods. Another difference to Subtask A is that the Case Study reviewers here are in most cases directly involved and therefore have access to detailed information as to cost structures and prices, business models or implementation strategies. This will allow for a much more detailed evaluation compared to Subtask A. This work is ongoing, led by the University of Linköping (Prof. B. Moshfegh, Prof. H. Zinko). Three of the Subtask B Case Studies are being presented at the WRE Conference [6-8].

2.3 Subtask C: Energy and Climate Change Strategies for Cities and their Implementation

With respect to international long-term energy and climate change targets, successful urban climate change policy is a key to success: without massive GHG mitigation in all cities, climate change targets can not be achieved. Compared to neighbourhoods, climate change strategies on city scale are much more complex and need much more time. Ongoing initiatives, such as the International Climate Alliance, ICLEI or the C 40 Initiative have been formed in the past, and more recently the EU-based "Covenant of Mayors", to support members of their organisations in the development of urban climate change strategies. However, really successful cities are still the exception rather than the rule.

As in Subtask B, methods and implementing strategies shall be evaluated using successful cities as Case Studies, but still more important is a description of the transition processes that cities have to undergo in terms of organisation and local implementation of their climate change master plan.

The Subtask C Leader is Prof. Kimman from Hogeschool Zuyd in Herleen (NL). Cities that are being evaluated in Subtask C are Tilburg and Apeldoorn (NL), Ludwigsburg (D), Stockholm, Zurich, St. Johann (A) and the City of Prince George (CAN). Results of this Subtask will be available in 2012.

2.4 Subtask D: Guidebook and Energy Model for Decision Makers

The main deliverables of Annex 51 for the general public will be provided by this Subtask, containing the essential results and conclusions drawn from the other Subtasks. The intention of the "Guidebook to Successful Urban Energy Planning" is to provide the necessary background of methods and usable planning tools to urban planners and decision makers, to select and explain the most interesting Case Studies of Subtasks B and C, which can serve as good examples for other cities, and to provide to the user a "Pathway on How to make an Urban Climate Change Action Plan and Implement it Successfully".

3. Conclusions

First results and experiences of the work made in Annex 51 have shown that for both Local and Urban Energy Planning, there is a lack in generally acknowledged and practically used methods and planning tools as part of the necessary knowledge base of planners and decision makers in municipalities. In addition, there is a need for learning processes from municipalities or cities that have proven to be successful in establishing a local energy and climate change master plan and transition into a successful implementation phase. Through the work being made in Annex 51, both needs shall be satisfied, with the aim to provide to this target groups a practical guidebook that is really beneficial in their every days work.

4. Acknowledgements

The author would like to thank all Annex 51 participants (being too large in number to be explicitly mentioned here) for continuous discussions during the course of our common project. In particular, I want to mention my Subtask Leaders, A. Koch and P. Girault from EiFER in Karlsruhe, Prof. B. Moshfegh and H. Zinko from the University of Linköping, Prof. J. Kimman with his assistant, W. Broers, Hogeschool Zuyd in Herleen, and H. Erhorn-Kluttig, Fraunhofer Inst. für Gebäudephysik, Stuttgart. In addition to these, I want to mention Prof. D. Robinson, ETH Lausanne, and Prof. U. Eicker, FH Stuttgart, for valuable discussions on the sometimes cumbersome issue of "energy models". My own contributions would not have been possible without the financial support of the Secretary of Economics and Technology, Germany, which has supported R&D in energy since decades in general and IEA co-operative projects in particular.

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Experimental investigation of the use of lignite ash for roof solar cooling

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Abstract: The moisture sorption properties of fly or bottom ash and their application prospect as evaporative coolers of roof surfaces were studied. Initially, samples were characterized through techniques like elemental analysis, x-ray diffraction, thermogravimetry, reflectance measurements and water vapor adsorption isotherms. Moreover, the water adsorption properties and the associated temperature variations were determined in a specific wind tunnel with controllable environmental conditions. The adsorption isotherms were of type III indicating hydrophobic materials with low water vapor adsorption. However, all samples were capable of lowering their surface temperatures due to water evaporation and the release of the latent heat. The maximum differences in temperature increase under simulated solar irradiation between fly ash and concrete were 3.8, 4.1 and 6.4 °C for the surface, middle and bottom, respectively of 3 cm material thickness. The toxicity assessment of materials implication in buildings roofs was performed by radioactivity and metal leaching experiments with rain water. According to the results, mixing of fly ash with either an inert material like soil or a green roof material or multifunctional nanocomposites is proposed in order to minimize its environmental impact.

Keywords: *Evaporative cooling, Solar cooling, Water vapor sorption, Fly ash, Lignite*

1. Introduction

The increased temperature in the summer time of the so called “urban heat island” effect is a major energy and environmental problem of urban areas. The effect leads to the increase of electricity generation for cooling purposes and the subsequent higher pollutants emission, the chemical weathering of building materials and the increase of the discomfort and even the mortality rates. Among the mitigation measures, building integrated evaporative cooling is an alternative and sustainable way to cool the surfaces of a building or the pavement of outdoor spaces by taking advantage of the sorption properties of porous materials. Stored water or night sorbed moisture inside the pores are evaporated during the hot day and the porous surface temperature is reduced due to the release of the latent heat [1-2]. Lower surface temperatures contribute to the reduction of air temperature since the intensity of heat transfer through the cold surface is lower while the heat flow inside the building is reduced. The method of roof evaporative cooling is considered to be the most effective method for roof and indoor temperature reduction [3]. Indirect benefits associated with the installation of roof integrated porous materials for evaporative cooling include water retention in heavy rainfall, increase of the thermal insulation pollutants uptake, reduction of roof materials’ degradation and carbon sequestration.

The materials’ rate of water vapor sorption and the sorption capacity are the primary factors in the selection of the porous materials. However, the outdoors stability, the affordable price, the local availability and the environmental non-toxicity are secondary parameters that should also be taken into consideration in the selection of the suitable material for evaporative cooling applications and for commercial use.

Moreover, around 37 and 4.8 million of tonnes of fly and bottom ashes (FA and BA) are produced every year in Europe while more than 20% of these are produced in Greece (10 million tonnes FA per year) [4]. Fly ash is beneficially used mainly in the building industry and road construction applications such as cement or asphalt additive, autoclaved aerated concrete block, concrete admixture or aggregate and highway ice control. The average ash utilization rate in Europe is 47% [4]. Other applications are zeolites synthesis and hazardous waste removal, blasting grit, flowable fill material, masonry block, structural fill, grouting etc. In spite of these applications, the largest proportion of the produced fly ash is directly discharged into landfills, increasing in this way the concern of environmental pollution. Therefore, the development of alternative applications and further means to facilitate the recycling of fly ash are urgently needed. To the best of our knowledge, the potential application of fly or bottom ash as a stand-alone material or roof additives for solar cooling has not been studied yet.

In this work, the moisture sorption properties of fly and bottom ashes from the major thermoelectric power plant in Greece were determined. Prior to moisture sorption experiments, materials were characterized by x-ray diffraction, thermogravimetry, reflectance measurements and water vapor sorption isotherms. Moreover, the water sorption properties and the associated temperature reductions were determined in a specific wind tunnel with controllable environmental conditions. Finally, an initial evaluation of the environmental impact of the fly ash application was performed by radioactivity and metal leaching experiments.

2. Methodology

2.1. Ash samples

Fresh lignite by-products of fly and bottom ashes, coded ADFA and ADBA, were obtained from the lignite power plant of Agios Dimitrios (1595 MW). Fly ashes were collected in a dry state from the electrostatic precipitators of the power stations while bottom ashes were air-dried at room temperature. All samples were ground by hand and sieved to a fragment size less than 200 μm.

2.2. Characterization

The major chemical constituents and trace elements of raw ashes were determined with the spectrometric methods of X-ray fluorescence (XRF) and proton-induced gamma-ray emission (PIGE) [5]. PIGE measurements were carried out at the 5.5 MV terminal voltage of the Tandem accelerator of the National Center for Scientific Research "Demokritos". Characteristic γ-rays emitted from the deexcitation of the residual nuclei following (p,p'γ) reactions, were used for the determination of light elements as Al, Si, Mg and Na. XRF measurements were performed by a vertical Si(Li) detector and a ring shaped radioisotope source (^{109}Cd or ^{241}Am) for providing the exciting radiation [5]. Cation exchange capacity was determined by cesium sorption isotherms, traced with ^{137}Cs [6].

X-ray diffraction patterns of the prepared materials were collected on a Bruker AXS D8 Advance Bragg–Brentano geometry with Cu sealed tube radiation source plus a secondary beam graphite monochromator. A step of 0.02 ° and a time of 6 s step^{-1} were selected. The thermogravimetry (TG) measurements were performed on a STA 449C (Netzch-Gerätebau, GmbH, Germany) thermal analyzer. The heating range was from ambient temperature up to 450 °C, with a heating rate of 5 °C min^{-1} under synthetic air flow rate of 40 cm^3 min^{-1}. The spectral reflectance of fly ash in comparison to that of a typical soil was measured using UV/VIS/NIR spectrophotometer (Varian Carry 5000 fitted with a 150 mm diameter, integrating sphere (Labsphere DRA 2500) that collects both specular and diffuse radiation) over the solar spectrum (200-2500 nm).

2.3. Water vapor sorption experiments

In the moisture sorption isotherms, samples were placed in desiccators with saturated salt solutions for controlling relative humidity (32.8, 57.6, 78.6 a nd 93.6 %) while temperature was air-conditionally controlled at 25 °C . Prior to measurements, samples were dried to constant mass in an air-circulated oven at 105 °C. In order to determine the sorption isotherms and kinetics, the samples were periodically weighed and the moisture content was calculated as the difference of mass measurements in different time periods and the initial dry state. The water sorption properties and the associated surface temperature reduction were conducted in a home-made wind tunnel of controllable conditions of air relative humidity, temperature and wind flow [7]. Wind flow (m^3 h^{-1}), relative humidity (%) and temperature (°C) of air inside the tunnel, weight of sample and temperatures of T-type thermocouples at the surface, middle and bottom layers of the sample cell were recorded by a CR1000 datalogger (Campbell Scientific). The solar radiation was simulated with a metal halide lamp of 400 W (Radium HRI-BT 400W/D).

2.4. Toxicity assessment experiments

The average fly ash yield of lignite burning is 10-15 percent by weight. Therefore, the concentration of most elements (radioactive and toxic) in solid combustion wastes will be much higher than in lignite. In this frame, the concentration of radioactive isotopes and toxic metals in the ADFA sample was determined by means of γ- and XRF spectrometry, respectively [8]. Furthermore, leaching experiments with rain water were conducted by mixing 5 g of fly ash with 200 ml of rainwater under stirring for 24 h. After vacuum filtering, leached metals was measured with XRF after preconcentration with ammonium pyrrolidine dithiocarbamate [8].

3. Results and Discussion

3.1. Ash characterization

Chemical analysis showed that SiO_2 is the dominant oxide, with appreciable Al_2O_3 in both ashes (Table 1). More than 90% of the composition of the studied samples consisted of Si, Al, Fe, Ca, Mg, Na, and K. Due to the high CaO content, the ashes were classified as Class C.

Table 1. Concentration of major elements in the fly ash (ADFA) and bottom ash (ADBA) samples.

Oxide	ADFA (%)	ADBA (%)	Oxide (%)	ADFA (%)	ADBA (%)
SiO_2	42.71	51.97	MgO	5.66	4.11
Al_2O_3	16.49	19.14	K_2O	2.24	1.44
Fe_2O_3	4.29	6.42	Na_2O	0.88	0.72
CaO	31.31	14.89	TiO_2	0.27	0.45

After lignite firing, the concentration of major compound of amorphous aluminosilicate glass is high in the produced ashes (up to 90%) and there are no intense crystalline phases in the XRD patterns, especially in the region of 20-30° (Fig. 1A). The minor crystalline structures are quartz (Q-SiO_2), anhydrite (An-$CaSO_4$), lime (CaO), calcite (C-$CaCO_3$) (mainly in the bottom ash samples), hematite (H-Fe_2O_3), maghemite (M-FeO.Fe_2O_3) and complexes like gehlenite (G-$Ca_2Al_2SiO_7$) (Fig. 1A). The cation exchange capacity of the samples was found 0.02-0.03 meq g^{-1}, much lower than the corresponding of smectites and zeolites. The results of thermal analysis are shown in Fig. 1B. Because of the sampling of fly ash materials directly from the electrostatic filter, the moisture content of fly ash was very small and the change in its mass was limited up to 400 ° C (1 wt%). The bottom ash showed higher reduction in weight, with values up to 6%.

The spectrophotometric reflectance data shown in Fig. 2 revealed that the tested sample exhibited a low reflectance in the entire spectrum. Moreover, the solar reflectance of the sample was calculated by weighted-averaging, using the ASTM G173-03 reference solar spectrum as the weighting function. The values of solar reflectance for each sample are shown in Table 2. In the same table, the calculated solar reflectance values for the ultra violet (UV), visible (VIS) and near infrared (NIR) part of the spectrum are also included. The reflectance of the fly ash sample was found to be higher than the reflectance of a typical soil sample. The highest difference was observed in the visible part of the spectrum since the ADFA was closer to the grey-white color than the dark-brown of the soil. Both the samples presented high absorptance in the UV and their highest reflectance in the near infrared part of the spectrum.

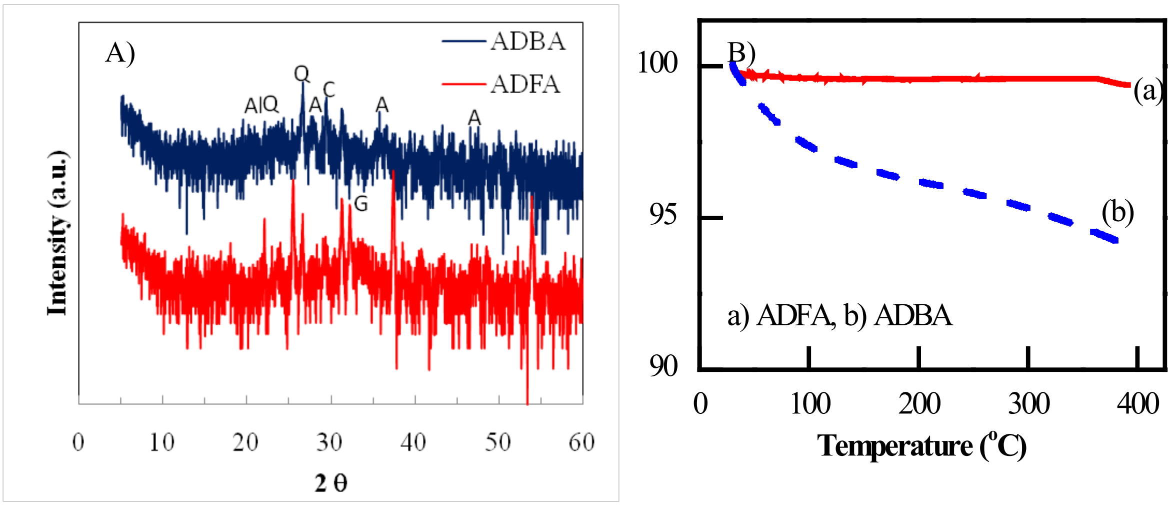

Fig. 1. A) X-ray diffraction patterns and B) TGA/DTA curves of the ash samples.

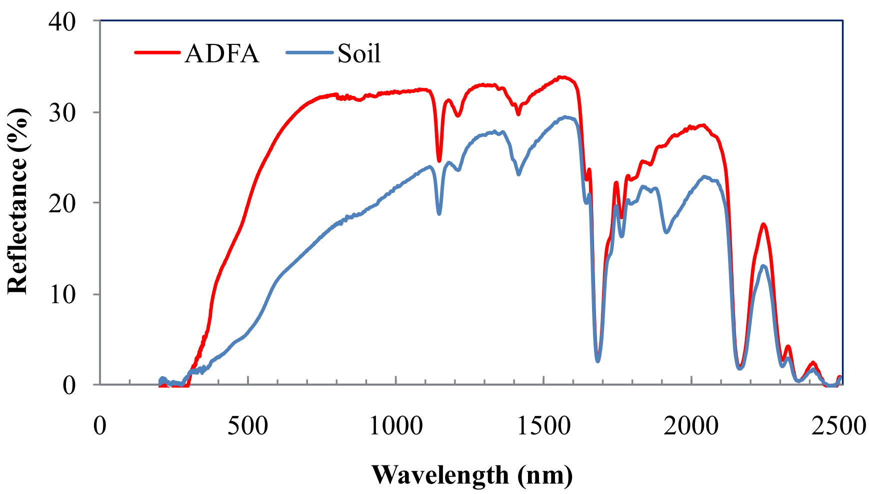

Fig. 2. Spectral reflectance of the ADFA and soil samples.

3.2. Water vapor adsorption

The kinetics of the two ash samples (ADFA and ADBA) and soil are shown in Fig. 3A. Upon comparison, the pseudo-second-order rate equation yielded the best results for water vapor adsorption on the samples. The fast rate of a few hours was responsible for more than 90% of water vapor sorption while the slow rate accounted for the rest of the adsorption.

Table 2. Solar reflectance values (SR, 280-2500 nm) and solar reflectance values in the UV (280-400 nm), VIS (400-700 nm) and NIR (700-2500 nm) part of the spectrum of the ADFA sample and a typical soil.

Sample	SR (%)	SR_{UV} (%)	SR_{VIS} (%)	SR_{NIR} (%)
ADFA	25	8	24	30
Soil	12	2	9	19

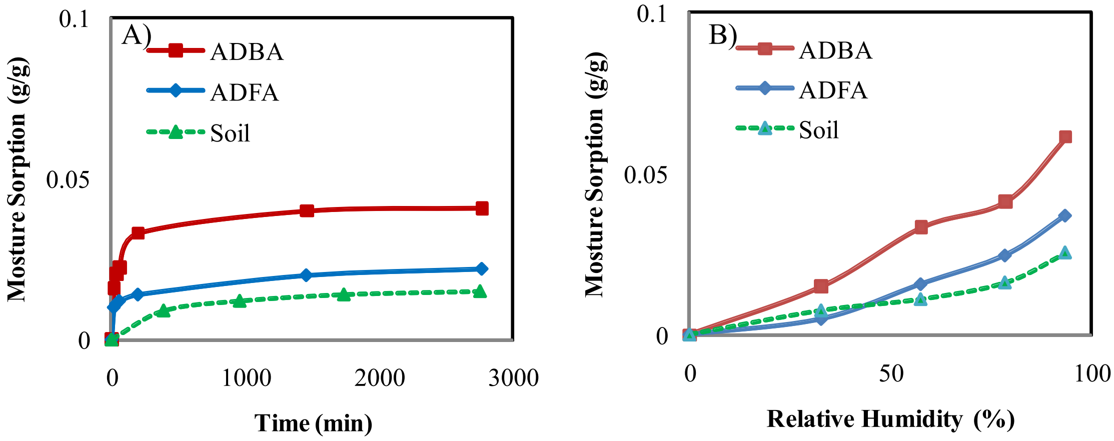

Fig. 3. Water vapor sorption A) kinetics at 60% RH and B) isotherms of the ash materials and soil at 25 °C.

According to the results of the kinetics experiments, water vapor adsorption in the pores of the ash samples was very low. This was further confirmed in the static measurements of sorption isotherms shown in Fig 3B. At low relative humidity, a small fraction of water was adsorbed on the samples (less than 7%). Bottom ash possessed a higher adsorption capacity than fly ash and soil which can be attributed to adsorption sites at the unburned carbon. However, water vapor adsorption at relative humidity more than 50% (normal outdoors) was higher in both ash samples than the soil. The isotherms of the ash samples were of type III indicating the hydrophobicity of the materials with chemisorption rather than physical sorption and monolayer sorption even at high relative pressure. This result is in agreement with the hydrophobic indices, recently published for Greek fly ashes [9]. It should be mentioned that the water-holding capacities in fly ashes are much higher than those of typical soils while water sorption on fly ash is strongly affected by its organic carbon as well as by the inorganic minerals of the fly ash, which have hydrophilic properties [10].

3.3. Evaporation cooling

The materials were further tested in the wind tunnel under simulated solar irradiation. The radiation was provided by a metal halide lamp over the top of the wind tunnel. The incoming radiation at the test cell position was measured 50 W/m^2 with a portable digital solar meter. Every material test lasted for 48 hours. Initially, 3 ml of water were sprayed on the surface of the material and left overnight. In the morning the lamp was turned on for a period of 12 hours and the cycle was repeated for one more day. All samples were capable of lowering their surface temperatures due to water evaporation and the release of the latent heat. Fig. 4 A)-C) shows the measured temperature increase for the three positions in the cyclic experiments with simulated solar radiation of two continuous cycles, starting from the first lamp on as the zero time. A volume cell of 3 cm thickness was used in all the samples while the relative humidity was raised from 60% to 80% at night with lamp off. The maximum difference of temperature increase under simulated solar irradiation was observed between the

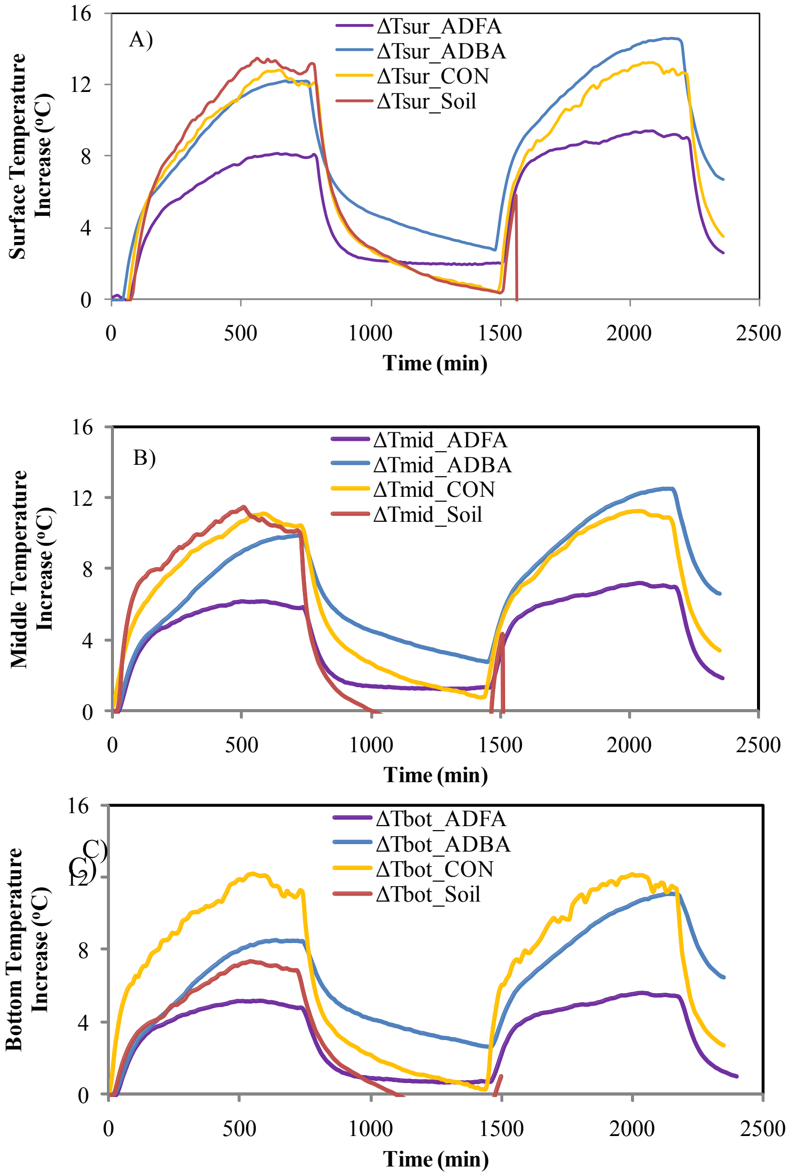

Fig. 4. Increase of the temperature at the A) surface, B) middle and C) bottom position of materials ADFA, ADBA, Concrete and Soil) cell due to simulated solar irradiation. (The cycle starts with the addition of 3 ml of water in order to monitor the retention property of its material in the first cycle. 1st cycle: 0-720 min-lamp on-RH 60%,720-1440 min-lamp off-RH 80%; 2nd cycle: 1440-2160 min-lamp on, 2160-2400 min-lamp off).

fly ash sample and the concrete with values of 3.8, 4.1 and 6.4 °C for the surface, middle and bottom position, respectively. These results indicate the material's suitability for the proposed application of evaporative cooling and further research regarding also the performance of the fly ash samples under the more realistic conditions of open fields will be performed.

3.4. Toxicity assessment

The toxicity of materials implication in buildings roofs was assessed by radioactivity and metal leaching experiments with rain water. For the proposed application, the risk from the use of fly ash is associated with three main reasons: a) outdoor exposure from the radioactive isotopes in the ash, b) internal exposure from the radioactive isotopes and toxic elements after inhalation of particulates and c) leaching of radioactive isotopes and toxic elements and contamination of water bodies. Regarding the direct exposure, the risk was estimated by the calculation of the radium equivalent activity (REA), the annual equivalent dose (AED) and the index of radiation protection (IRP) [8, 11]. Prior to the calculation, the concentration of minor elements, toxics and radioisotopes was determined by the methods described in Ref [8]. According to the results shown in Table 3, the AED and IRP can be higher than the existing limits and therefore the fly ash sample should be mixed with an inert material in order to minimize the risk. The second way of inhalation can be eliminated by material aggregation with a binder, reducing in this way any possible wind resuspension. Regarding the third reason, leaching experiments in a worst case scenario of heavy rainfall, indicated the availability of some of the metals even at the high pH of the Class C fly ash [12]. Therefore and in order to minimize the environmental impact of the use of ashes for solar cooling purposes, mixing of the fly ash with either an inert material like soil or a green roof material or multifunctional nanocomposites with high water vapor adsorption [13] is proposed.

Table 3. Concentration of minor elements and radioisotopes in the ash samples and radiotoxicity indices.

Element (mg/kg)	**ADFA**	**ADBA**	**Element (mg/kg)**	**ADFA**	**ADBA**
V	41.4	BDL	Rb	26.8	68.0
Cr	169. 9	138.5	Sr	292. 6	255.1
Mn	299.2	396.2	Y	7.9	16.7
Ni	299.0	1824.2	Zr	129.2	171.8
Cu	13.9	42.1	Nb	11.2	20.4
Zn	38.9	31.5	Mo	3.2	2.4
Isotopes (Bq/kg)			**Isotopes (Bq/kg)**		
^{226}Ra	645±20	390±12	^{235}U	30±3	16±2
^{232}Th	43±2	38±2	^{40}K	222±12	224±13
REA (Limit 370 Bg/kg)	722	460	AED (Limit 1 mSv/y)	0.41	0.26
IRP (Limit <1 or 6 and 1 mSv/y)	2.44	1.56			

4. Conclusions

The extended use of air-conditioning and electricity to compensate the increased temperatures during the summer time has raised the need for the development and application of passive and efficient ways to cool down urban surfaces. In this work, fly and bottom ashes were tested as alternative applicators of the evaporative cooling principle. Cycle experiments with controllable laboratory conditions and under simulated solar irradiation, showed maximum differences between fly ash and concrete of 3.8, 4.1 and 6.4 °C for the surface, middle and bottom temperature increase, respectively. The substantial temperature reductions with the use of the fly ash material indicate their significant potential for cooling applications. Since, the environmental assessment revealed non negligible impact due to the high concentration of radioisotopes, further research on the treatment of fly ash for the removal of toxic elements and the increase of water vapor adsorption are in progress.

Acknowledgment

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Building refurbishment to passive house standards of the quarter Brogården in Alingsås, Sweden

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Abstract: In Sweden, the transition of the society from agricultural to industrial occupation caused millions of people to move from the country-side into cities and in the 1960-ies and 1970-ies a broad building construction program was performed in order to build 1 million new dwellings in Sweden. However, these buildings are now after 40 years under urgent need of refurbishment and therefore offer a great opportunity for being supplied with modern and efficient construction details and heating systems. An example of such a project is the refurbishment of residential buildings in the quarter Brogården of Alingsås, were 16 buildings with 300 dwellings are to be converted from 1970-standards to modern passive house standards. The housing company Alingsåshem has in partnership with the construction company Skanska and under the consultancy of efem architects and the local Passive House Centrum started a refurbishment project for Brogården. The project involves the extensive renovation of the buildings with passive house techniques, and includes the installation of new façades and roofs, thicker insulation and new ventilation systems. The refurbished buildings do not use conventional heating systems and require very little energy for space heating. Hot water is primarily produced by solar energy, peak load energy is supplied by district heating,

Keywords: *Building refurbishment, Passive house, Energy efficiency, Urban development*

1. Introduction

In order to fulfil EU's action Plan for Energy Efficiency from 2006 it is important to apply energy saving measures not only to new buildings but also to existing buildings. In Sweden, like in many other countries, this is a very important issue with a high potential as reduced energy use for heating purposes is concerned. The transition of the society from agricultural to industrial occupation caused millions of people to move from the country-side into cities and in the 1960-ies and 1970-ies a heavy building construction program was therefore performed in order to create 1 million new dwellings in Sweden. However, these buildings are now after 40 years under urgent need of refurbishment and therefore offer a great opportunity for getting renovated and supplied with modern and efficient construction details and heating systems [1]. In Sweden, this could mean that EUs plans for energy efficiency for both 2020 and 2050 could well be met.

1.1. Objective

This paper presents the refurbishment project in Alingsås, Sweden, performed by the municipality-owned housing company Alingsåshem, which is in train to renovate 16 buildings with 300 apartments to passive house standard. The project is affecting about 650 people. It started 2008 with the renovation of the first building with 18 apartments indented to serve as a demonstration and for motivating the tenants to undergo the total construction work and to accept all the inconveniencies during the refurbishment. Up to the end of 2010, 4 of the 16 buildings have been renovated and again taken into use.

In this paper, the important features of the refurbishment task and its planning is shortly described as well as first experiences from living in the new apartments.

2. General project information

The ***housing company Alingsåshem*** is owned by the municipality Alingsås which applies a policy of ”*serving the tenants with the different needs which occur in the housing sector and to contribute to a sustainable habitation*”. The owner has a. o. specified that Alingsåshem should

- offer the inhabitants of the city an attractive and secure residence
- offer a varying and interesting selection of dwellings
- offer good availability and integration for everyone
- be responsible for that planning and construction of dwellings meets the demands.

Figure 1: The apartment houses of the Brogården area.

The principal working form of Alingsåshem is *Partnership*, which means that the cooperating companies are selected for a period of five years in order to give the partners enough time for together developing and applying new ideas and methods. The renovation work in Alingsås is facilitated by the fact that a renowned *Passive House Company* with a leading passive house Architec**t** *Hans Eek* is located in Alingsås. Hans Eek and Ing-Marie Odegren, the general manager of Alingsåshem have a similar view on housing refurbishment: *“Our general view means to include economy, health, sustainability and quality in the total optimisation”*.

In the case of Brogården (Figure 1), the partnership consists of the following companies:

Construction work

- Building owner: Alingåshem AB
- Main entrepreneur: Skanska Sverige AB

- ***Design team***
- Architect: efem arkitekter (Hans Eek)
- Structural engineer: WSP Byggprojektering AB
- Electricity consultant: COWI AB
- HVAC consultant: Andersson och Hultmark AB
- Measurements: SP Technical Research Institute of Sweden
- Advice and evaluation: Lund University, Energy and Building Design

Skanska Sverige AB is one of the larger Swedish construction companies and contributes to the project by further developing the initially selected methods for refurbishment and energy saving.

3. Specific information about the settlement/neighbourhood structure

3.1. The buildings

The dwellings of Brogården consist of a suitable mixture of 2-, 3- and 4-room apartments, plus kitchen, hall and sanitary rooms. The neighbourhood is a relatively open green area of

100 000 m^2, of which 6000 m^2 are occupied by buildings (Figure 1). The total living area is 18500 m^2, resulting in an average dwelling size of about 60 m^2. This occupancy is typical for the living situation in minor cities in Sweden and is contributing to the relatively high living quality in Swedish provincial towns. The average age of the buildings in year 2010 is 37 year. The buildings in the quarter of Brogården are for pure residential applications, i.e. service and commercial locals are not foreseen there.

3.2. Reason for refurbishment

Due to the age of the buildings, the need for a refurbishment program was getting more and more accentuated. The tenants complained about draughts and low indoor temperatures. Earlier renovation of similar buildings showed that these complaints did not disappear after the renovation process; the buildings needed to be made more air-tight. Also the sanitary equipment was worn out and the general feeling was that the apartments were draughty and noisy. And last not least, the façade was in an urgent need of repair, façade bricks were just braking out of the façade (Figure 2).

Furthermore, the annual energy and maintenance were increasing with time. The house-owner's capital cost for the houses in the Brogården area were at the same order as the annual energy costs. *Therefore it was the basic idea that the apartments should be renovated aiming at the energy levels of passive houses and that by saving energy costs the rent received could instead be used for amortizing the investments for the renovation.*

Figure 2: Details of the façades of the old building

4. Sustainable building construction

4.1. The philosophy of sustainable construction

The base for the refurbishment project Brogården is the consciousness of achieving a *sustainable environment*, which a. o. means also a reduced energy use on a sustainable level. The driving force for Alingsåshem was a generalised view about the role of a public company in the society, i. e. not only to achieve maximum profit for the company but to strive for the maximum profit of *company and the society*. Thus for the first time, such a generalised planning philosophy could be realised in Alingsås, after having fallen prey to short time profits on many other places.

In practice, the idea of sustainability was threefold:
Economy: In total, the project must be economic, otherwise the company will not survive and the tenants will be the looser.
Ecology: Environmental sustainability is one of the main issues which nowadays come into vogue at some places, but in the long term it is a necessity in all construction work.
Social welfare: The Stockholders (Municipality of Alingsås) have put the directive on Alingsåshem to work for the best of the tenants, with a long-term perspective on sustainability and not only looking on short run margins.

4.2. The realization

The old buildings have been examined regarding possible moisture problems and air leakage. Even though the brick façade is worn out, there was no trace of moisture in the wooden wall construction. The new wall construction is based on a steel frame which allows an increased insulation area. For the outer protection, a new ceramic façade material is chosen, which gives the buildings the same architectural expression as the old brick façade, but which is able to withstand the influences of the climate for a long time. The floor of the balconies in the old construction consisted of the same concrete slab as the rest of the floor. This caused a large thermal bridge that now is eliminated by moving out the façade and balconies and hanging the balconies on the outside of the building. The result of this reconstruction is seen in Figure 3. This new solutions gives also a new, friendly look to the houses.

Figure 3: Renovated building in Alingsås with new façade material and new balcony construction.

A big effort has been put on insulation and air tightness of the buildings. Figure 4 illustrates the construction and the ventilation system with incoming/exaust air heat exchangers. The air leakage rate is below 0.3 l/s,m^2 at ±50 Pa. In winter time, the air is preheated by district heating (which is existent from before).

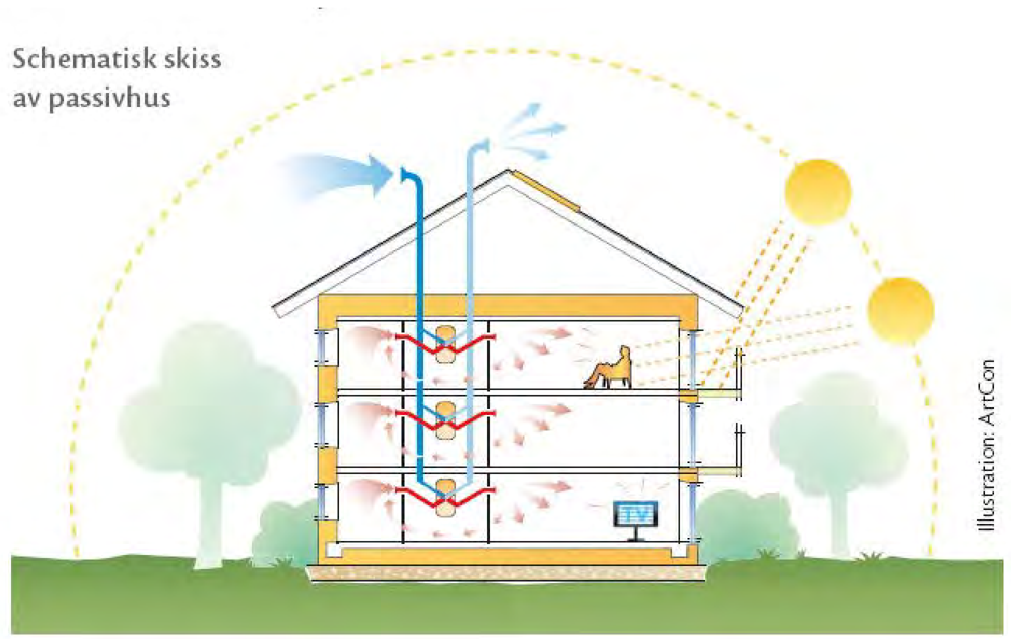

Figure 4: Principle of ventilation air heating system. Fresh air is transported via heat exchangers of each apartment to living room and sleeping rooms. Used air is taken from bath and kitchen. Attic insulation is 40 cm, wall insulation 44 cm and ground floor insulation 20 cm. Solar collectors provide domestic hot water. Balconies help to regulate solar radiation. Windows are of highest insulation standard.

In all, the following measures were undertaken in connection with refurbishment:

- Thermal insulation on the ground floor and the outer walls
- Acoustic insulation on inner walls
- New façade material
- New (3-glass) windows
- Increased air-tightness, building envelope
- New ventilation with exhaust air heat exchanger
- Energy-efficient household appliances
- Solar collectors for domestic hot water (providing 50% of DHW on annual basis)
- Moved balconies
- Entrance vestibules
- Increased access to indoor stores
- IT - access
- Individual heat metering - DHW and household electricity
- Handicap adapted entrance staircases, elevators and doors.

4.3. *Social aspects*

Beside energy efficiency, the project 'Brogården' aims to create a sustainable area of housing that promotes social integration. The projects main principles are *accessibility, social structure and environment*. The project started with a survey of the area to illustrate Brogården's qualities and its 'soul'. Through this survey, inadequacies in these aspects could be identified and the needs of Brogården's tenants documented. Customer focus groups with residents and various partnerships were created, f. i. with the elderly care services, municipal social management, child care services and schools, association activities and the social welfare administration. The customer focus groups were arranged through meetings with an idea workshop for the residents. It turned out that for the tenants it is was very important that families and single peoples could meet each other and - if possible - could also keep the physical neighbourhood. Another important factor for the living quality was the improved accessibility for handicapped people. That means that elderly people can stay longer time in their familiar environment.

5. Savings on energy and environment

Alingsås is situated about 100 km north-east of Gothenburg, i.e. in the southern Swedish climate zone. The annual mean temperature is about 6.5ºC, the mean monthly minimum temperature is – 3.1ºC in February and the mean monthly maximum temperature is 15.6ºC in July. The normal Sunshine time is 1715 hours/year and the annual global irradiation on a horizontal surface is about 960 kWh/m^2.

The Brogården quarter was in the last years heated by district heat from the district heating company Alingsås Energy. This company runs since 1996 a biogas heating plant which drastically reduced the CO_2 emission compared to the oil plant used before. In 2009 the specific CO_2 emission from district heat production in Alingsås was 0.032 kg CO_2/kWh$_{th}$ heat (including a primary energy factor of 1.7 [2]) and we assume the same value for the expected savings. For the impact of the use of electricity in Sweden, different ways are used for assessing the primary energy for energy calculations, essentially depending on two different ways to think about the energy use: Marginal use of energy or average use. When considering individual projects, it is recommended to use the *marginal electricity* use which is based on coal condensing power imported from Denmark and Germany. Hence the primary energy factor for the saved kWh electricity is relatively high. According to the State Energy Administration [3] the primary energy factor = 3.0 (3 kWh_{th}/kW_{el}) and the related CO_2 emission is 1 kg CO_2/kWh_{el}. So far, the evaluation of the new construction is only based on simulations, but measurements are going on. The supply of solar heat to the tap water system is based on expectations. Measurements and simulation results are summarised in Table 1:

Table 1: Energy demand, before and after renovation, if the proposed measures will be applied.

Energy Demand (kWh/m²,yr)	**Before** (Measured average) **(kWh/m²,yr)**	**After** (Calculated) **(kWh/m²,yr)**
Space Heating	115	30
DHW	30	25
Household electricity	39	27
Electricity, common areas	20	13
Sum	**204**	**95**

It can be seen from Table 1 that the expected energy use will be considerably decreased. The highest reduction belongs to the passive house conversion which reduces the need for bought energy by 74 %. The posts for household electricity and the electricity for operating the common areas are of course very uncertain estimates because they depend strongly on the lifestyle of the tenants. The operating energy of the fan-driven air heating system is included in the heat balance. The total electricity consumption is expected to be reduced by 32 %.

Table 2: Use of primary energy and CO_2 emissions of the Brogården project

Specific energy use	**Before**		**After** (kWh/m^2)		**Saving**	
	Bought	Primary	Bought	Primary	Bought	Primary
Heat	115	195,5	30	51	85	144,5
Electricity	89	267	65	195	24	72
Sum	**204**	**462,5**	**95**	**246**	**109**	**216,5**

Spec. CO_2 emission		(kg/m^2)	
Heat	3,7	1	2,7
Electricity	89	65	24
Sum	**93**	**66**	**27**

As can be seen from Table 2, the total use of primary energy will be almost reduced to the half (53 %) whereas the resulting CO_2 emission is reduced by 29 %. That means that the Brogården project in total will reduce CO_2 emissions by 500 tons a year.

6. Cost information

The management of Alingsåshem divides the renovation cost into three parts. One part is *energy saving*, the second *is investment in higher standard in the apartments* (f. i. larger bathroom, new surface materials, etc.) and the third is the *maintenance cost*, the cost for renovations anyway needed. Since the need of renovation was so extensive, the cost for making the building energy efficient at the same time is not dominating.

Because we are dealing with an on-going project and continuous developments within it, the management is reluctant of telling exact costs for the moment. A cost indication gives the following estimates: Planned total costs are 300 – 400 Million SEK, which is a cost of SEK15000 - 20000/m^2 living area. The costs of new apartments in Sweden are about the double of that. The reason for the high renovation costs is of course the fact that both outer walls and roof are substantially reconstructed.

These costs can be allocated to the following positions:
- 30 % renovation
- 50 % increase of standard and comfort
- 30 % energy saving measures.

The saving of used energy corresponds to about 109 kWh/m^2 or totally about 2 GWh/yr, worth for the tenants ca. 3 Million SEK/year. Hence the amortisation time for the energy part is around 30 years. Another part concerns comfort, for which the tenants have to pay an increased hire with 1000 SEK/month. The remaining position 'maintenance' goes on the expense of Alingsåshem which replaces direct service costs by depreciation of investment (at least in the next years). Alingsåshem expects that these costs will be depreciated in 20 years. In the recently decided next refurbishment stage for 3 buildings of Brogården, the costs were calculated to 55 million SEK for 65 flats, i.e. 850.000 SEK/flat.

7. How the tenants react

The organization plan has foreseen that the buildings should be renovated in a certain time sequence and the first building served as both demonstration and exercises object for the entrepreneurs. A demonstration apartment was also created in the first completed building, which allowed Brogården residents to visit and understand how their apartments were to be redeveloped. At most are three buildings under reconstruction at the same time. The duration of the refurbishment work is about 8 months. The tenants were supposed to move around in the areas empty flats. An important feature is therefore the continuous feedback from Alingsåshem to the tenants and vice versa. The tenants were informed about the special features and the economical consequences of the refurbishment work.

For this purpose, Alingsåshem publishes an in information folder on bimonthly basis and holds regularly information meetings with the tenants. The main entrepreneur Skanska participates with detailed explanations about the new techniques used in the refurbishment process. The tenants can express their degree of satisfaction with the different measures and their own situation.

Some people mentioned that it took a while until they understood the severity of the interference in their life, both economical and regarding the living. But in the long term, they think, it will be to their advantage. After the first buildings have been accomplished, there were claims about low winter and high summer temperatures as well as odours and noise from neighbour apartments [4]. Lessons from that were taken into the construction of the consequent buildings.

The biggest change for the individual tenant belongs to the economy, the hire is higher and the energy use (which earlier was included in the hire) has now to be paid separately. That means that a bath in the tub costs about 1 €, which is a new experience to Swedish tenants. On the other hand the energy costs are lower than before and compensate partly for the increased hire bill. The total increase of the bill for hire and energy is around 1000 SEK per month.

8. Summarising conclusions

- An important feature of the passive house refurbishment project is the political and social vision of the public (municipality) stockholders in the housing company, namely to apply an integrated view regarding an optimal solution for the living including economy, health, sustainability and live quality. An additional achievement is the internal selling of the project to the people who finally had to pay for it.
- A further ingredience is the engagement of an interested construction company in a winn/winn partnership with the building owner. The goals with the partnership is to develop working methods and building processes according to a learning curve which could be applied in a continuous way to the 300 apartments of the whole quarter. This partnership helped to start the project by minimizing risks and gives both partners economic and technical incentives according to the lessons learned during the project.
- An additional important feature in the project is the mutual communication with the tenants by keeping them informed by means of newsletters and meetings and by listening to their arguments and comments. This participation of the tenants increased their comprehension of the passive house ideas, the implications for the future living in these houses and finally the acceptance of the increased hire connected with the refurbishment.
- The benefit to the society is a demonstration that it is possible to reduce the energy use of existing buildings and especially of these mass produced buildings of the Million Programme that would have been worn out in the next 20 years. Hence it is demonstrated that they can be refurbished by satisfying strong new construction and environmental standards.
- The annual energy use was shown to be reduced by more than 100 kWh/m^2 flat area, summing up to about 6 – 7 MWh/per flat, which corresponds roughly to a reduction of 1,5 tons CO_2 per flat and year. This is a relatively low value for achievable saving due to the fact that the heating energy is based entirely on renewable energy (biogas). The energy saving is mainly by achieved additional insulation, application of highest window standards, solar water heating and a low flow air-heating system. District heat is only used for peak power.
- The critical issue of the project is its relatively high costs, i.e. about half the cost for a completely new construction. However, the Standard of the buildings is that of new construction and it can be argued that if the tenants had to leave their homes and move in to newly constructed buildings, their hire would become higher. However, in order that this argument holds, the longevity of the refurbished buildings has to be demonstrated.
- Summarising, we can state that the expected heating energy is with 55 kWh/m^2 annual heating energy relatively close to the passive house standard 45 kWh/m^2 for southern Sweden. If this value will be reached in practice, it would stand for a real breakthrough as far as refurbishment projects for the Million Programme buildings are concerned.

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Energy performance indicators for neighbourhoods applied on CONCERTO projects

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Abstract: Current practice of energy efficient neighbourhoods shows that building energy performance ratings are commonly used to characterise the energy performance of the neighbourhood itself. The main inconvenient of this practice is that this indicator usually does not consider the energy efficiency of the neighbourhood energy infrastructure and does not allow for comparisons between neighbourhoods with different characteristics (urban form etc.). In the context of the new neighbourhood developments in CONCERTO, a set of more suitable indicators was developed. The paper presents the calculation methodology for these indicators and their application to chosen CONCERTO neighbourhoods. Given the relative small number of neighbourhoods considered, it is not yet possible to propose benchmarks for energy efficient communities in different European countries. The next step in this direction would be to apply this assessment framework to a statistically relevant number of neighbourhoods in Europe.

Keywords: *Energy performance indicators, neighbourhoods, CONCERTO*

Nomenclature

RES Renewable Energy Sources ....
TEC Thermal energy carrier ....
B Number of buildings in a neighbourhood.. -
A_b Gross floor area of building b .... m²
EPR Energy performance rating .... kWh/m².a
F Number of facilities in a neighbourhood ... -
E_f Energy use of facility f .... kWh/a
FE Specific final energy demand ... $kWh_{FE}/m^2.a$
PE Specific primary energy demand $kWh_{PE}/m^2.a$
DE_{el} Electrical energy delivered .... kWh_{FE}/a
DE_{tec} Thermal energy delivered............. kWh_{FE}/a
GE Generated electricity from RES........ kWh/a

1. Introduction

Whereas the use of energy performance indicators is rather diffused for buildings and overall indicators as total CO_2 emissions are frequently used at city level, few dedicated indicators are currently used at neighbourhood scale. Usually a description of the energy performance standards of the buildings located in the neighbourhoods is used to characterise the neighbourhoods' energy performance [1]. This approach reaches its limits when it comes to comparing neighbourhoods having different urban forms and consisting of different building types with different building energy performance standards. As urban development is usually interpreted in terms of neighbourhood developments, using simplified aggregated indicators expressed at neighbourhood scale would help urban planners to assess the energy performance of different master plan configurations and in particular to assess the impact of urban form on the neighbourhood's energy performance [2].

Following the needs to propose benchmarks of energy efficient neighbourhoods based on the experience of the European CONCERTO initiative [3], indicators had to be developed and calculated for all neighbourhood projects assessed. In the CONCERTO initiative, one of the requirements was to select geographical areas "within which all of the dynamic interactions and relevant energy flows between centralised and decentralised energy supplies and demands [could] be identified for measurement and assessment purposes" [4]. This could lead to a satisfactory amount of data for calculating energy performance indicators at neighbourhood scale.

After a presentation of the proposed indicators and their relevance, the indicators are calculated for all new neighbourhood development projects of the CONCERTO initiative. Based on these results and a statistically relevant amount of data available, benchmarks for energy efficient neighbourhoods can be proposed in future.

2. Methodology: proposed set of indicators

2.1. Requirements for indicators

2.1.1. Considering energy performance of buildings

At first place an energy performance indicator for a neighbourhood should refer to the energy performance level of the buildings located in the neighbourhood. There are two possibilities to implement this requirement.

On the one hand, the distribution of the energy performance ratings (EPR) of the entire building stock of the neighbourhood can be graphically represented, using a typical distribution curve as shown by Fig. 1. The EPR can refer to energy needs or energy use, expressed for heating, cooling (space heating and domestic hot water) and electricity, and can be obtained from monitoring data or energy performance calculation. A set of diagrams based on Fig. 1. provides therefore a detailed picture of the energy performance of a building stock in a neighbourhood. The effect of the urban environment on the building energy performance can be considered if this factor is taken into account in the building energy performance calculation.

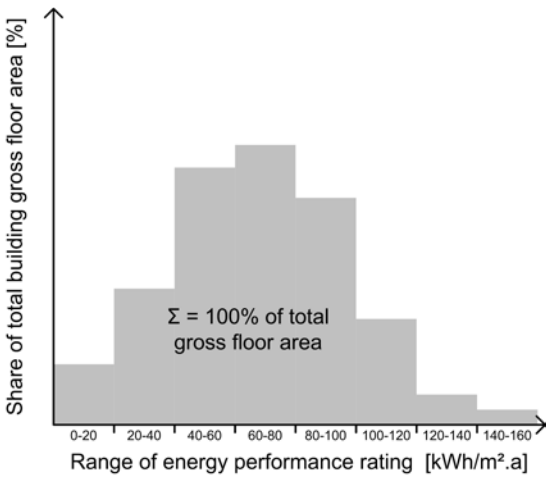


Fig. 1. Example of the distribution of energy performance ratings of the entire building stock in a neighbourhood

On the other hand, the weighted average of the EPR of each building in the neighbourhood can be calculated. This has the advantage to summarise the energy performance of many buildings and facilities (public lighting etc.) in one indicator, thus easing comparisons between projects. The EPR for a neighbourhood based on the energy use of buildings and facilities would be expressed by applying Eq. (1). Like for Fig. 1, the EPR can be calculated for heating, electricity, and possibly cooling energy use.

$$EPR = \frac{\sum_{b=1}^{B} A_b \times EPR_b + \sum_{f=1}^{F} E_f}{\sum_{b=1}^{B} A_b} \qquad (1)$$

Another advantage of using an overall indicator consists in being able to integrate the energy use of facilities, i.e. applications which are not assigned to buildings but are to be included in the energy performance assessment of a neighbourhood (e.g. public lighting). Expressing them as ratio to the total gross floor area of buildings in the neighbourhoods is a way to relate the public facilities to the buildings (and people) they serve.

2.1.2. Considering the efficiency of energy supply in the neighbourhood, in particular the use of onsite RES

A second requirement for a neighbourhood energy performance indicator would be that is has to consider the efficiency of the energy supply infrastructure. In a low-density neighbourhood supplied by a district energy system, the relative thermal distribution losses are higher than in a high density neighbourhood where network piping length is reduced due to high settlement compactness. This influences also the electricity demand of pumps and therefore has to be considered in the indicator.

In addition to this, the contribution of onsite renewable energy technologies has to be considered as well because it influences the theoretical neighbourhoods' dependency from energy flows from outside the system boundaries.

The most suitable approach for including these requirements is to use an efficiency indicator of the overall energy transformation chain, considering extraction, conversion, storage and distribution to the final end-user. The primary energy factor for an energy system, defined in the sense of [5] seems to be the most appropriate factor. It can be determined also for district energy systems [6] and therefore can be used at the scale of a neighbourhood.

2.1.3. Considering the geographical extension of the neighbourhood and the settlement density

Last but not least, it is important to quantify the energy intensity in relation to the settlement density and to point out the links between land and energy use. For a given area, one of the main requirements for urban master plans consists in specifying the targeted plot ratio, defined as the "ratio of total gross floor area of a development to its site area" [7]. Comparing the EPR of different master plans proposed for a given plot ratio is a way to quantify the land-use efficiency in energy terms.

2.2. Proposed indicators

Based on these considerations, it is clear that a combined set of indicators needs to be used to express the energy performance of a neighbourhood:

- using only building EPR based on final energy use would not take into account the renewable energy sources available onsite and the efficiency of the energy supply infrastructure

- using only EPR based on primary energy use would not make building energy efficiency visible, since a low primary energy use due to high contribution of renewable energy sources would possibly hide a low building energy efficiency

It is therefore proposed to graphically represent couples of indicators in order to consider all relevant parameters and obtain an appropriate assessment of the energy performance of a neighbourhood considering the dimensions previously mentioned.

2.2.1. Combined representation of specific average final and primary energy use

Following the general principles already presented in [8], the combined representation of specific average final and primary energy use requires the calculation of specific final and primary energy use ratings at neighbourhood scale.

Applying Eq. (1) in a way to consider all energy flows delivered to the buildings (electrical and thermal energy flows) leads to Eq. (2). In this case the EPR of the neighbourhood is expressed as specific final energy demand.

$$FE = \frac{\sum_{b=1}^{B}\left(DE_{b,el} + DE_{b,tec}\right) + \sum_{f=1}^{F} E_f}{\sum_{b=1}^{B} A_b} \tag{2}$$

The primary energy demand of a neighbourhood is then calculated by weighting the delivered energy flows by the primary energy factors of the related energy carrier, as shown by Eq. (3). All thermal energy carriers are to be considered here: renewable energy carriers, district heating, heat from small-scale combined heat and power plants and non-renewable energy carriers. The electricity yield from onsite renewable energy technologies in monovalent processes is substracted from the total after multiplication by the primary energy factor for electricity.

$$PE = \frac{\sum_{b=1}^{B}\left(DE_{b,el} \times PEF_{el} + \sum_{tec=1}^{TEC_b} DE_{b,tec} \times PEF_{tec}\right) + \left(\sum_{f=1}^{F} E_f - GE\right) \times PEF_{el}}{\sum_{b=1}^{B} GFA_b} \tag{3}$$

In case of small-scale combined heat and power plants located in the neighbourhood, the primary energy benefits from electricity generation are assigned to the heat based on Eq. (4).

$$PEF_{Heat,CHP} = \frac{Q \times PEF_{gas} - W \times PEF_{el}}{H} \tag{4}$$

where Q is the calorific value of natural gas multiplied by the amount of gas yearly used in the CHP, W the yearly amount of electricity generated by the CHP and H the yearly amount of heat generated by the CHP and used in the building.

The set of indicators consists in representing the energy performance of the neighbourhood placing FE (Eq. (2)) on the x-axis and PE (Eq. (3)) on the y-axis.

2.2.2. Combined representation of specific average final energy use and plot ratio

The combined representation of specific average final energy use and plot ratio does not require a particular additional effort in data collection, but a special care in calculating the plot ratio and in particular the site area. The same conventions should be used in all projects assessed, mainly regarding the non-built spaces (roads, parks…).

When this is done, the set of indicators consists in representing the energy performance of the neighbourhood placing the plot ratio on the x-axis and *FE* (Eq. (2)) on the y-axis.

2.2.3. Normalised indicators

Assuming that a statistically relevant number of communities would be available for benchmarking, final and primary energy performance ratings could be normalised referring to the benchmark, mainly depending on building type and climate conditions. In this context, a neighbourhood energy performance index can be calculated based on Eq. (5).

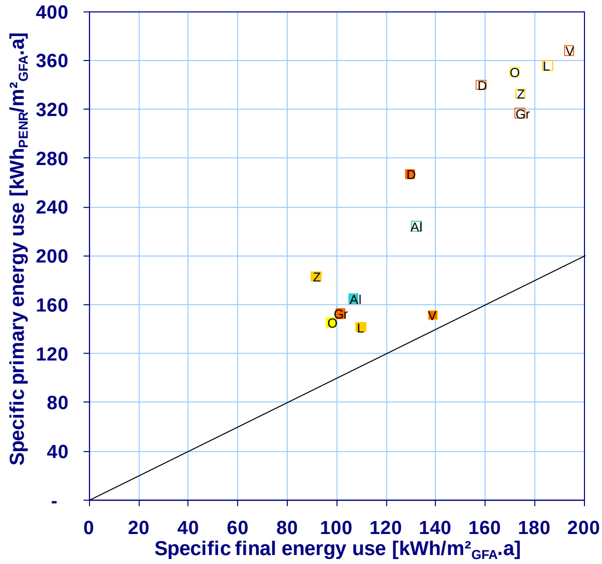
$$EPI = \frac{\sum_{b=1}^{B} \frac{Q_b}{Q_b'} \cdot A_b}{\sum_{b=1}^{B} A_b} \tag{5}$$

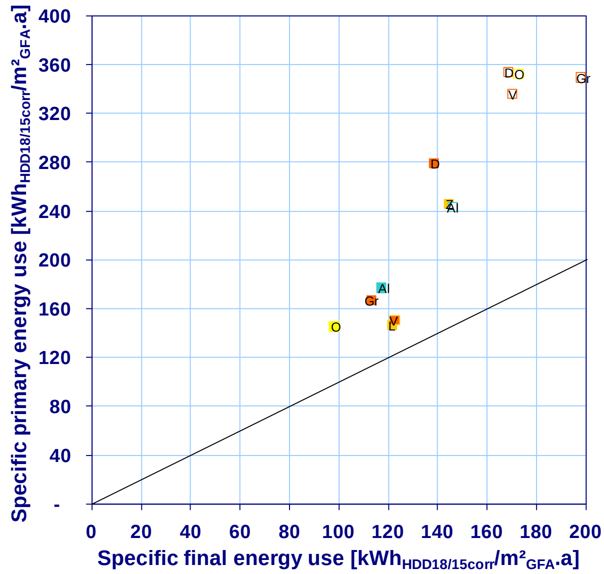
where *EPI* is the energy performance index of the neighbourhood, Q_b the specific final or primary energy demand of the building b, Q_b' the benchmark for energy performance rating, depending on building type and climate conditions and A_b the gross floor area of building b.

3. Results

The methodology presented here was applied to the CONCERTO communities which included new neighbourhood developments or neighbourhood renovation as demonstration projects. In the following, the results are presented for the new neighbourhood development projects and are only related to buildings. Other facilities (e.g. public lighting) located in the neighbourhoods are not included since they were not considered in CONCERTO.

3.1. Specific average final and primary energy use





Legend

Reference situation: without CONCERTO

Situation with CONCERTO

Each square represents the performance of a neighbourhood, calculated as a **weighted average** of all buildings of the neighbourhood.

Conventions used for calculations:

- Energy use for **heating, cooling and all electrical appliances** is considered.
- If electricity use for appliances is not available, **average figures** are taken from projects providing data.
- All energy performance ratings are expressed as ratio to the **Gross Floor Area** (gross floor area of heated spaces).
- Only the **non-renewable part** of primary energy is considered.
- Common **EU-wide primary energy factors (PEF)** are used for **gas (1,36) and electricity (3,14)**.
- PEF are **calculated** for each district heating network, if **energy balance is known**.
- **A default value (0,8)** is used as PEF for district heating networks **if energy balance is not known**.

List of neighbourhoods considered:

- **Al: Almere**
  Neighbourhood „Noorderplassen West“
  Neighbourhood „Columbuskwvartier“
- **D: Delft**
  Neighbourhood „Harnaschpolder“
- **Gr: Grenoble**
  Neighbourhood „De Bonne“
- **L: Lyon**
  Neighbourhood „Confluence Lots A, B, C“
- **O: Ostfildern**
  Neighbourhood „Scharnhauser Park“
- **V: Växjö**
  Neighbourhood „Biskopshagen“
- **Z: Zaragoza**
  Neighbourhood „Valdespartera“

Fig. 2. Specific final and primary energy use of new neighbourhood developments in CONCERTO (top: without heating degree days correction / bottom: with heating degree days correction).

Specific final and primary energy use figures for the new neighbourhood developments in CONCERTO are presented in Fig. 2. The bottom graph considers a correction of all heating energy use figures by normalizing them to the average heating degree days in Europe.

The best neighbourhood energy performance levels are reached when both the primary energy use and the final energy use reach low values, i.e. the points are located on the bottom-left part of the graph. The neighbourhoods of Scharnhauser Park (Ostfildern (D)) and Confluence (Lyon (F)) reach high levels of performance in this comparison, mainly because they combine energy efficient building standards (ambitious compared to 2005 levels) with a high share of heat generated from biomass (district heating in Scharnhauser Park and individual boilers in Confluence). The De Bonne neighbourhood in Grenoble (F) reaches comparable energy performance standards and the use of small-scale gas CHP plants allows for a high primary energy performance.

3.2. Combined representation of specific average final energy use and plot ratio

As shown by Table 1, there is a high variety of urban settlement typologies in the chosen CONCERTO neighbourhood projects, ranging from low-rise terraced house (Almere, neighbourhoods Columbuskwartier and Noorderplassen West) to rather dense urban forms with multi-storey building blocks (Lyon, neighbourhood Confluence (Lots A, B, C)).

Table 1. Settlement typologies in the chosen CONCERTO neighbourhoods

			
Almere	Zaragoza	Grenoble	Lyon

Following the plot ratio definition of [7] and considering the entire land area of the developments (i.e. including all internal roads, parks etc.), Fig. 3 shows the various plot ratios obtained for the neighbourhood developments of Table 1 and the average specific final energy use of these neighbourhoods (without considering any heating degree days correction).

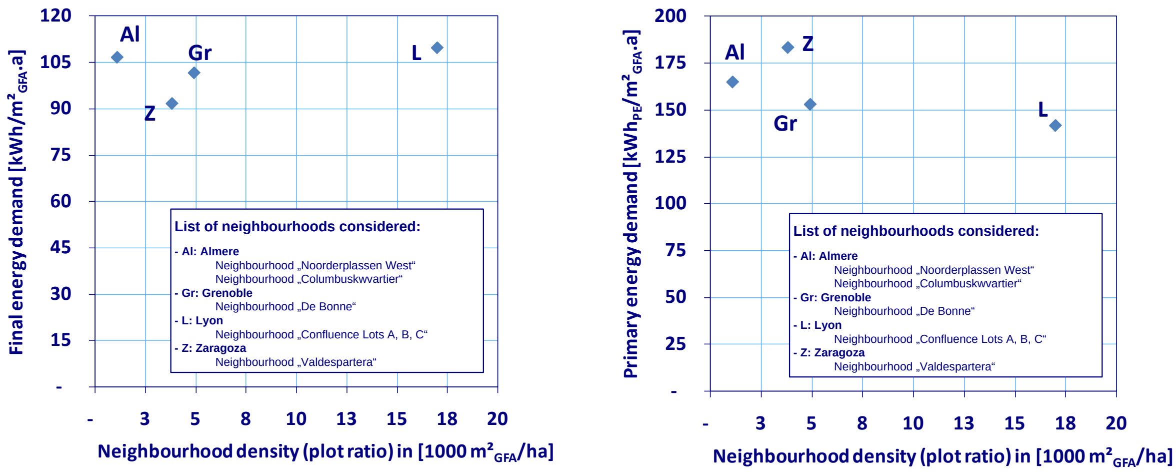


Fig. 3. Specific final energy demand and plot ratio.

Fig. 3 clearly shows that in the Confluence (Lots A, B, C) neighbourhood in Lyon, a high plot ratio is associated to ambitious energy performance standards, whereas the other neighbourhoods are not so densely built, even having similar performance levels. Considering final energy and on the basis of these examples, one could say that this level of energy performance can be reached independently of the plot ratio chosen. However, it would be interesting at this point to compare the energy performance of other neighbourhoods having the same plot ratio as Confluence, in order to compare the effect of different master plans proposed at a given plot ratio.

4. Conclusion and outlook

An attempt to establish benchmarks for energy efficient neighbourhoods was presented in this paper, mainly based on the definition of new sets of indicators and their application to some of the CONCERTO communities.

The proposed sets of indicators allow for considering the most relevant dimensions when it comes to energy use in the built environment of neighbourhoods, which are the final and primary energy use calculated on the basis of unified conventions for balancing energy flows, and the plot density as indicator of land-use intensity.

In the case of CONCERTO, the neighbourhoods combining ambitious energy performance standards in buildings with a high share of biomass in heat generation or combined heat and power reach the highest levels of neighbourhood energy performance. The high range of plot ratios in the neighbourhoods assessed show the different ways of dealing with land-use in CONCERTO.

Nevertheless, given the relatively low number of neighbourhoods assessed, the statistical relevance of the assessment results is rather limited. It will be necessary in future to apply this methodology to a high number of neighbourhoods, considering in particular a range of settlement typologies, different climate zones and sets of technologies.

In future, the energy demand for the overall public infrastructure (public lighting, street cleaning, gardening etc.) should be included in the indicators, as mentioned in Eq. (1).

Aknowledgement

The author thanks all participants in the CONCERTO initiative for sharing their experience, knowledge and data about their projects, and particularly for this paper the project teams in Almere, Delft, Grenoble, Lyon, Ostfildern, Växjö and Zaragoza. He thanks also Darren Robinson for his ideas and improvements.

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Towards a Net Zero Building Cluster Energy Systems Analysis for US Army Installations

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Abstract: U.S. federal agencies are required by law to eliminate fossil fuel use in new and renovated facilities by 2030, and to reduce overall facility energy usage by 30% by 2015 (EISA 2007). Army policy is to achieve 5 net zero energy installations by 2021, 25 net zero energy installations by 2031 and for all installations to achieve net zero energy status by 2058.

The Army operates what are essentially small campuses, or clusters of buildings on its installations. The US Department of Energy (DOE) is focused on the national grid scale or on individual buildings, while the commercial focus is on retrofits to individual buildings. There is a lack of tools and there are only few case studies worldwide that address dynamics of energy systems at the community scale. The Army's future building energy requirements is a mixture of ultra-low and high energy intensity facilities. Achieving net zero energy economically in these clusters of buildings will require a seamless blend of energy conservation in individual buildings and building systems automation, utility management, and control, power delivery systems with the capability to offer integration of onsite power generation (including renewable energy sources) and energy storage.

When buildings are handled individually each building is optimized for energy efficiency to the economic energy efficiency optimum and then renewables are added until the building is "net zero." This process works for buildings with a low energy intensity process for its mission, such as barracks and administrative buildings. When the mission of the building requires high energy intensity such as in a dining facility, data center, etc., this optimization process either will not end up with a net zero energy building, or large amounts of renewables will be added resulting in the overall technical solution that is not cost effective. However when buildings are clustered together, after each building is designed to its economic energy efficient option, the building cluster is also energy optimized taking advantages of the diversification between energy intensities, scheduling, and waste energy streams use. The optimized cluster will minimize the amount of renewables needed to make the building cluster net zero. This paper describes this process and demonstrates it using as an example a cluster of buildings at Fort Irwin, California.

Keywords: *Energy efficiency, Energy generation and distribution, Building cluster, Renewable energy source, Integrated optimization process.*

1. Army Energy Policy Overview

Buildings contribute to a large fraction of energy usage worldwide. In the United States alone, buildings consume about 40% of total energy, including 71% of electricity and 54% of natural gas. Army alone spends more than $1 billion for building related energy expenses. The Army Energy Security Implementation Strategy sets the general direction for the Army including elimination of energy waste in existing facilities, increase in energy efficiency in new construction and renovations, and reduced dependence on fossil fuels. The 2005 Energy Policy Act requires that federal facilities be built to achieve at least a 30% energy savings over the 2004 International Energy Code or ASHRAE Standard 90.1-2004 as appropriate, and that energy efficient designs must be life-cycle cost effective. According to the Energy Independence and Security Act (EISA 2007), new buildings and buildings undergoing major renovations shall be designed so that consumption of energy generated offsite or on-site using fossil fuels is reduced, as compared with such energy consumption by a similar building in fiscal year 2003 (as measured by Commercial

Buildings Energy Consumption Survey (CBECS) or Residential Energy Consumption Survey (RECS) data from the Energy Information Agency), by 55% in 2010, 80% by 2020, and 100% by 2030.

In an increasingly energy constrained world, the Army and its logistic support envisions a future where its energy needs are designed and fulfilled by a suite of ultra low energy solution options that can be tailored for adaptation at any Army installation depending on climatic zone, mission needs, mix of building types, availability of different sources of renewable energy, etc. Presently there is no overarching power “delivery/energy storage/demand” architecture and methodology to accomplish this. Commanders also need the capability to meet their energy use reduction goals with the requirements for energy security, affordability, environmental footprint, occupant well-being and productivity, and building sustainability (as appropriate) depending on the threat conditions, mission needs, utility market prices, etc.

2. Integrated Optimization Process

The Army is rapidly changing its views on energy usage to reconsider energy conservation and efficiency [1]. Army installations are essentially small campuses, comprised of clusters of buildings. Energy efficiency requirements dictate a serious tracking of all waste energy flows, their use, and their storage within the “Installation Boundaries,” with consideration of realistic thermodynamic constraints for all rejected energy. To accomplish these ends is neither straightforward nor inexpensive. The concept of improved standards and increased energy efficiency in buildings can help individual buildings achieve more efficiency. However, it is difficult to adapt existing buildings to achieve Net Zero Energy (NZE) goals on their own. Net Zero Energy cannot be met with efficiency increases alone; there must be efficiency gains on the conversion, supply, and distribution side as well. Achieving NZE cost effectively will be possible if an optimum mix of demand reduction, energy distribution, energy supply, and renewable sources are put in place at a community (installation) or building cluster scale.

The knowledge base needed to build, renovate, and maintain Army installations with the highest levels of energy efficiency do not penetrate far enough into the market. There are a multitude of available technologies [2] related to the building envelope, ventilation, advanced “low exergy” heating and cooling systems, central energy plants with co- and tri-generation, hybrid and high efficient lighting systems designs and technologies, integrated solar thermal and electrical systems, etc. Due to economies of scale, a number of technologies, like cogeneration or combined heat and power, waste heat recovery, biomass, geothermal energy, solar heating (and cooling), and others, are more efficient —in technical and economic terms— when used in large systems rather than in small or individual building systems. Taking advantage of these technologies will enable an optimized system to reduce the primary energy consumption achieved (including demand and supply) to the best available standards, and also to lower costs.

Community energy planning and central system optimization do not require development of a new approach. Energy planning methods in the past were used to design the components of the energy supply systems, e.g., a district heating network connected to local combined heating and power plant was often planned by the local utility using an “optimization strategy.” Existing energy planning methods used energy balancing methods and available planning models that include environmental models. This approach was then, and is still today, unfamiliar to energy planners. An important feature that is necessary in community-wide energy planning is the integrated consideration of supply and demand, which leads to optimized solutions. Therefore, it is the objective to apply the principles of such a holistic approach to community energy planning and to provide the necessary methods and instruments to master planners, decision makers, and stakeholders.

Thermal Energy Systems consist of three major elements: generation of energy, distribution of energy, and the demand of energy. The goal is to find the optimum for the entire energy system, where each element requires consideration. This process can be outlined in a several step analysis:

2.1. Site Setup and Analysis

Determine building locations, geography, utility locations, etc.:

1. Gather Building Energy Data for Benchmarking – gather utility bills, available energy demand data, etc., for all new and existing buildings.
2. Characterize All Buildings in Inventory – determine the building type and use characteristics and determine appropriate building model to simulate for demands.
3. Pre-Planning and Data Gathering – Gather all building and site data from stakeholders and partners. Gather all of the data with no pre-conceived answers.

2.2. Building Simulation

Simulate base and efficient cases for each building type selected in the site inventory:

1. Determine Baseline Model – simulate each building classification type identified in the building characterization step from the inventory.
2. Energy Efficiency Measures (EEM) – determine the appropriate building energy efficiency measures for each simulated building type.
3. Simulate the Energy Efficiency Cases – simulate the energy efficiency scenarios and produce the optimization curve for each building type.
4. Generate the EEM Project List – during the optimization process generate the project list to bring the building to net zero ready status.
5. Produce Building Energy Use Profiles with Peaks – Develop hourly, monthly, and annual use profiles for all demand energy

2.3. Distribution and Supply Optimization

Take data from the building efficient cases to setup the load and network design to determine the optimal distribution and supply network:

1. Integrate All Building Energy Demands – use the efficient case for the building cluster to be analyzed.
2. Develop Load Duration Curves – integrate all energy demands for the building cluster to be optimized and produce curves.
3. Use Hydraulic Simulation – develop the hydraulic parameters for integrated heating and/or cooling systems.
4. Determine Supply Equipment Inventory – Determine all of the existing and planned boilers, chillers, solar thermal, generators, renewables, etc. locations, sizes, age, etc.
5. Use Electric Distribution Simulation - do a grid analysis and determine the optimized distribution of the electrical system and electric renewable energy supplies.
6. Use Supply & Distribution Optimization Simulation – use a model like “POLIS” to determine the optimal distribution and supply systems for both the thermal and electrical and the integrated loads to calculate primary energy demands with the included distribution losses.
7. Determine Centralized and De-Centralized Options – optimization needs to consider both sets of scenarios

2.4. Financial and Emission Analysis

Integrate energy and fuel usage using the efficient buildings and optimized distribution systems and supply scenarios calculate the fuel costs and associated emissions. Using energy, fuel, distribution and supply costs, the initial costs, investment costs, and annual income, yearly and cumulative cash flows are calculated for the project life for each scenario.

2.5. Overall Scenario Results and Project Recommendations

Estimate the sensitivity of important financial indicators in relation to technical and financial input assumptions and develop final results for each of the scenarios investigated. Display overall scenario results showing risk and reward for the project and make scenario/project recommendations with the development of the project business plan. The primary goal is to calculate the amount of energy delivered, in various forms, by the energy systems. The challenges of the model are to assess the system's energy needs in terms of heating, cooling and power generation; and then to estimate how those needs can be met by the various energy systems that are ultimately chosen. The model is devoted to calculating the system's load and energy use and to evaluating how they can be optimally met.

2.6. Building Level Optimization

The Army's present and future building stock is comprised of a variety of building types. Energy requirements in some of them (i.e., barracks, office buildings, child development centers, maintenance facilities and hangars) are dominated by climate (heating, cooling and humidity control) with a smaller effect from plug-in loads. Other buildings (e.g., command and control facilities, hospitals, training facilities with simulators, dining facilities, laboratories) have high energy loads dominated by internal processes and high ventilation requirements.

While some energy use reduction methods in most of these facilities are similar and well understood (building envelope improvement, better lighting systems designs and technologies, etc.), in buildings with high internal loads, energy use reduction can result only with intervention into specific processes use of energy efficient appliances and use of significant waste streams [2], which is currently rarely addressed. More work is needed to address energy uses and wastes at such energy intensive facilities like data centers, laboratories, training simulators, hospitals, etc.

The energy demand determines the amount of energy that needs to be provided by the distribution and supply generation side. Building level energy simulation and optimization can be accomplished using models such as EnergyPlus, ESPr, TRANSYS, or another accurate hourly energy analysis program. When a community or a cluster of buildings is evaluated there are more opportunities available for energy savings and more challenges for analysis and optimization. In addressing buildings as a community, you not only need to deeply evaluate each building, but you also need to take the individual analysis and apply it to a community, or cluster, with possibilities for integrated supply services.

The building optimization process starts with identifying typical buildings and energy systems on Army installations and existing energy wastes and inefficiencies related to these buildings and systems [2], developing load profiles for typical base case buildings and identifying an analysis of suites of technologies for ultra-low energy installation to include waste recovery and energy conserving (ultra-low energy), energy generation and storage technologies that could be applied to buildings and the energy systems that support those buildings to minimize traditional electrical and fossil energy use.

There is a debate over whether to conserve energy first or just generate energy with renewable alternatives. Figure below shows the theoretical path for optimization and the process for each individual building and building cluster optimization process.

Point 1 is the base case building that is either required to be built by the local code body requirements or is an existing building. If renewables are added at this point, the total annual cost of the net zero energy building will be as shown in point 8, using a constant cost for a unit of photovoltaic system ($/m^2 of a PV panels or $/kWh electricity produced). Another alternative from point 1 will be to add energy efficiency technologies at the building level, which will require investing in these technologies (additional first cost) and eventually point 2 is reached with the lowest total annual cost. One would not add renewables at this point since many more energy efficiency technologies can be added that are more cost effective than adding renewable generation. Point 3 is reached when the same total annual cost as existing building or base case building built to code, but this building is now much more energy efficient and in many cases much more comfortable to inhabit. By continuing to add energy efficiency improvements to the building, the building will eventually reach point 4, where adding more energy efficiency measures will result in diminishing returns, or cost more than adding renewable generation. For an individual building analysis, this building would be at the Net Zero Ready point. For different types of buildings and climate locations, fossil fuel based energy reduction will vary [3] for each case.

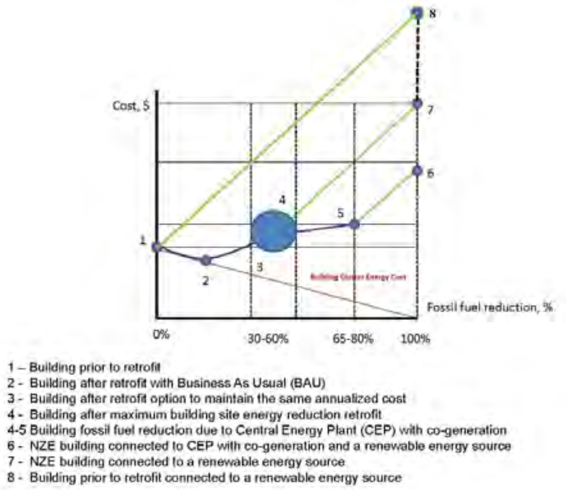

Fig. 1. Building fossil fuel reduction optimization process

In buildings with low internal energy loads, reduction of fossil fuel can be significant (50 to 75%), but only 20 to 30% in buildings with high internal loads. This is true even for buildings built or retrofitted to “passive house” requirements and using advanced “low exergy” systems to satisfy remaining heating and cooling needs. The remaining energy requirements will be dominated by electrical power needs for lighting, appliances and internal processes and by domestic hot water needs, i.e., for showers and other domestic needs. Adding renewables from point 4 will result in the total annual cost, shown by point 7. Depending on the building internal load, building fossil fuel based energy reduction can reach 30 to 60%.

Alternatively, the building characterized by point 4 can be connected to co-generation plant serving either this individual building or cluster of buildings. This will require a smaller investment compared to the cost of decentralized boilers and chillers for single buildings, and the cost of larger renewable generation equipment [9], but result in a significant fossil fuel reduction due to use of waste heat accompanying electricity generation. This heat can be used either to satisfy heating, cooling, and domestic hot water needs of the building cluster, or be exported to another building cluster. Connecting to a Combined Heat and Power (CHP) plant, fossil fuel usage by the building cluster (point 5) can be further reduced by another 20-25%. When CHP uses biomass or biogas as a fuel, the connected building(s) become “Net Zero” fossil fuel. Typically at point 5, buildings do not require additional thermal energy from renewable energy source, but may require additional electrical power. After point 5, adding solar or wind generated electrical power becomes a cost-effective supply option, and this point, by definition, states that the building cluster is “Net Zero Ready.” As one can see from the graph, path 1-2-3-4-5-6 is the lowest cost path for building improvement leading toward net-zero fossil fuel based energy strategy.

When this process has been completed for each building, the results from all of the individual buildings are integrated and put into annual load duration curves. The load duration curve shows the cumulative duration for different loads in the system over a full year. Due to diversity of energy use in buildings comprising the cluster (community), the peak of the resulting load curve is much smaller than the sum of peaks of individual buildings and thus the needed generation and a back-up capacity is much smaller.

2.7. Building Cluster or Installation Analysis

To develop the community energy concept, energy models can be used that optimize distribution of energy from central generation/production to the energy usage by the buildings and systems. The building simulation gives results for demand curves for domestic hot water consumption, electricity consumption, heating, and cooling for those buildings at existing climatic conditions and these are passed to the next step. These models will minimize energy waste and losses and optimize first and operating costs (First Cost + Operating Cost = Total Cost). Based on this concept, a Master Planning process can be developed that will provide an orderly approach to changing the typical Army installation to an ultra low energy consuming community.

2.8. Distribution and Supply Optimization

Simulation of supply systems can be done using an energy system optimization model like POLIS [4]. Between energy generation and energy demand points (at each building level), a distribution system is used to transport the energy via a hot or chilled water system. While "energy balancing" means just calculating the correct energy flows (and perhaps also carbon emissions) in a system, to estimate energy costs and to benchmark with other similar systems, simulation and optimization is necessary for system planning. For principal comparisons of available alternatives, a simpler simulation approach will be favorable, one that provides a possibility to make an energy balance for the whole system and to compare the effects of different demand or supply side measures in terms of energy efficiency, capital and energy costs, and GHG (Green House Gas) emissions with the simulated demand curves from the building simulation optimization step.

For this purpose, energy system models might be applied that have been developed for the optimization of large systems. However, to be used as a regular planning tool, skilled planners are needed that are familiar with them. POLIS models an energy system as a closed system including the entire chain from demand, the distribution system, to supply systems. Every element like buildings, boilers, generators, grids, etc. are described as "knots"; energy- and cost-related parameters are linked together to an interconnected system in which different usages are interlinked. Power supply, heating, and air-conditioning is modeled in a common system. This offers the opportunity to compare efficient technologies like co-generation (power + heat) and tri-generation (power + heat + cooling). The result of this type of model offer the best suited solution to reduce the energy usage of a building cluster, and leads the way to net zero installations with least cost. More than that, the approach of optimizing building clusters will offer new and/or additional options that reduce the fossil energy footprint of community systems cost efficiently.

In POLIS, an energy system can be modeled by using prototypes of generation equipment, distribution systems, and load profiles. Cost, emissions, and technical parameters are used to describe existing or future elements of the system. Simulation is performed using hourly load profiles for the thermal and electrical energy demand throughout a year (8760 hours), which is generated from the summation of the building cluster energy simulations. POLIS allows calculation of the best suited combination of paths to meet the load with the objective to minimize total system costs, or minimize total GHG-emissions. Since the distribution systems play a significant role in an overall thermal energy system, a hydraulic flow model should be used to analyze critical capacities and flows in the system. Through an iterative process, these two models will determine whether an optimization of the energy system (POLIS results) will lead to a feasible optimized supply and generation system.

3. Fort Irwin, CA Building Cluster Case Study Results

The integrated energy optimization process described to this point includes analysis of building energy efficiency improvements and optimization of energy generation and distribution. The tools required to optimize an individual building were applied to the analysis of eight types of Army buildings. The goal was to meet or exceed EPACT 2005 requirements for new construction [5,6,7] as well as for the "Integration of Energy/Sustainable Practices into Standard Army

MILCON Designs" study [3] of five common types of Army buildings with aggressive goals to achieve 60 to 80% energy use reduction against CBECS 2003. Continuing the discussion started in [8], this section of the paper illustrates the proposed approach using the example of the building cluster to be renovated at Fort Irwin.

Fort Irwin is located in the High Mojave Desert midway between Las Vegas, NV and Los Angeles, CA. The energy required to serve the needs of more than 1600 buildings located on the installation is not generated on site; it must be conveyed over long distances. Electric power is transmitted from distant generators through the power grid; LPG for heating and domestic hot water (DHW) is trucked to Fort Irwin in bulk.

The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), with support from a group of industry experts, conducted an energy study [9] at Fort Irwin with a focus on a representative group (cluster) of buildings that included five barracks buildings, a dining facility, and a central energy plan to which all these buildings were connected. The integrated optimization process used in this analysis includes optimization of each building in the cluster to meet its economic energy efficient optimum. The building cluster is then energy optimized taking advantage of the diversification between energy intensities, scheduling, and waste energy streams use between the buildings.

3.1. Modeling of Buildings and Systems

The modeling of the buildings, the systems within the buildings, and the systems supporting the buildings was done by using the eQuest – an hourly annual building energy analysis tool that provides professional-level results with an affordable level of effort.

The estimated energy use of the five barracks and dining facility as operating during the site visit was 3.1 million kWh/yr and 9193 million Btu (2,694,202 kW-hr) of LPG gas. The data generated by computer analysis indicate that a typical upgrade of a barracks building only saves 8% of the electricity use compared to the barracks "as we found them" and 7% of the heating energy. In other words, a typical barracks upgrade is not very energy efficient.

The results of further analysis (Table 1) show that upgrades to Net Zero energy ready buildings allow the reduction of the energy consumed to heat, cool, and ventilate the cluster facilities by 44 to 49% of electrical use and 30 to 59% of heating use with paybacks of 2 to 10 yrs depending on the alternative chosen. Since the proposed energy efficiency work includes the implementation of DOAS and high efficiency dehumidification systems that would dramatically reduce the potential for biological growth, in climates where mold is an issue, the avoided costs of mold mitigation can decrease the payback to 1.2 yrs.

A renewable energy use analysis to achieve "Net- Zero" energy status building cluster must provide the remaining energy amount using renewable energy sources. For the location of Fort Irwin, the most attractive renewable energy sources are solar and waste products. For development of the renewable energy concepts the following exiting conditions were used. The Barracks and the Dining Facility are connected to the Central Heating Plant (Bldg 263) by a district heating grid. Three LPG boilers, 2060 MBtu/hr (603 kW) each, are generating heat for domestic hot water DHW needs and space heating (SPH). No water storage tanks are installed in the Central Heating Plant. DHW storage tanks with a capacity of approximately 1500 gal (5678 L) are installed in each building. The LPG and electricity prices are the actual values given during the energy assessment. Renewable energy opportunities for the building cluster, including installing solar thermal, biomass (wood chip), and PV electrical generation systems can save 4832 million Btu/yr (1,416,119 kW-hr/yr) and generate 41,630 KWh/yr. Renewable thermal energy generation is cost effective and has a simple payback period of less than 10 years. Using photovoltaic panels to generate renewable electrical energy is not a cost effective solution since it has a significant payback period of 47 years.

4. Conclusions

The integrated optimization process is being developed under the Army research and development project "**Modeling Net Zero Installations-Energy (NZI-E)**" [11] and the International Energy Agency (IEA) Energy Conservation in Buildings and Community Systems (ECBCS) Annex 51. The process includes optimization of each building clustered together to meet its economic energy efficient option; then the building cluster is also energy optimized taking advantages of the diversification between energy intensities, scheduling, and waste energy streams use. The optimized cluster connected to CHP plant will minimize the amount of renewables needed to make the building cluster Net Zero fossil fuel energy.

The recommended, integrated energy solution demonstrates that vastly improved energy efficiency and greenhouse gas reductions are feasible in the context of a normal scale development using proven approaches from the United States and elsewhere.

"Business as usual" leads to individual boilers and chillers for each building, which leads to significant total overcapacity, and over time, to a wide range of boiler inefficiencies and chiller COP's with limited overall system control to meet the diverse demands of an installation. Alternatively, district heating and cooling systems link buildings in common networks that eliminate inefficient boiler and chiller over-capacity, and allow the integrated system to meet the integrated peak loads instead of individual peak loads. The addition of efficient technologies now, allows future technologies to be added to one location instead of to each building at the location.

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A Study of Urban Form and the Integration of Energy Supply Technologies

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Abstract: Buildings account for a substantial share of the energy consumption and CO_2 emissions in the UK. Reduction of energy consumption and the use of low carbon technologies in buildings constitute a vital part in achieving the government's CO_2 reduction goals. Based on six existing urban form examples in the UK, this paper explores the potential for integrating different low carbon technologies for buildings taking into account factors relate to built forms. The study suggests that dwelling density has a significant influence on energy demand; however, it is not the only factor that influences the potential for low carbon energy supply. The combination of dwelling density and site coverage are the crucial built form factors that determine the potential of CO_2 reductions from low carbon technologies. The initial findings suggest that medium to low density housing may in some cases enable a greater saving in CO_2 emissions than higher density development because of the greater amount of space for collection of renewable energy. However, the effects of density on the energy use by other sectors such as transport, water and waste management, also needs to be considered and this integrated approach is part of our ongoing research on the ReVISIONS project.

Keywords: *Urban Form, Integrated Energy Supply, Renewable Energy, Low Carbon Technologies*

1. Introduction

Buildings in the residential, commercial and public sectors account for an estimated 48% of the total final energy consumption and 42% of all carbon emissions in the UK. The UK government has made a commitment in the Climate Change Act 2008 that the carbon account for the year 2050 is to be at least 80% lower than the 1990 baseline [1]. Reduction of energy consumption and the use of low carbon technologies in buildings constitute a vital part in achieving the government's carbon emission reduction goals. The Code for Sustainable Homes [2] requires that new homes are zero carbon by 2016. However, the rate of new house building in the UK is less than 1% per year compared to the existing housing stock and so around two thirds of the housing stock of 2050 already exists. Therefore, a substantial reduction in the carbon emissions from the existing housing stock is vital for achieving carbon reduction targets.

Energy use in buildings can be attributed to three main factors: building design, systems performance and occupant behaviour. Building design parameters such as plan, section, orientation and façade design account for a 2.5x variation in energy consumption. Services system parameters such as the efficiencies of lighting, boiler and other equipments contribute a 2x variation and occupant behaviour for a 2x variation. These factors cumulatively lead to a total variation of tenfold in energy consumption of buildings with similar functions [3]. Clearly, the design of built form and service systems has significant energy implications; they not only influence the energy demand but also determine the potential for renewable energy supply and the use of low carbon technologies. The government has committed to delivering 15% of energy from renewables by 2020 in accordance with the European Union Renewables Directive [4]. In order to achieve this goal, a significant increase of small-scale to community-scale renewable electricity and heat generation is expected [5]. The UK government launched a consultation in 2009 on its Heat and Energy Saving Strategy [6] which proposed that by 2030 all homes would have received a 'whole house' package including all cost effective energy saving measures plus renewable heat and electricity measures as appropriate. The policies are still tentative at this stage because there are a range of uncertainties about how these measures will be implemented. There are some exploratory ongoing schemes such as the Carbon Emissions Reduction Target 2009-2012 (CERT) and the Community Energy Saving Programme 2009-2012 (CESP) which place obligations on energy supply companies to reduce carbon emissions and improve energy efficiency. The aim is to achieve a 30% reduction in carbon emissions from households by 2020 compared to 2006. However, there are a number of uncertainties about how large scale retrofitting of existing dwellings can be achieved and guidance is required on what measures are appropriate and cost effective for different urban forms and densities.

Many of the energy-efficient and renewable energy technologies available today (such as solar thermal, photovoltaic, micro-wind turbine, heat pumps, CHP, etc.) have already been in development for several decades; we have profound understanding of the science and engineering of these technologies. However, our knowledge concerning the integration and optimization of these technologies in buildings with respect to built form and spatial layout is limited. In the current planning practice, the decision about the built form for a particular target density is often driven by a combination of economic, social and cultural factors. The final form however would ultimately govern the potential of renewable energy sources that could be exploited on-site. In order to deliver a sustainable low carbon development, the design of built form, its energy implications and the potential for renewable and low carbon technologies needed to be considered together with other non-environmental factors in an integrated manner.

This study explores the potential for integrating different low carbon microgeneration technologies for buildings taking into account factors relate to built forms and spatial layouts. This paper represents our first step in understanding the interaction between energy demand and the supply technologies. This work forms part of the ReVISIONS project[1], a wider study investigating the inter-relationship between spatial planning and infrastructure policies for transport, water, waste and energy at the regional and local scales.

2. Existing urban form examples

Six existing urban form examples in Cambridge and London in the UK are selected for this study (Figure 1). The examples are largely domestic areas built up from Census output areas. Census output areas are statistical geography developed by the Office for National Statistics (ONS) as part of the 2001 Census in the UK; they are generated in consideration of population size, mutual proximity and social homogeneity. Land use information in each of the example area is sourced from General Land Use Database (GLUD) and the number of dwellings and dwelling type data are sourced from Neighbourhood Statistics Database.

The six urban form examples exhibit a diversity of densities and morphologies:

1. Comprises mainly rows of two-storey terrace houses at a gross residential density[2] of 55 dph. Each dwelling has its own private garden but communal open space is scarce in close vicinity. This setting is commonly found in many urban residential areas in England.
2. Comprises mainly detached and semi-detached houses at a density of 18 dph; this setting is typical of suburban areas where dwelling density is low and the dwelling plot size is large.

[1] ReVISIONS Regional visions of integrated sustainable infrastructure optimized for neighbourhoods project website: http://www.regionalvisions.ac.uk

[2] The residential density measure used throughout this paper is expressed in dwelling per hectare (dph) and is the gross density within selected Census output areas of predominantly residential use. It is calculated as the ratio of total number of dwellings to entire selected site area; the measure of site area takes into account all land use types (e.g. domestic, non-domestic, road, green space, etc.)

3. Is characterized by a courtyard-form layout which comprises mainly four-storey terrace houses and flats at a density of 33 dph. This spatial arrangement results in large areas of communal open space whilst private garden area is limited.
4. Represents a mixed urban form at a density of 27 dph. It has semi-detached houses with large private garden in the west, courtyard-form apartment blocks with communal open space in the east and rows of terraced houses in the middle.
5. Comprises a ten-storey courtyard-form apartment block which houses over 1200 flats; it has a very high density of 523 dph. Although primarily domestic, the development contains spaces for other uses: however this paper focuses on the built form of dwellings and does not consider non-domestic spaces.
6. Consists of three distinctive built forms: a fifteen-storey high-rise tower (~181 dph), a cluster of terraced houses (~93 dph) and a group of multi-storey slab-block flats (~97 dph). The entire study area has a gross residential density of 100 dph. The high density and diverse spatial arrangements may give rise to the potential of communal infrastructures for low carbon energy generation.

Fig. 1. The six urban form examples selected for this study (shown on the same scale).

3. Domestic energy demand

The domestic energy demand of each urban form example is estimated using the Domestic Energy and Carbon Model (DECM) developed as part of the ReVISIONS project [7]. DECM consists of two major components: a housing stock database and a building energy model. The housing stock database is primarily developed based on the English House Condition Survey 2007. The survey contains 16194 sample dwellings covering a range of typical domestic building types in England. The building energy model is based on SAP-2005 with modifications to improve the energy estimation. DECM incorporates regional climate data and performs monthly calculations for electricity, water heating and space heating demands. Comparison of the model prediction with national statistics published by the UK Department of Energy and Climate Change (DECC) confirms the capability of DECM in providing good estimations at both national and Local Authority (LA) levels. At national level, the model estimation of CO_2 emissions and gas and electricity consumptions are respectively 4.5%, 3.4% and 1.0% higher than the DECC figures. At the LA level, the correlations between the model estimations and the DECC records are statistically significant and substantial (all r_s>0.9 and p<.01).

Using DECM, average dwelling energy demand and CO_2 emissions for the four main dwelling types are produced (Table 1)[3]. The heat and electricity demands for each urban form example are estimated by multiplying these figures by the corresponding number of dwellings in each example. This method assumes the energy demand of dwellings in the urban form examples do not significantly deviate from the national averages. This is a rough estimation because the occupancies per dwelling will vary locally depending on the supply and demand for housing in different areas. Table 2 summarizes the key building parameters and estimated energy demand of each example area. It shows that energy demand per dwelling decreases with increased gross residential density (r_s=-0.829, p<.05). It is mainly due to the changes in dwelling mix; more flats and fewer houses at high density and vice versa in low density. This observation is consistent with a wider analysis conducted by the main author based on national housing stock and domestic energy consumption statistics.

Table 1. Annual average dwelling energy demand and CO_2 emissions for four main dwelling types

	Detached	**Semi-detached**	**Terraced House**	**Flat**
Floor area (m^2)	137.7	94.4	85.4	62.2
Occupants (number)	2.6	2.5	2.5	1.8
Energy demand (kWh)				
Space heating	14064	10490	9553	5547
Water heating	2469	2010	1901	1590
Electricity	3949	3105	2932	2320
CO_2 emissions[4] (tonnes)	7.4	5.7	5.3	4.0

Table 2. Key building parameters and estimated annual energy demand of each urban form example

Urban Form	**1**	**2**	**3**	**4**	**5**	**6**
Site area (ha)	8.0	8.3	8.1	9.3	2.4	4.8
Gross density (dph)	55	18	33	27	523	100
Site coverage[5]	0.3	0.1	0.2	0.2	0.5	0.3
Dwelling mix (number)						
Detached	20	40	8	34	0	3
Semi-detached	42	64	25	70	0	0
Terraced	322	18	159	39	0	51
Flat	55	29	73	110	1236	426
Total	439	151	265	253	1236	480
Energy demand (kWh)						
Water heating	833294	307712	488298	473674	1965438	781755
Space heating	4103152	1566740	2298678	2195206	6855780	2892334
Electricity	1281106	476748	744790	721207	2868070	1149888
Energy per dwelling	14163	15571	13327	13400	9457	10050
CO_2 emissions[6]	2311t	870t	1334t	1293t	4925t	1990t

[3] Energy demand refers to the energy required to meet the various end-uses; it is different from energy consumption as the latter also takes into account system efficiency.
[4] Emission factors: gas (0.184 $kgCO_2$/kWh), electricity (0.47 $kgCO_2$/kWh), oil (0.265 $kgCO_2$/kWh) and solid fuel (0.333 $kgCO_2$/kWh).
[5] Site coverage is calculated as the ratio of total domestic building footprint area to entire site area.
[6] Existing CO_2 emissions (tonne/year) are estimated based on average dwelling emissions as shown in Table 1.

4. Urban form and low carbon energy generation technologies

The low carbon energy technologies considered in this paper include solar thermal panel, photovoltaic (PV) panel, ground source heat pump (GSHP) and combined heat and power (CHP) device. Table 3 provides a general view and the spatial requirements of these technologies [8]. Micro wind turbine is not considered in this study owing to the limited wind potential in urban areas.

Table 3. Low carbon technologies and their requirements

Technology	Requirements		Typical cost of one unit	Typical size in kW
Photovoltaics	Roof or space facing SE/SW	Can export electricity if connected to grid, more cost effective if high on-site demand	£5k to £25k upwards	1 to 4 upwards
Solar thermal	Roof or space facing SE/SW	Hot water demand on-site	£2k to £5k	2 to 3
Ground Source Heat Pump	Land area for ground collector or a water source	Building with a space heating (and possibly cooling) demand and low temperature heating system (e.g. under-floor)	£5k to £25k upwards	3.5 kW to 15 kW upwards
Micro-CHP and CHP	Domestic or communal space	Proportional heat and electricity demand, scope for heat network	£500 to 800 /kWe and £660/kWe	kW to MW

The government has plan to significantly increase the uptake of low carbon and renewable energy technologies; the lead scenario set out in the RES suggests that over 30% of our electricity (including 2% from small scale generation) and 12% of heat demand supplied by renewable sources [5]. Using the urban form examples, we examine the prospect of achieving these targets, the potential savings in CO_2 emissions and cost effectiveness of the installations. Table 4 shows the proposed energy supply technology mix for each urban form example[7]. The technologies are selected on the basis of economics (mainly costs), technological suitability (scale and scope), environmental (associated emissions), resource potential (availability), and social (acceptance and policy) factors. The proposed options are considered in conjunction with the national electricity grid so that surplus or shortage of electricity can be exported to or imported from the grid.

[7] The following assumptions are used in the calculation: solar thermal panel of typical 100 litre capacity requires 2.03m^2 of roof space; PV panel of 210We capacity requires 1.64m^2 roof/facade space; and GSHP of 23.1 kW$_{th}$ capacity. The heat and power ratios for micro-CHP and large-scale CHP are 3.0 and 1.8 respectively; they are assumed to be powered by gas and the overall efficiencies are 85% and 75% respectively. Excessive heat demand is assumed to be met by conventional gas boiler with efficiency 76%.

Table 4. Low carbon energy supply options for each urban form example

Urban Form	**1**	**2**	**3**	**4**	**5**	**6**
Water Heating Demand (kWh)	Solar thermal: 437 panels of 100 (lit) capacity	Solar thermal: 148 panels of 100 (lit) capacity	Micro-CHP: 488298	Micro-CHP: 340400; GSHP: 133274	CHP: 1965438	CHP: 781755
Space Heating Demand (kWh)	GSHP: 4158000; electricity required: 864000	GSHP: 1663200; electricity required: 345600	Micro-CHP: 1746072	GSHP: 2195206; electricity required: 483840	CHP: 3197088	CHP: 1288043; GSHP: 1663200; electricity required: 345600
Electricity Demand (kWh)	PV: 1026205	PV: 720804	Micro-CHP: 744790	PV: 691619; Micro-CHP: 113467	CHP: 2868070	CHP: 1149888
Renewable/ low carbon supply	6017498 kWh	2691716 kWh	2979160 kWh	3473966 kWh	8030596 kWh	4823977 kWh
Other supply (kWh)	Grid elect.: 1118901	Grid elect.: 101543	Gas: 4232007	Grid elect.: 399961 Gas: 533961	Gas: 20399786	Grid elect.: 345600 Gas: 6431969
Renewable/ low carbon	84%	96%	41%	79%	28%	42%
CO_2 savings (tonnes/year)	1757	777	409	943	325	381
Capital & operations costs	£9.1M	£5.1M	£0.8M	£5.0M	£2.7M	£3.7M
Effective costs (£/tCO_2 saved)	£259	£328	£98	£265	£416	£486

5. Discussion and Conclusion

The fraction of total energy demand which can be supplied by renewable and low carbon technologies varies remarkably from 28% to 96% across the six urban form examples; the variation is dependent of built form as exhibited in different dwelling types. Houses in general provide more opportunities for the application of low carbon technologies (especially renewable technologies) as they have suitable roof and garden areas where natural energy can be harvested. Urban Form 1 and 2 with high proportion of houses in the dwelling mix facilitate the use of solar thermal, PV and GSHP and result in the highest proportions of renewable and low carbon supplies. The spatial layout of apartment buildings significantly limits the exploitation of renewable energy; the strategy of low carbon supply lies on efficient cogeneration of heat and electricity. The high concentration of energy demand and the generally high proportion of heat to electricity demand in apartment buildings are conducive to the use of cogeneration systems. As illustrated in Urban Form 5, assuming a 20-year lifetime for the CHP system, an estimated 258 tonnes of CO_2 can be saved on average annually by switching the conventional centralized energy supplies to a cogeneration system; the saving is equivalent to around 6% of the total emissions produced by the existing centralized system to 2030.

The capital and operational costs of the proposed technology mix for each urban form example vary widely from less than £1 million to £9 million. The high costs shown in Urban Form 1, 2 and 4 are mainly due to the use of PV panels. The use of PV technology, although seemingly expensive, results in remarkable reduction in CO_2 emissions. Table 5 presents an alternative energy supply option for Urban Form 1, 2 and 4 where the use of PV is excluded; the demand for water heating is provided by solar thermal systems and space heating provided by GSHP. The entire electricity demand is assumed to be met by the national grid.

In order to gain a fuller picture of the cost effectiveness of the proposed technology mix, the effective costs which represent the costs per tonne of CO_2 saved are examined. The effective costs are calculated based on an average 20-year lifetime of the technologies applied in conjunction with the UK government projection of the carbon dioxide emission factors for different fuels for 2030 [9]. The government expects to see a substantial reduction of coal-fired power plants and a considerable increase of renewable sources in the national electricity generation in 2030. As a result, the emission factor of grid electricity is projected to fall from the current 0.47kgCO_2/kWh to 0.19kgCO_2/kWh in 2030; whilst for fuels other than electricity, the emission factors are assumed to remain constant to 2030.

Table 5. Carbon savings and effective costs for energy supply options without PV.

	1	2	4
Renewable/ low carbon supply	4991294 (70%)	1970912 (71%)	2802154 (70%)
CO_2 savings (tonnes/year)	1401	527	767
Capital & operations costs	£4.1M	£1.5M	£2.2M
Effective costs (£/tCO_2 saved)	£145	£144	£143

As shown in Table 4, the effective costs vary between £98 and £486 for every tonne of CO_2 saved across the urban form examples. The application of micro-CHP to supply all of the electricity and heating for Urban Form 3 results in the option with the lowest cost per tonne of CO_2 saved but uses gas which not renewable and this technology will become less cost effective as gas supplies become scarcer and more expensive. The proposed technology mix for Urban Forms 5 and 6 is the least cost effective because communal CHP at this scale of application works out more expensive than the micro-CHP used for Urban Form 3. On the other hand, the technologies for Urban Forms 1, 2 and 4 are relatively expensive but achieve a much greater reduction in CO_2 emissions and are therefore more cost effective per tonne of CO_2 saved than Urban Forms 5 and 6. The complete elimination of direct fossil fuel use in the proposed technology mix for Urban Form 1, 2 and 4 derive the most benefits from the government's decarbonisation strategy for grid electricity but the cost per tonne saved is far greater than the 2030 value of £70 per tonne of carbon mitigation by DECC [10]. Table 5 shows that if PV is omitted from the technology mix for Urban Forms 1, 2 and 4 then the cost per tonne of CO_2 saved is substantially reduced but is still around twice the DECC value. These renewable energy technologies may become better value for money if their costs can be reduced and if grid electricity can be decarbonised to a greater extent than assumed in this paper. The above comparisons suggest that the most cost effective building-scale technologies are those that supply heat. Further research is now being carried out by our ReVISIONS project on how these low carbon technologies could function as part of wider systems and how technologies such as CHP may become more cost effective when considered at a wider communal scale. This research will continue to focus on how urban spatial form affects the feasibility of these technologies.

Dwelling density has a significant influence on energy demand per household; however, it is not the only factor that influences the potential for low carbon energy supply. For instance, Urban Form 1 is more than three times as dense as Urban Form 2 but both show high potential for the application of these renewable and low carbon technologies. The combination of both dwelling density and site coverage are the crucial built form factors that determine the potential reductions in carbon emissions from these technologies. The small number of urban form examples recruited in this study limited the feasibility of a quantitative analysis of the effects of morphological parameters such as site coverage and plot ratio on the potential of low carbon supply. The examples shown in this paper suggest that medium to low density housing may in some cases enable a greater saving in carbon emissions than higher density development because of the greater amount of space for collection of renewable energy. However, the effects of density on the energy use by other sectors such as transport, water and waste management, also needs to be considered and this integrated approach is part of our ongoing research on the ReVISIONS project.

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IEA-ECBCS Annex 51: energy efficient communities. Experience from Denmark

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Abstract: The paper describes the Danish contribution to the IEA-ECBCS Annex 51: "energy efficient communities". We present three case studies, two from Annex subtask A (state-of-the-art review) and one from subtask B (ongoing projects). The first case study is "Samsoe: a renewable energy island". In a ten-year period, the community achieved a net 100% share of renewable energy in its total energy use, relying on available technical solutions, but finding new ways of organizing, financing and owning. The second project is "Concerto class I: Stenloese Syd". The buildings in the settlement are low-energy buildings class I (Building Regulation 2008). The project envisaged the implementation of selected key energy-supply technologies and building components and carried out an evaluation of user preferences to give suggestions to designers and constructors of low-energy houses. The third case study is: "low-energy neighborhood in Lystrup, Denmark". The project integrates sustainable solutions both for the building sector and the energy supply side, which in the case consists on a low-temperature district heating network. The analysis of the successful/unsuccessful factors in the projects contributes to develop the instruments that are needed to prepare local energy and climate change strategies and supports the planning and implementation of energy-efficient communities.

Keywords: *energy efficiency, urban planning, renewable energy, district heating*

1. Introduction

The main objective of the IEA-ECBCS Annex 51: "energy efficient communities" is the design of integrated long-term energy conservation and greenhouse gas (GHG) mitigation strategies within a community, with optimal exploitation of renewable energy (RE) [1]. A holistic approach is used, comprehending generation, supply, transport and use of energy. Annex 51 explores effective paths that implement technical innovations in communities with an increased rate, enabling communities to set up sustainable energy structures and identify the specific actions necessary to reach ambitious goals. We consider both short-term and long-term plans, and their economic feasibility. Furthermore, we prepared recommendations, best-practice examples and background material for designers and decision makers.

2. Methodology

The title of subtask A is "existing organizational models, implementation instruments and planning tools for local administrations and developers – a state-of-the-art review". Each participating country describes the national legislative and economic framework for urban energy and climate change policies and prepared a review of data acquisition methods and tools for monitoring municipal energy and GHG balances. Next, we consider local energy system modeling and simulation tools and their combination with conventional planning tools for the design of energy supply systems and demand calculation. Finally, we discuss successful examples of community energy planning projects within the participating countries. The focus is on methods and planning principle, implementation strategies and the final comparison and evaluation of approaches in different countries.
In subtask B, "case studies on energy planning and implementation strategies for neighborhoods, quarters or municipal areas", we describe methods to characterize the actual state of a project in terms of energy and GHG performance. We investigate scenarios and planning alternatives arisen during the case study timeframe, and we report cost structures and

cost/benefit analyses. The process organization, the role of the decision makers and the implementation strategy are put into focus. Finally, we report R&D issues, methods and tools used by the decision makers and the results achieved, with regard to GHG targets and economic feasibility.

3. Results and Discussion

3.1. Samsø: a renewable energy island

In 1997 Samsø island (114 km^2, 4124 inhabitant in 2010) won a competition, announced by the Danish Ministry of Energy. It dealt with the choice of a local community with the most feasible plan for the transition to energy self-sufficiency with exploitation of RE.

3.1.1. Objectives and milestones

The objective was to study what share of RE a well-defined area could achieve using available technology, and without extraordinary state subsidies. The master plan described the available resources and how the transition could be made, with descriptions of both technical and organizational figures. Reduced energy consumption in all sectors, i.e., heating, electricity and transportation was an essential requirement. The degree of local participation was another top priority for the project: the business community, local authorities and local organizations had to support the proposed master plan to give it credibility. It was expected to envisage new ways of organizing, financing and owning the sub-projects proposed.

Table 1: Comparison between energy and economical figures in Samsø, period 1997-2005.

Energy and economical figures	Master Plan (1997)	Achieved (2005)
Share of renewable energy [%]	100	99.7
Degree of energy self-sufficiency [%]	100	35
Share of district heating [%]	65	43
Heat use [TJ/year]	140 (+ 0%*)	155 (+10%*)
Electricity use (no for heat) [TJ/year]	70.0 (-12%*)	77.3 (-3%*)
Onshore wind turbines [TJ/year]	86	100
Offshore wind turbines [TJ/year]	260	285
CO_2 emissions [tons/year]	-14000	-15000
Private investment [$€ \cdot 10^6$]	78.7	53.3
Public subsidies [$€ \cdot 10^6$]	9.3	4.0
Private investment [€/inhabitant]	20000	13500
Public subsidies [€/inhabitant]	2300	1000

*Reference year: 1997

3.1.2. Energy conservation

Campaigns were made concerning energy savings, among those the "pensioner project". The Danish Energy Authority granted funds (50% of the investment, max. 3250 EUR) to pensioners for energy saving renovations in their private houses. Informative letters were sent to the 444 pensioner families of Samsø and a free visit by an energy adviser was offered. 43% of the families made use of it. Local business increased its turnover by 1.1 million EUR. Nevertheless, the total energy use (electricity, heat and transport) increased by 4% in the period 1997-2005, from 305.4 TJ to 318.6 TJ, mainly due to an increased heat demand (+10%, partly because of a cold winter in 2005) and energy use for transportation (+ 7%).

3.1.3. Energy supply

The municipal council guaranteed the mortgage loans that financed the district heating (DH) plants, whose fuel (straw and wood chips) is produced by local farmers. Buildings built in areas with existing or planned DH were compelled to connect to the system, while the houses that complied at least with the low-energy class 2 standard (Building Regulation 98, [2]) were exempt. Outside DH areas, the actual planning process began when 70% of consumers using regular oil furnaces or boilers had signed up for the conversion to DH. The energy utilities introduced a new financial model, who was an exception to normal practice. The consumer paid a connection fee of around 10 EUR, if registered before the establishment of the network, while the fee increased up to 5000 EUR afterwards. This method guaranteed a high degree of connection and aimed at encouraging end-users' energy savings, due to higher energy supply costs. The production increased from 39.6 TJ in 1997 to 82.4 TJ in 2005 [3]; at the same time, the expansion of the existing networks caused the distribution heat losses to increase from 19.9% to 24.2% of the delivered energy. The main figures about the DH systems are shown in Table 2. A cooperatively owned regional utility, NRGi, own and operates two DH systems; another system is owned by a local commercial operator, while the consumers themselves own and finance the last system.

Table 2: District heating in Samsø (2005).

Location	Nordby/Mårup	Tranebjerg	Ballen/Brundby	Onsbjerg
Ownership	NRGi*	NRGi*	Consumer-owned	Private
Consumers	178	400	240	76
Investment costs [€*10^6]	2.7	3.5	2.2	1.1
Subsidy [€*10^6]	1.2	-	0.3	0.4
Peak power [MW]	1.6	3.0	1.6	0.8
Energy [MWh/year]	n.a.	9500	3300	1500
Solar collector area [m^2]	2500	-	-	-
Solar storage tank [m^3]	800	-	-	-
Year of establishment	2002	1993	2005	2002
Resources	Biomass/ solar	Biomass	Biomass	Biomass
Fuel consumption [tons/year]	1250	n.a.	1200	600
Fixed fee [€/(consumer·year)]	344	362	345	350
Price [€/MW]	92	104	90	90
Connection fee* [€]	3350	3350	6000	6000
Connection fee* [€/m_{pipe}]	150	150	-	-

* Only for customers who connect after the establishment of the DH network

Individual solutions were applied in areas not reached by DH networks: 860 solar thermal systems, 35 heat pumps and 120 biomass-based units were installed [4]. To cover the electricity demand, 11 onshore wind turbines were installed, with a total peak capacity of 9 MW_{el}. An offshore wind turbines park was dimensioned with a capacity of 23 MW_{el}, corresponding to the difference between the actual energy use in the transport sector and the energy savings to be realized in the master plan. Five of the 10 off-shore wind turbines are owned by the municipality of Samsø. The proceeds from the windmills are reinvested in future energy projects as Danish law does not allow local municipalities to earn money by generating energy. Three of the off-shore turbines are privately owned by local farmers. Nine offshore wind turbines are owned privately by small groups of farmers and two are owned by local cooperatives with up to 1500 shareholders [5]. Spreading the ownership improved citizenship acceptance for the construction of the wind turbines. Electricity production prices are regulated by law and include a ten-year fixed price agreement which is the same for all the wind turbines on the island. The agreement stipulates a guaranteed price of about 0.08 EUR for the first 12000 full-load running hours and afterward about 0.06 EUR, until the ten year period expires.

3.1.4. Analysis

The strengths, weaknesses, opportunities, and threats (SWOT) analysis is shown in Table 3.

Table 3: SWOT analysis for the Samsø case study.

	Helpful	**Harmful**
Internal origin	*Strength* - Political support - Internal energy market - Local coordination - Local ownership - Organizational structure - Local resources - Challenging jobs	*Weakness* - Minor energy savings - No cogeneration - Municipality administration - Uncertainty of energy prices - Training and education - Protests against placement of wind generators and DH plants
External origin	*Opportunity* - External investments - EU incentives - Lower tax for electricity from RE - Creation of new employment opportunities - El. contracts avoid price fluctuations - Positive effect on tourism	*Threat* - Removal of subsidies by new government - Immaturity of electric car technology - Lack of suppliers and companies for maintenance

3.2. Concerto class I: Stenløse Syd

The project Class1 began in 2007, after the municipality of Egedal decided to strengthen the energy requirements for a new settlement to be erected in the municipality [6]. The project is part of the "EU Concerto initiative project" [7]. During the years 2007-2011 a total of 442 dwellings were or are designed and constructed with a heating demand corresponding to the Danish "low-energy class I". This means that the energy consumption will be 50% below the energy frame set by the Danish Building Regulation (DBR 08). The energy frame is calculated with the following formula, where A is the heated floor area:

$$\text{Energy frame} = 70 + 2200/A \text{ in kWh/m}^2\text{/year} \quad (1)$$

Figure 1: Site area (left) and status of the settlement in 2010 (right).

During the first year of the project, the municipality itself has constructed a kindergarten in compliance with the above restrictions and a social housing association has completed an ultra low-energy house project (heating demand of 15 kWh/(m2.year)) – comprising 65 dwellings. Besides, the constructions of the elderly centre and 13 single family houses have commenced. The Class 1 project focuses on selected key technologies and building components: slab and foundation insulation, window frames, mechanical ventilation with heat-recovery combined with heat-pumps, biomass-CHP, heat distribution for local DH and user-friendly building energy management systems.

3.2.1. Evaluation of user preferences and legislative analysis

One part of the demonstration activities deals with the evaluation of the user preferences to improve target future buyers/builders of low-energy houses. The methodology was determined and the initial interviews were carried out. The final report is available in [6]. Proactive attempts have been identified and documented to understand legislative and planning means in the process of promoting sustainable community projects [8].

3.2.2. Key-product development

Industrial partners have made progress in developing new and/or improved products suitable to low-energy buildings: a low energy window, whose production costs were reduced by 30% by process changes and machinery investment and a ventilation unit with heat recovery and integrated heat pump for low-energy houses. Moreover the low-rise, dense building sites will be supplied by a local low-temperature DH network. During the summer period the bio-mass CHP plant will be closed down and the solar heating systems will deliver the heat for domestic hot water (DHW).

Table 4: SWOT analysis for the Stenløse Syd case study.

	Helpful	**Harmful**
Internal origin	*Strength* - Integration of different sectors - Comparison of strategies in the different participating countries	*Weakness* - No obligatory monitoring concept implemented in all the sub-projects
External origin	*Opportunities* - Mix of energy savings and renewable energy policies, R&D and dissemination activities - Intelligent management and monitoring of water and energy consumption	*Threats* - Coordination of many partners

3.3. Low-energy neighborhood in Lystrup

The project deals with the realization and evaluation of a sustainable housing area in Lystrup, Aarhus. The residential area B was completed in “Lærkehaven” in May 2008 and represented the first step towards the vision of a sustainable housing development, with a total of 122 low-energy buildings. The residential area C was completed in early 2010. The last stage (residential area A) will be finalized in 2011. The main characteristics of each area are [9]:
A: 32 two-storey family houses according to the German Passive House Standard.
B: 33 two storey houses (Danish low-energy class I) and 17 single-storey houses (Danish low-energy class 2), LED lighting, phase change materials (PCM), common solar cell facility.
C: 40 residences (Danish low-energy class I, expected energy demand of 30 kWh/m^2, total heated floor area: 4115 m^2), connected to a low-energy DH network.
In the paper, we focus on the area C. The project integrates sustainable solutions in the end-user side (building sector) and in the energy supply side (DH network). The former deals with finding cost-effective solutions for the construction of low-energy buildings and at the same time promoting high architectural quality and comfort; the latter refers to the demonstration of

the technical and economical feasibility of DH applied to areas with low heat demand densities and to the testing of two heating unit designs with focus on return temperature.

3.3.1. The low-energy and low-exergy district heating system

The project is among the first in the world, where a low-temperature DH network is applied. The DH network (total trench length: ~800 m) was designed according to low-temperature operation in the supply pipe (55°C) and in the return pipe (25°C). The application of the low-exergy concept to the DH technology aims at three main targets. The first one is to guarantee comfort, with regards to delivery of DHW and to space heating requirements, by exploiting low-grade energy sources and RE. The second objective is to match the exergy demand of such applications with the necessary exergy available in the supply system, by making the temperature levels of the supply and the demand closer to each other. Finally, it aims at reducing the heat loss in the distribution network, so that the total profitability is ensured from the socio-economic point of view. The main design concepts are:

-Low-size media pipes. This is achieved by allowing a high pressure gradient in the branch pipes connected to the unit with instantaneous DHW preparation or by installing units with storage of DH water. The latter one consists on a heat exchanger coupled to a water storage tank on the primary side, which ensures low continuous water flow from the DH network and therefore media pipes of lower size in the distribution lines.

- Low-operational temperatures: down to 50-55°C in the supply line and 20-25°C in the return line.

- Twin pipes are used. Furthermore flexible plastic pipes replace steel pipes, wherever it is possible. This leads both to lower investment costs for the civil works connected to the laying of the pipeline and to lower total heat loss.

- Installation of a circulation pump. The pump ensures an increase of the available differential pressure in the network and it compensates for the choice of small-diameter media pipes.

Figure 2: Sketch of the DH network with the location of the meters (adapted from [10]).

Two types of DH substations are installed: 30 Instantaneous Heat Exchanger Unit (IHEU) and 11 District Heating Storage Unit (DHSU). This former utilizes a heat exchanger between the primary side (DH loop) and the secondary side (DHW loop) for instantaneous production of DHW, while there is a direct system for space heating. The unit is equipped with an external by-pass, meaning that the by-pass water does not flow through the heat exchanger. The latter includes a storage tank and a heat exchanger. Heat is stored with DH fluid as medium. The DHW is produced by a heat exchanger, supplied from the tank. A flow switch detects a water flow and starts the pump. There is no need for by-pass flow in this type of unit. The DHSU are all placed on the same street line so that it is possible to measure both the performance of the unit itself and the implications at street level. The total investment cost for the whole network, including the substations, lies between 350000 € and 400000 €.

3.3.2. Analysis

We highlight here the main findings, with regards to the planning process.

- The project took profit of the extensive collaboration among different partners: the housing association, industrial partners, architectural and engineering consultants, research institutions and governmental agencies.
- The international architectural competition and the import of prefabricated building envelopes from abroad succeeded to ensure high standards and reasonable economy.
- To some extent, the Danish building construction tradition has been a barrier for planning the community as a whole, more than as a collection of individual building units. In fact, the tendency in the sector, related to low-energy buildings, is to provide solutions based upon individual energy supply systems, mainly heat pumps, and the building types are often not developed with a friendly interface to DH systems. On one hand, this means that standard and reliable offers for low-energy buildings already exist; on the other hand, it could hinder the chance of implementing a sustainable and holistic vision that gathers both the end-user' side and the energy supply side.
- A conflict between different goals arouse during the planning and implementation process. A target pertained to the high expectations about reaching the "climate goal", which for Denmark is defined by the political will of developing an energy system based on 100% RE by 2050 and it is translated to action at national, regional and local level. Another objective was connected to the need of finding solutions that can lead the process in a cost-effective way. The conflict was critical at least in two phases: during the definition of the budget for the construction of the low-energy buildings in the residential area A, and during the planning of the energy supply system for the residential area C. In the first case, the maximum allowed budget was constrained by the requirements of the social housing in Denmark, whose requirements limit the economical burden for the tenants. The implementation phase was then delayed and the construction started only when it was decided to exceed the maximum budget. In the preliminary plan for the energy supply system for the residential area B, the planners chose a traditional DH network based on a pair of single pipes, directly connected to the main network in Lystrup (T_{supply}= 80°C and T_{return}=40°C). The cost-effectiveness of such network was questioned, so that individual solutions, such as heat pumps were considered as alternative. The final decision was taken when an external R&D project took over the planning responsibility, bringing along also more capital to be invested. The final outcome was successful, since it was demonstrated not only that the low-temperature DH concept is applicable to low-energy buildings, but also that the total long-term economy (30 years) improved in comparison to the original design solutions.
- The recognition of the existence of a market in Denmark in relation to sustainable, energy-efficient and environmental-friendly houses was an additional motivation for starting the project, from the housing association point of view. In fact, the completed dwellings were fully occupied by tenants faster than in other newly established areas, despite the housing sector suffered a crisis in that period.

4. Conclusions

We conclude by summing up the main findings, which will be extensively discussed in the final report of IEA-ECBCS Annex 51. The case study of Samsø demonstrates how a community can base its whole energy system on RE, without extraordinary external subsidies. The process towards such communities benefits from local participation and local ownership. Taking the results from the experience in Samsø and simply transferring it to a national level, the transition towards a fully RE-based nation would cost about 90 billion EUR, giving savings for 8 billion EUR/year and a pay-back time of about 11 years (considering 2005 figures). Although these data are encouraging, the Danish average energy use per inhabitant is 25% higher than in Samsø, while the potential biomass per inhabitant is one third. Moreover, the potential of wind energy is lower in the rest of the country. Therefore, substantial energy conservation efforts are needed to achieve the goal of 100% share of RE in the country as a whole. Such issue is central in the project in Stenløse Syd, where proactive attempts have been identified and documented to understand legislative and planning means in the process of promoting sustainable low-energy community projects [8]. With regard to energy planning, the "neighborhood approach" is more profitable and can achieve better results than the "local approach", as demonstrated by the project in Lystrup. The best social-economy is obtained only if the energy plan is done for the community as a whole, instead of considering local plans for the single housing units. Moreover, the combination of energy saving policies in the building sector and an energy efficient supply system based on RE, such as a low-temperature DH network, is seen as a promising concept for achieving ambitious climate goals.

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Towards optimization of urban planning and architectural parameters for energy use minimization in Mediterranean cities

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Abstract: This paper reports observations and first experimental results from a field measurement campaign at the neighbourhood/urban scale, which was conducted in July 2010 in Nicosia (Cyprus) under the European Research Project TOPEUM funded by ERA-NET (Urban-Net Call). The ultimate goal of this work is to investigate the influence of urban design and architectural parameters in the resulting urban climate and the resulting energy usage. The field measurement campaign was carried out in the capital city of Cyprus, Nicosia, reflecting a typical Mediterranean city both in relation to buildings architecture and fabrics, street geometry and neighbourhood morphology. The field measurements include meteorological measurements as well as on-ground and aerial thermography, covering a range of spatial scales, from local-street canyon to meso-scale. The measurements record the meteorology, the thermal response of the buildings in the field site area and the resulting local microclimate particularly in the street.

Keywords: *Urban Heat Island, Intensive Observation Period, Field Measurements, CFD Modelling, Wind Tunnel Measurements*

1. Introduction

Urbanization has been increasing at an alarming rate: while in the 1800's, only 3% of the world's population lived in urban areas, by the 1950's the urban population increased to 30% and in 2000 it reached 47%. With this ever increasing growth, numerous issues have been raised, such as air quality issues, sustainable use of energy, maintenance of waste materials and socio-economic status of urban inhabitants [1]. All these issues depend on the sustainable urban planning, the type of materials used in buildings [2] as well as the organisation of economical and social life. The complexity of the task to aim at ideal sustainable city goes through accounting for contradictory effects by any kind of measures. Therefore, basic and applied research is needed in order to investigate the city as human-made environment. The task is to achieve sustainability in the use of energy, food, waste, air and water quality. Recent studies on the influence of climate change on Northern–European cities suggest that within 50 years they may experience a climate close to that of South-European cities today. This has enormous resource implications when the design and layout of the urban fabric and the individual buildings are not well suited to mitigate extreme conditions [3,4] There is therefore a strong need for strategic designs to be developed which would mitigate such environmental changes. For example, whilst the general cause of overheating of cities is known, it is not well understood how much influence different urbanization characteristics and building materials have on the intensity of the city overheating [5,6].

In this study the energy exchange processes between buildings and air in a typical South-European city as well as the ventilation properties in relation to urban-planning and architectural parameters, for the purpose of energy use minimisation are examined. The complexity of this problem requires complementary methods to be employed. In a boundary layer wind tunnel the basic flow under neutral conditions of different generic city configurations will be studied. The wind tunnel data will serve also as calibration data for

CFD simulations which will in turn be utilised to evaluate heating effects and material properties. The computational fluid modelling will predict the effect of city layout and building materials on temperatures. Based on predicted temperatures the energy use for air conditioning will then be assessed. Heat absorption phenomena occurring at building surfaces have a major impact on the urban climate: field measurements of surfaces heat flux and material thermal properties will be carried out for urban sites in Cyprus. For these reasons an intensive observation period of 1 month was carried out in which a series of measurements were taken both for the air, solar radiation and humidity as well as the building surfaces.

2. Methodology

2.1. Multidisciplinary approach

The methodology for the implementation of this study consists of the following steps:

1.Selection of the site under investigation: The identification of the site to be investigated was performed under prescribed criteria based on the building materials, the geometry and the location of the buildings.

2.The field measurements involved meteorological measurements at three different scales (from meso-scale to micro-scale), while the thermal response of buildings was simultaneously recorded through thermography (both aerial and on-ground) as well as in-situ measurements of temperature and moisture. In this paper the results from this field measurement campaign are presented, the analysis and interpretation, as well as results from supporting studies in the wind tunnel and computational simulations to assist in the understanding and derivation of guidelines for “climatically-informed” urban design.

3.Laboratory experiments: The selected city blocks will be scaled down and applied in a wind tunnel, where ventilation and heat efficiency effects will be investigated. The determination of the velocity field will be achieved by employing Laser Doppler Anemometry (LDA) and Particle Image Velocimetry (PIV).

4.CFD modelling will contribute to the study, by examining the air flow as well as the thermal performance of building materials taking into account the structure of the modelled urban areas. It will raise the opportunity to understand the contribution of heat conduction and heat radiation in the generation of thermal discomfort in urban canyons for the case of Cyprus.

2.2. Site Selection

In terms of the site selection, the parameters of building height, building density and paved and unpaved area coverage were examined. This analysis provided fundamental data for all the subsequent tasks and actions. The objective was to create a complete database of the investigated area in order to assess the status of urban environment in Cyprus. Hence, major groups of building blocks (approximately 350 building blocks) were analyzed and scaled down for the applied channel, in order to support the parameterization studies for the investigated scenarios. Within this task, the geometries under investigation were also be modelled for the purposes of the CFD study. The building energy behaviour and performance are heavily influenced by the density of the building space that is why the facades chosen have different SVF. For example facades that are placed in front of an open parking area (H/W<1) can be compared with some others that are placed in a canyon. Some other important factors were the orientation of the chosen facades and the properties of the surrounding surfaces in the same canyon.

Among the investigated neighbourhoods, the old city centre of Nicosia appeared as being the most representative for the Mediterranean-like architecture, therefore it was decided that the field campaign should be carried out in this area (see Fig. 1). The old town centre, which is the historical centre of the city, is delimited by Venetian type walls. It is generally characterized by narrow canyons with Mediterranean-style planning but also includes some buildings of contemporary architecture and also some large squares. From the West to East, four major sub-neighbourhoods (SN) could be identified according to homogeneity and packing building density SN1 to SN4. SN1 includes some larger open spaces/parking lots so that it has an overall lower packing density and it is less homogeneous. SN2 is homogeneous over relatively large distances in neighbourhoods units. SN3 has some broader avenues and squares so that it has a lower packing density. SN4 has a very large packing density being also relatively uniform.

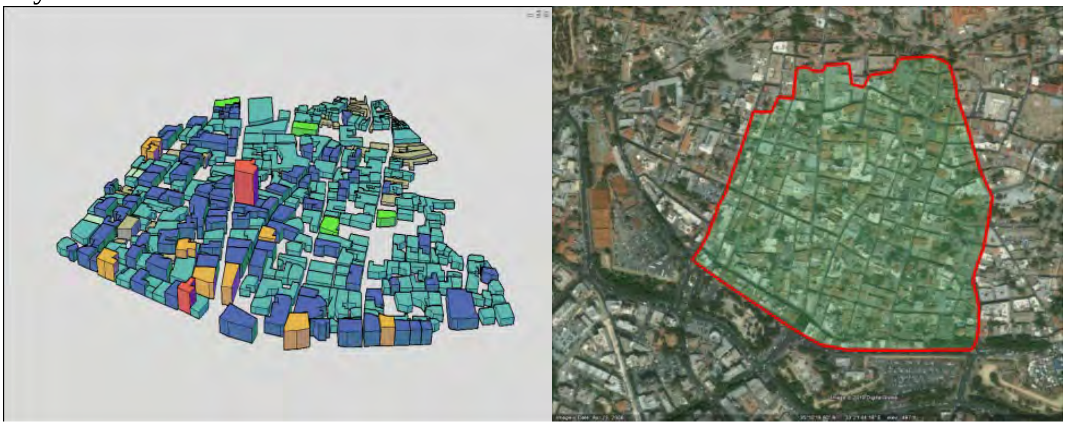


Fig.1. Investigated Site

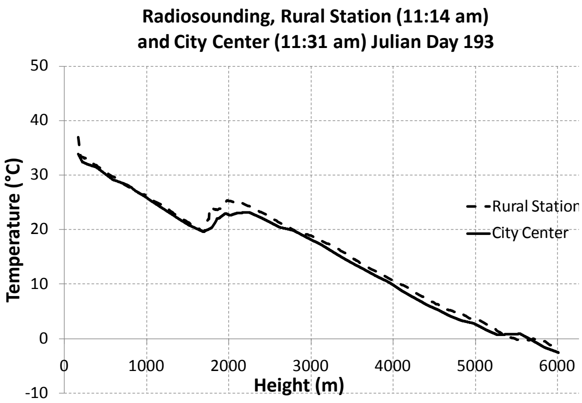
2.3. Intensive observation period

During the intensive observation period, measurements in neighbourhood, micro- and meso-, scale were performed. Regarding the meso-scale, an upper air sounding system was employed. The sounding system provided the profile of the air pressure, temperature and humidity as well as of the wind speed and direction from ground level up to 2 km altitude. Sets of the measured data were sent down to a receiving station (ground station) as the radiosonde was carried aloft by a balloon. The characteristics of the micro-scale were determined by means of aerial thermography and a weather station consisting of a hypersonic anemometer and instrumentation for temperature and humidity measurements. InfraRed thermal and visual images were captured via a high-resolution (640x480) FLIR P640 IR-camera from a helicopter at approximately 500 m above the ground. The aerial thermography measurements were performed along a flight path of a total length of 7 (km) traversing from the eastern rural area, over the urban area of the town centre and up to the western rural area. The measurement schedule was based on the time lag of the building materials with respect to the sunrise calendar of the location and the solar exposure of the materials. For the meteorological data, stations with temperature and humidity sensors were installed close to the sonic anemometers. Surface temperature and moisture measurements, as well as measurements of the ambient temperature, humidity and wind speed and direction were performed. Surface temperatures were determined by means of building IR thermography, as well as with the use of thermocouples and a FLUKE 62 Mini IR thermometer with an accuracy of +/- 0.1 °C. For the measurement of the buildings moisture an EXTECH moisture meter (model MO250) with an accuracy of +/-0.1% was employed. IR thermal images of surface temperature were captured with a FLIR T335 camera at specific locations within the city. The thermal images of the building façades were acquired over the space of an hour, every two hours during the time period from 10th to 12th of July 2010 at 3 different locations. At each location, 4 thermocouples were used (one at ground level and 3 at heights of 40, 120 and 200cm from ground respectively).

3. Results

3.1. Meso-scale measurements

In Fig.2a, the measurement of the temperature in the meso-scale above the city centre is provided. According to these results, the surface is very hot and therefore super adiabatic gradient is observed in the first 300m above ground. This is, in fact, the surface layer in terms of temperature. Above 300m, and up to 2000m a well-mixed (convective) layer is formed. In order to clarify the observed temperatures, the schematics of the boundary layer over an urban area is also provided (Fig.2b). The upper zone represents the urban internal boundary layers where advection processes are important. The regime below shows the inertial layers that are in equilibrium with the underlying surface and where Monin-Obukhov scaling applies. The lower region is the roughness layer that is highly inhomogeneous both in its vertical and horizontal structure. Finally the region between the inertial layer and the roughness layer represents adjustment between neighbourhoods with large accelerations and shear in the flow near the top of the canopy [7]. The same clear top of the convective boundary layer was also observed also in the relative humidity profiles and thus the entrainment zone was very shallow. The air mass above the convective layer was dryer and the wind direction was found to change substantially.



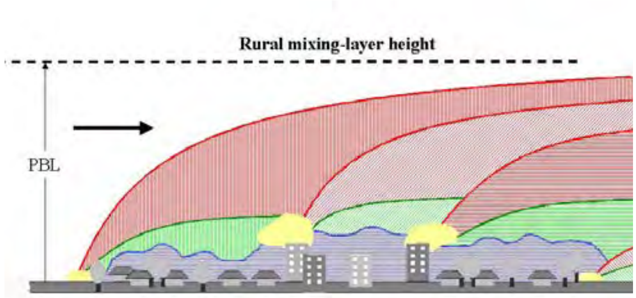


Fig.2a. Radio-sounding temperature measurement above city centre
Fig.2b. Boundary layer over an urban area

3.2. Micro-scale measurements

In Fig.3 the ultrasonic anemometer measurements of the wind speed and direction, over the intensive observation period at Ledras Street on the rooftop level are provided. The analysis of the sonic data shows clear difference in the regime of wind during the day and the night. The sonic on the roof shows weak easterly wind every night (24 – 6) and much stronger westerly wind during the day (9-18). Therefore, two different regimes can be simulated, easterly wind of 2 m/s and westerly of 5 m/s. The transition periods are rather short around 9 in the morning and 21 in the evening. From the time series of wind direction we can note that during the intensive observation period (Julian Day 190-193) the flow is slightly disturbed, and is predominantly easterly, also during the day. The friction velocity measured by the sonic at the roof is much higher than the value ($u^*=0.08u$) suggested by similarity theory. The mean value for the 2 weeks of measurements is $u^*=0.14u$. This is a value typical for urban areas. The wind direction within the street canyon is strongly modified by the buildings, but the two regimes (day and night) are distinguished as well. The wind speed is between 0.5 and 7 m/s.

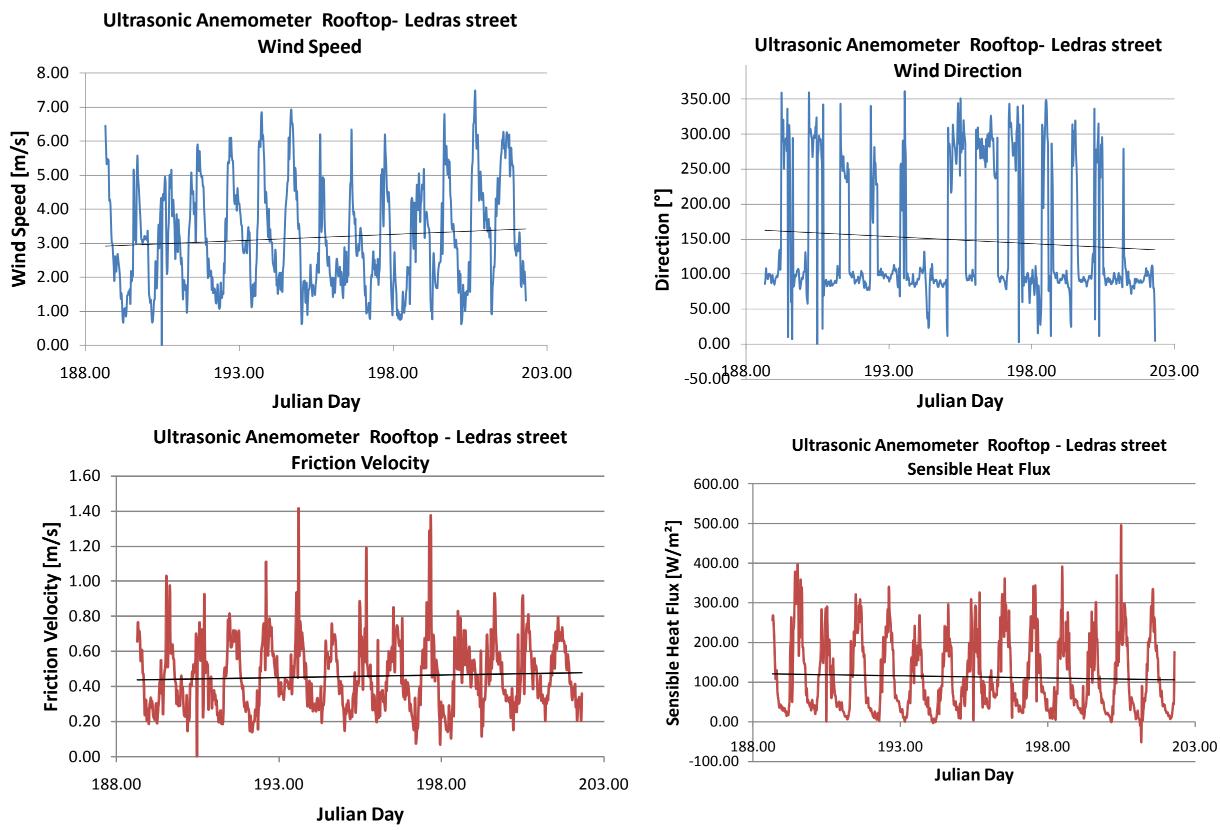


Fig.3. Ultrasonic Anemometer Measurements, Ledras Street, Rooftop Level

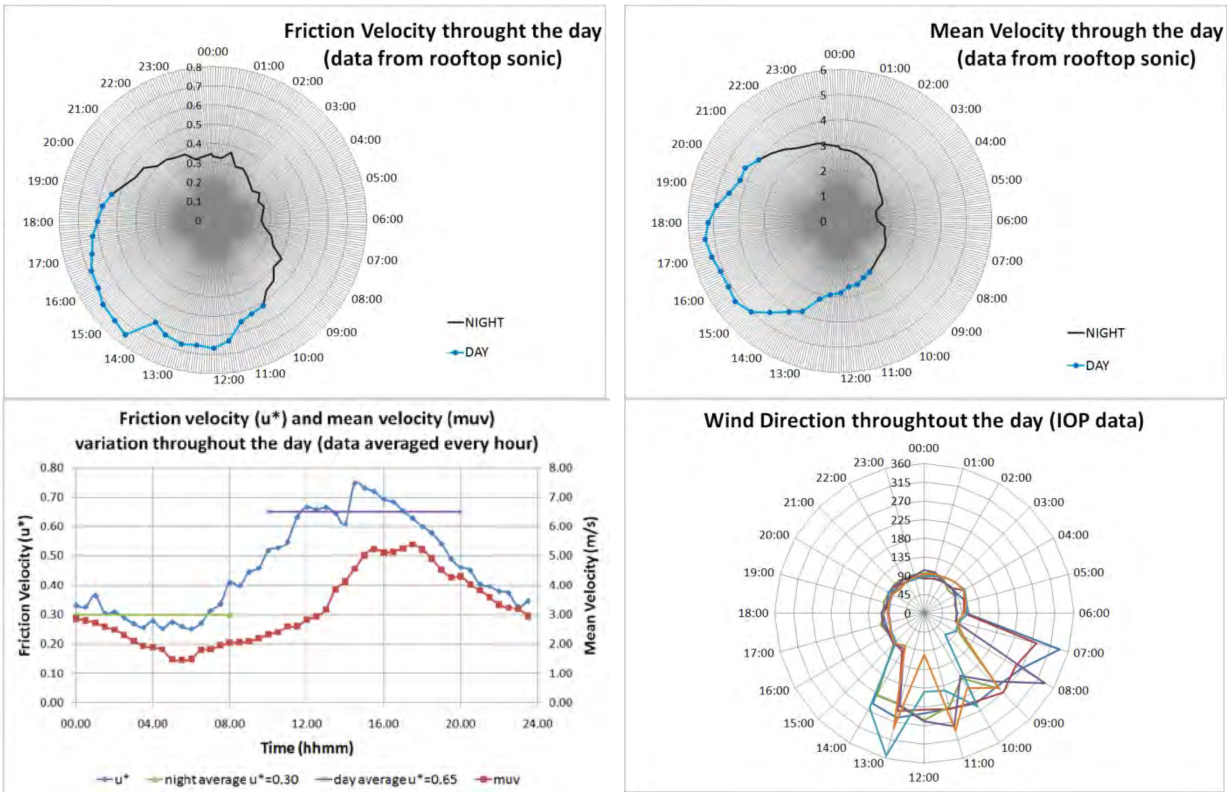
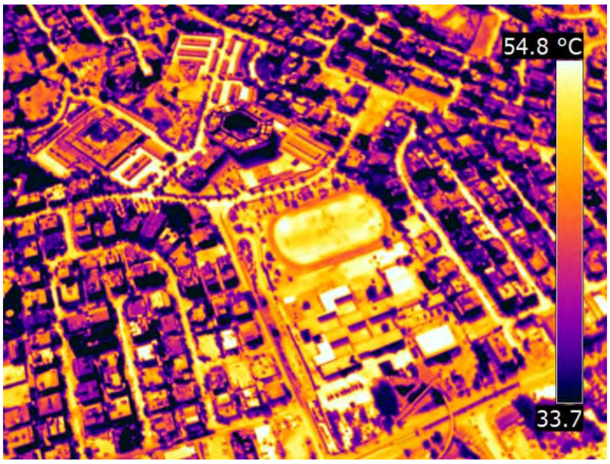


Fig.3. Ultrasonic Anemometer Measurements, Ledras Street, Rooftop Level

Aerial Thermography was also performed in order to determine the intensity of the heat radiation emmited by the built environment in the investigated field. For this purpose, a statistical analysis of the temperature intensity was performed by means of the SPSS software. The temperature distribution was compared for several city environment providing some useful conclusions regarding the importance of thermal radiation resulting from the applied building materials.



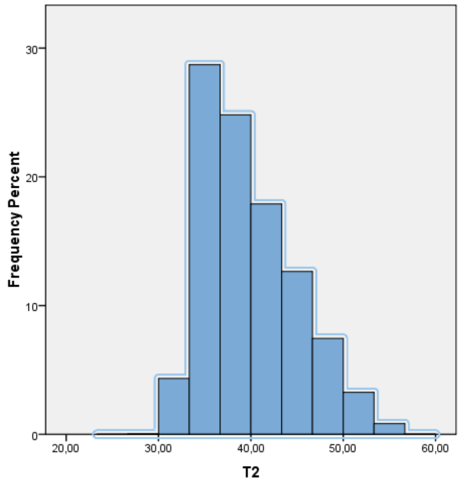


Fig.4. Aerial thermography and statistical analysis of temperature distribution

3.3. Neighbourhood scale

The Urban Heat Island Intensity (UHII) was also identified by means of data comparison from the weather station in the investigated site and from a rural weather station 5km outsite the city. According to these measurement UHII was found equal to 4 °C, especially during the midday (see Fig. 5).

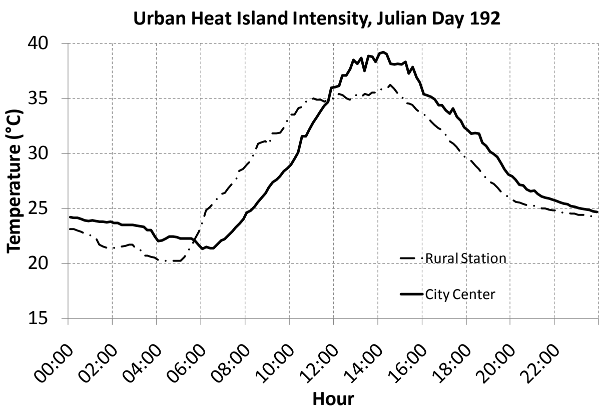


Fig.5. Urban Heat Island Intensity.

The impact of the building materials on the intensity of the urban heat island intensity was approached by means of measurements of surface temperature of building materials at the field site. Fig.6 and 7 presents the temperature profile during the IOP. In the first case the ambient temperature was measured at the rooftop of the building, whereas in the latter case it was measured next to the building element, and was, as expected affected by the environment radiation. The measurement in Fig.6 was performed on a wall constructed with forced cement, and the measurement in Fig.7 on a stone wall. The thermal emissivity of both materials is almost equal (around 0.85), whereas in the latter case, the heat capacity of stone wall is increased, compared to the heat capacity of forced cement. Therefore, although the temperature peaks were observed more or less to be equal, the duration of the peaks was greater in the case of stone wall. Another important outcome of this measurement was that the contribution of thermal radiation as well as of the anthropogenic emissions in the street canyons led to an important temperature increase, which was observed throughout the day.

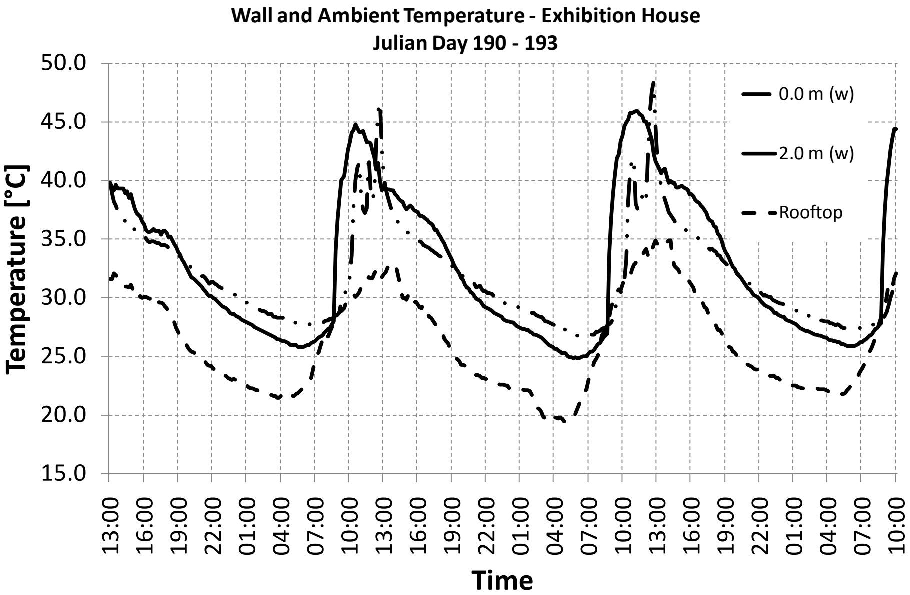


Fig.6. Wall temperature Measurement

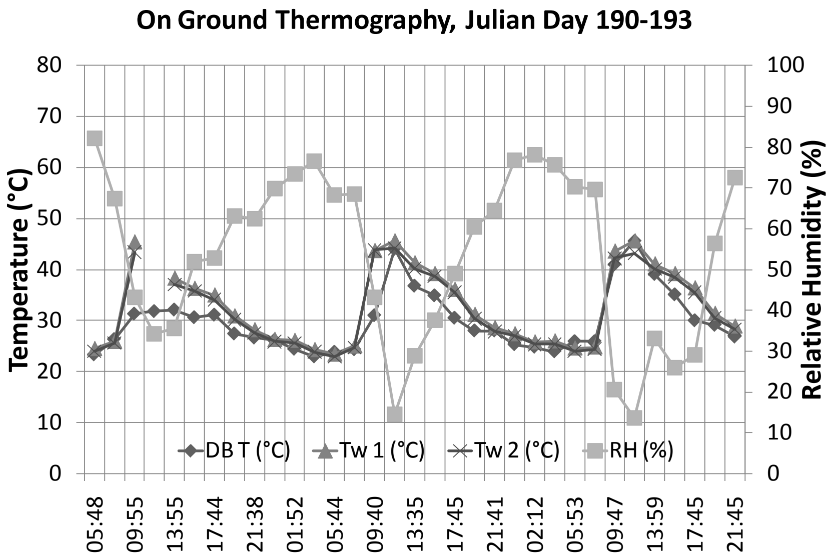


Fig.7. Wall temperature Measurement – on ground Thermography

4. Conclusions and future work

A series of simultaneous measurements of urban meteorology and the associated thermal response of buildings has been conducted in Nicosia, reflecting a typical Mediterranean setting for climate and urban architecture. Some preliminary observations show a consistent temperature difference in the ambient air between the urban and rural areas of about 2K with an approximate temperature difference for the thermal response of the buildings in their corresponding peaks and lows of 5 to 8 K (wall surface temperature). Simultaneous diurnal measurements of the moisture of the buildings show also a direct correlation with the corresponding wall surface temperatures. Further post-processing and analysis are in progress and in addition complementary methods will be employed; therefore, the field measurement campaign will be followed by detailed experimental and numerical studies. The investigated city blocks will be scaled down and applied in a wind tunnel, where ventilation and heat efficiency effects will be investigated using Laser Doppler Anemometry (LDA) and Particle Image Velocimetry (PIV). In order to calibrate the CFD modelling the pressure on the ground around the buildings will be measured in 400 points. Thus, the experimental results, as well as the results of the field measurement will be used in order to optimize the adopted models used to performed numerical simulations by means of Reynolds-Average Navier-Stokes (RANS) modelling. The experimental feedback will enable also the performance of further investigations concerning radiation effects from building surfaces assuming unsteady state conditions.

Acknowledgements

The authors wish to acknowledge a number of organisations and persons for their contribution and assistance during the field measurement campaign, without which this work would not have been possible: Cyprus Police for providing the helicopter for 4 flights and assistance during the flights, Nicosia District Mayor, Cyprus Meteorological Service, United Nations, Prof. Joe Fernando (from Notre-Dame University, USA) for sharing experience and advice in Urban Heat Island Experiments, as well as a large number of volunteers who helped at various stages in various ways for this work to be realised. The project is funded through ERA-NET (Urban-Net Call) and the Cyprus Research Promotion Foundation under the contract ΔΙΕΘΝΗ/URBAN-NET/0308/02.

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Case study on the effects of smart energy community construction at Kanazawa seaside district in Yokohama

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Abstract: This research worked on the measure against CO_2 reduction according to the characteristics of the area for the Kanazawa seaside area in Yokohama city. This area consists of a collective housing complexes and a minor scale industrial complex, and also locates a waste incineration plant, a wastewater treatment plant, and a sludge treatment facility. Having been chosen as a measure with the large amount of CO_2 discharge reduction, it is the system which feeds into an incinerator the methane gas by carrying out mixed digestion of the kitchen garbage together with sewer sludge, and supply heat from a waste incineration factory through the transmission line. However, since this system has large initial cost for construction of transmission line, marginal abatement cost (MAC) for CO_2 emission reduction is very as large as 166.16 [USD/CO_2]. Then, when the pay-back year of the transmission line was changed from 20 years to 31.5 years which is equivalent to 70% of legal durable years, MAC was reduced to 104.40 [USD/CO_2]. Moreover, when Non Energy Benefit (NEB) by system introduction, such as job creation and an environmental improvement of the area, was taken into consideration, MAC was greatly reduced to -124.22 [USD/CO_2].

Keywords: *Exhaust heat from waste incineration plant, Solar energy, Digestion of sewage sludge mixed with kitchen garbage, CO_2 reduction cost*

1. Introduction

1.1. Background and objectives of research

As the countermeasures against the issues of global climate change, it is essential to reduce CO_2 emissions from building sectors. To promote the reduction of CO_2 emissions from building sectors, various countermeasures should be executed, not only for building sectors but also for the community. The Kyoto Protocol Target Achievement Plan was materialized in Japan in April, 2005 [1]. Until then, main measures for the energy conservation such as heat-insulation and introduction of efficient equipments were implemented on individual buildings only. In this plan, measures for advance energy saving and low carbonation in the community were also specified in addition to the measures for individual buildings. For advance energy saving and low carbonation in the community, the mutual cooperation of various stakeholders of the community is indispensable. It is important to make the process which shares the target of energy saving and low carbonation, distributes profits impartially, and shares a risk equally within the community. Therefore, the objective of this study is to propose the measures for energy saving and low carbonation and examine the technique of presenting the effects (benefits) and risk (cost) clearly for Kanazawa seaside district in Yokohama city.

In this study, the countermeasures for the CO_2 emission reduction in the community are focused. There are lots of options for the reduction of CO_2 emissions at the community scale, such as PV’s, solar thermal use, biomass, exhaust heat from waste incineration plant, and so on. But these options may not be suitably introduced anywhere. Thus, it is very important to recognize characteristics of the community to introduce the suitable countermeasure options. The case study area is Kanazawa seaside district in Yokohama City, Japan.

The main purpose of this research is to determine the countermeasures for CO_2 emission reduction which is appropriate for this community, and to analyze the cost effectiveness of these countermeasures.

1.2. Study area

The case study area is Kanazawa seaside district in Yokohama city. This district is reclaimed land with an area of 121.9ha [2] where collective housings were sold in lots from around 1970. A railway runs through the center of this district to the south north. Residential area is located at the west side of the railway. At present, 7,500 households with the population of about 20,000 persons are living in this district [2]. It had been about 30 years after a sale in lots and now many housing complexes are aged and expected to be reconstructed and repaired. On the other hand, the east side of the railway is industrial complex area for middle to minor scale factories. There are some urban facilities in this area, such as a waste incineration plant, a sewage treatment plant, and a sludge treatment plant.

Kanazawa waste incineration plant incinerates about 300,000[t/year], and generates 130 [GWh/year] electric power by using exhaust heat of waste incineration [3]. Kanazawa wastewater treatment plant has treatment capacity of 265,900 [m^3/day] [4] , and generates treated water (recycled waste water). Nanbu sludge treatment plant has treatment capacity of 14,700 [m^3/day], and generates methane gas through digestion tank [5]. In addition, there are some office building, hotels, and the campus with the hospital of Yokohama City University.

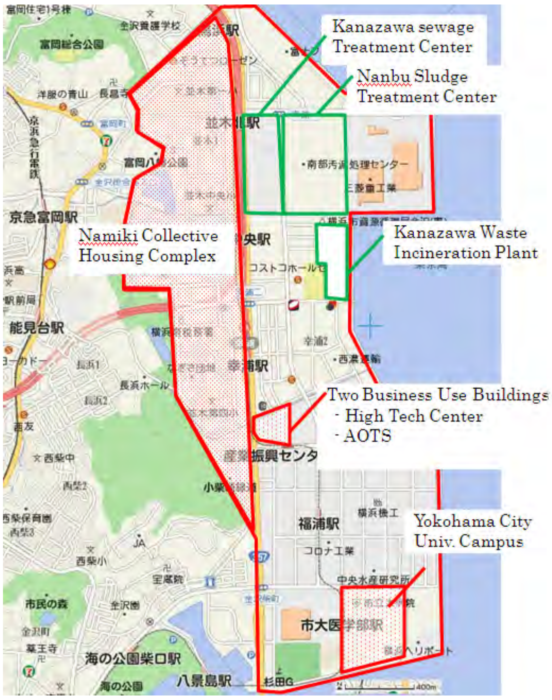

Figure 1 Kanazawa Seaside Area

In the road map for environment model city realization, Yokohama city government regards this area as an important area, and the Yokohama Green Valley project is in operation. The amount of CO_2 emission from energy consumption in this area is assumed about 72,000 [t-CO_2/year]. About 60% of this emission is due to energy use in residential and business sectors.

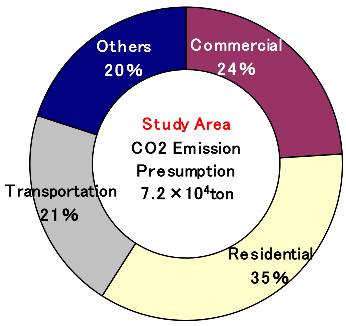

Figure 2 Estimated CO_2 emission of Kanazawa seaside area

2. Countermeasures for smart energy community

2.1. Outline

Figure 3 shows the smart energy network in the proposed area. Four stages were assumed as present condition (2010), the first stage (2015), the second stage (2020), and final stage (2025). Various countermeasures for each building promoted by Japanese government were executed, and also the other measures for community scale were tried to be executed. While planning the smart energy network in this area as a whole, the effective use of urban facilities such as sewage treatment plant, waste incineration plant etc. were considered to have significant role.

Table1 Present energy demand of subject buildings in this area

		Total Floor Area m²	Demand (Present)			
			Electricity GWh/year	Heating TJ/Year	Cooling TJ/Year	Hot Water TJ/Year
Namiki Collective Housing Complex	House	721,400	32.75	51.26	54.28	144.74
High-Tech Center	Office&Hotel	50,000	8.06	13.29	14.59	16.40
AOTS	Office&Hotel	12,000	1.73	4.78	3.36	10.78
Yokohama City University	Hospital&University	107,000	10.48	40.79	20.62	78.37

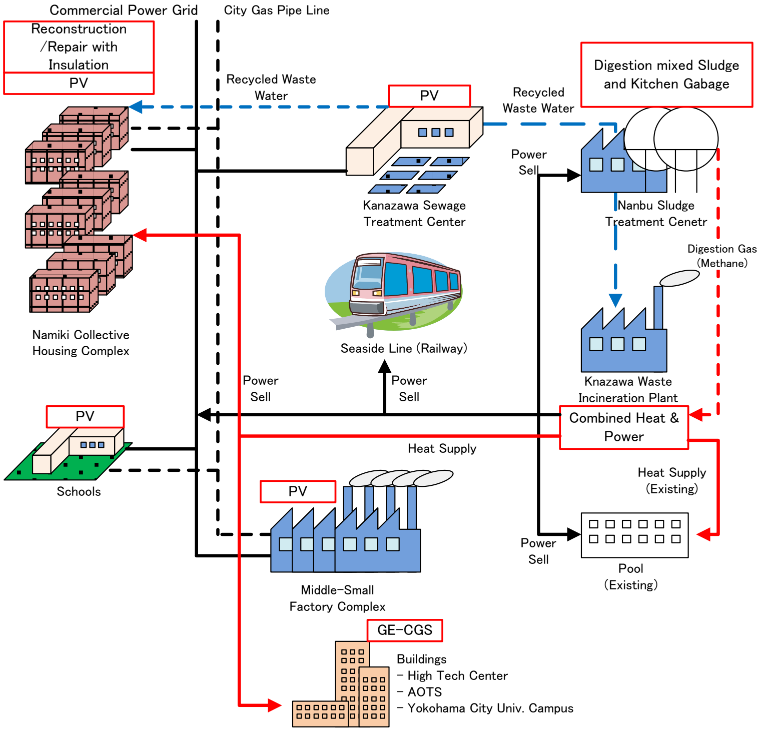

Figure3 Proposed smart energy network at Kanazawa seaside area

2.2. *Remote ownership of Photo Voltaic Panel*

In the Electricity Enterprises Law of Japan, the photovoltaic generation panels set up in places other than home are not permitted to be owned [6]. Therefore, families living in high-rise housing complexes don't have their own roof and so cannot own the PV panels.

However, the development of smart meter and smart grid technology may solve this problem in near future. In this case study, the remote ownership of PV panels is proposed. People living in high-rise housing complexes can set up PV panels on the roof of factories, sewage treatment plant, and schools.

2.3. *Exhaust heat from waste incineration plant*

Today, exhaust heat from waste incineration is used for power generation. As incinerated waste includes wet kitchen garbage, the energy loss for the latent heat is caused. It was proposed that wet kitchen garbage to be collected separately and sent to sludge treatment plant for the methane generation by mixed digestion with sewage sludge. Generated methane is supplied to waste incineration plant as input to the boiler. Although the waste incineration plant supplies only electricity in the present condition, it was considered to supply heat also in this case study. If wet kitchen garbage is not incinerated, by rough estimation, calorific value of wet kitchen garbage and the energy loss for the latent heat decrease. When the kitchen garbage is not incinerated with other garbage, the quantity of heat generated by the incineration will decrease by a calorie of kitchen garbage. When the kitchen garbage is also included, an additional quantity of heat is required to evaporate its moisture content. Hence, if the additional quantity of heat is avoided then there will be no change of heat in total. Ministry of Land, Infrastructure, and Transportation in Japan had examined to increase the speed and the quantity of methane generation by digestion of sewage sludge mixed with slurry of kitchen garbage. This project was named LOTUS project [7]. Result of this LOTUS project was that it was possible to digest the kitchen garbage slurry which was equivalent to 13% of the sewage sludge, in addition two times of methane was generated compared to the case without the kitchen garbage slurry. Methane gas generation potential was calculated in the condition that the amount of mixed digested kitchen garbage was set half of the amount of kitchen garbage incinerated in the current condition because the cost for collecting the kitchen garbage separately was very large. Cost for the collection of kitchen garbage separately, removal of impurities contained in the garbage, and making of the garbage slurry were calculated.

2.4. Cogeneration installation for business use

Three large business use buildings were installed with GE-CGS in this study. Those buildings were hotels, offices, and university campus. Campus of Yokohama City University has also hospital building, and 700kW of GE-CGS was installed as part of ESCO project in 2009. High-Tech Center has hotel, office, and research laboratory, and 360kWof GE-CGS was installed in this study. AOTS is training facility with lodging for foreigners, and 90kW GE-CGS was installed in this study. This GE-CGS's were operated from 8:00am to 9:00pm.
The initial cost of CGS was considered as 2,000 USD per kW, and the annual maintenance cost as 2.0 USD per 100 kWh.

2.5. Thermal transmission network

Heat supply transmission line was newly constructed in this district that connected sludge treatment plant, waste incineration plant, Namiki-collective housing complex area, and three larger business use buildings. Construction cost of the transmission line was considered, but the distribution pipes from the transmission line were not considered in the cost calculation.
This transmission line supply steam from waste incineration plant and sludge treatment plant as a heat load for Namiki- collective housing complex area, and three larger business use buildings. The quantity of heat that can be supplied from a garbage incineration plant and the amount of methane generated increased after the mixed digestion of sewage sludge and kitchen garbage were large enough. Therefore, it could provide all of the hot-water demand of the collective housing complexes, and the required heat demand of three business-use buildings.

3. The result of CO_2 Reduction effect

Table 2 shows calculated reduction potential of CO_2 emission by each countermeasure that had been considered in this case study. The amount of CO_2 emission reduction by implementation of the countermeasures in each building was divided proportionally from statistical approach, such as population of the region, based on "Local government environmental report 2007 [8]". CO_2 reduction potential through steam supply by transmission line was the largest of all measures. Of course, increment in the methane generation by the digestion of the mixture of raw sludge and kitchen garbage was also included in this measure.

Table2 CO_2 emission reduction potential

		Measures	CO_2 Emission Reduction Potential [t-CO2/year]			Measures	CO_2 Emission Reduction Potential [t-CO2/year]
①	[Residential]	Changes in Lifestyle	454	⑩	[Commercial]	Commercial Cogeneration	848
②	[Commercial]	Changes in Workstyle	131	⑪	[Commercial]	Introduce of BEMS	19,344
③	[Residential]	Lighting Efficiency Improvements, etc	565	⑫	[Joint Commercial and Residential]	Incineration Plant Waste Heat and Sludge Treatment Plant Digestion Gas	1,010
④	[Residential]	Heating and Cooling Efficiency Improvements	753	⑬	[Residential]	Household appliances efficiency improvements	2,447
⑤	[Commercial]	Lighting Efficiency Improvements, etc	311	⑭	[Commercial]	Photovoltaic power generation	105
⑥	[Commercial]	Air Conditioning Equipment Efficiency Improvement	233	⑮	[Residential]	Photovoltaic power generation	1,815
⑦	[Residential]	Introduce of HEMS	444	⑯	[Residential]	Higher insulation in newly constructed housing	412
⑧	[Commercial]	Power and Other Efficiency Improvements	109	⑰	[Residential]	Improved existing insulation	108
⑨	[Commercial]	Use of Solar Thermal Energy	870			Total	**29,959**

4. Cost-benefit Analysis

4.1. Additional cost curve for reduction of CO_2 emission

Based on the method of the marginal abatement cost (MAC) curve advocated by McKinsey [9], the amount of CO_2 discharge reduction in this area and the relation of that measure cost are analyzed. Subsequent analysis has adopted the analytical idea of MAC and the method in consideration of NEB which Kuzuki and others proposed [10].

4.1.1. Case of short pay-back time

Figure4 shows the case which calculated MAC based on short pay back year.
This short pay-back year refers to the value used by the Central Environment Council [11], the Ministry of Environment, in order to calculate the MAC of CO_2 emission reduction. It was about 3 to 5 years. In this case, as the initial cost including the MAC of photovoltaic, heat insulation repair of building and thermal transmission line was large enough; the MAC will also be higher. The average MAC of all measures was 237.11 [USD/t-CO_2] for a year, and installation is difficult as long as there is no financial support of the subsidy etc.

4.1.2. Case of long pay-back time

On the other hand, since a building and a thermal transmission line were used over a long period of time, it could be thought that 3-5 years of the pay-back year was too short.
Then, 70% of legal durable years were re-set as the pay back years of each measure. Pay back years become longer and were from 20 years to maximum of 31.5 years.

Figure5 shows the calculated MAC based on these long pay back years. In the case of these long pay back years, the MAC per year decreased sharply, and the average MAC of all measures was 124.57 [USD/t-CO_2] per year. Especially MAC of thermal transmission line reduced greatly to 104.40 [USD/t-CO_2] from 166.16 [USD/t-CO_2], because pay back years changed from 20 years to 31.5 years.

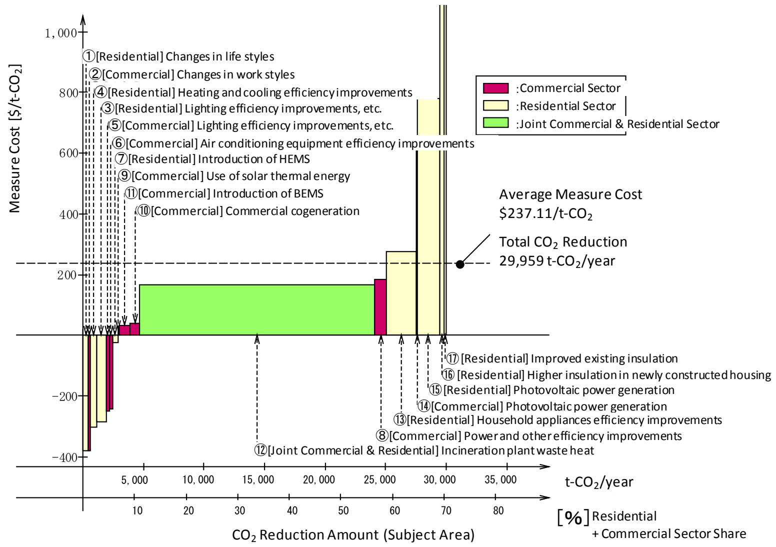

Figure4 Calculated MAC based on short disinvestment years

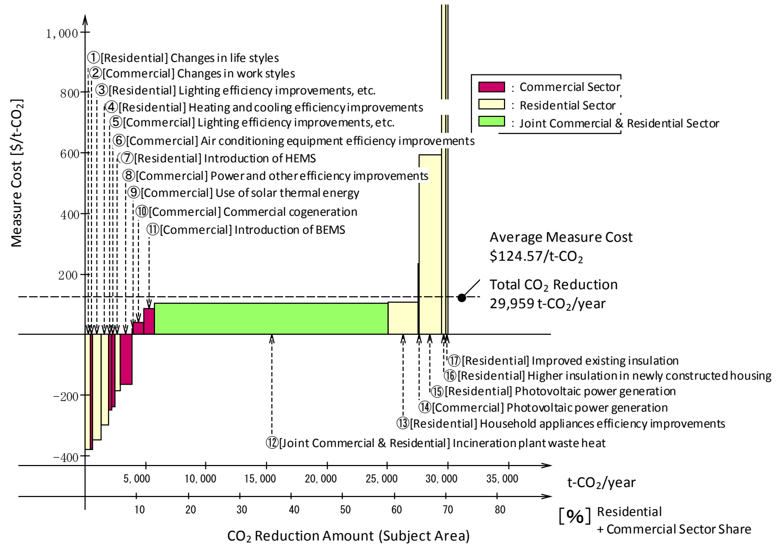

Figure5 Calculated MAC based on long disinvestment years

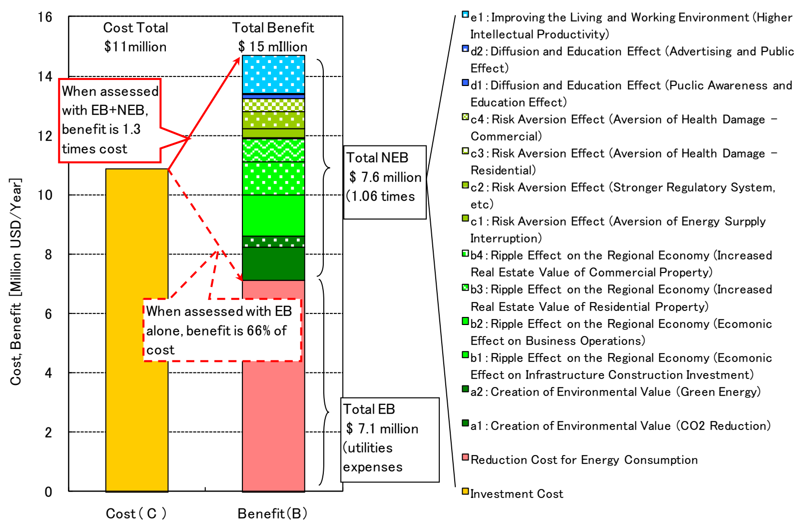

Figure6 B/C including NEB

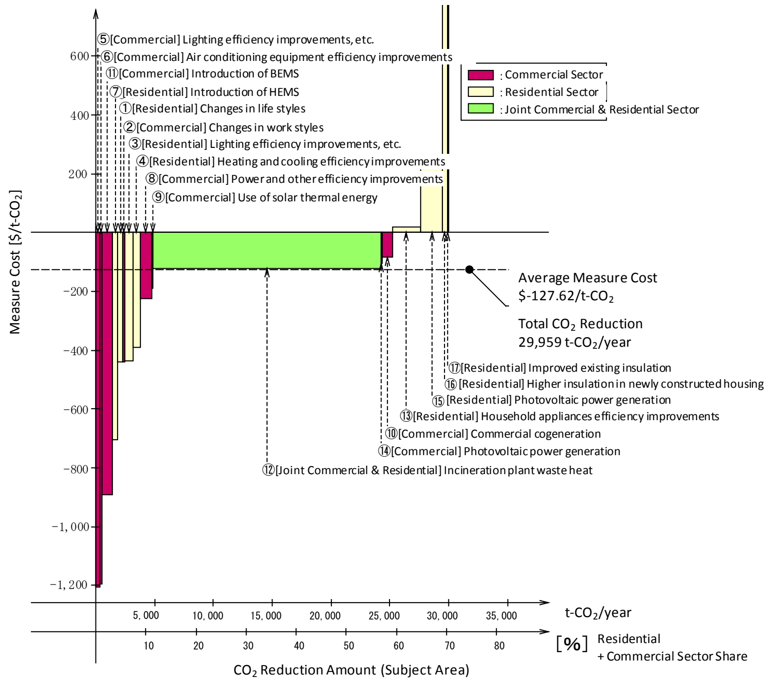

Figure7 Calculated MAC based on long disinvestment years in consideration of NEB

4.2. Non-Energy Benefits

These measures against CO_2 emission reduction resulted the benefits of not only the decrement in energy cost but also the job creation, the environmental improvement of this area, etc. Then, NEB (Non-Energy Benefit) by the implementation of CO_2 emission reduction measures in this area was computed based on the calculation method of the NEB which R. Kuzuki and others has advocated [4].

Figure6 shows the relation between annual cost and NEB. The B/C including only direct benefits such as cut in fuel, lighting, and water cost by a measure was 0.66. Then the B/C including indirect benefits such as for example job creation etc., increased to 1.35.
Moreover, the calculation result was divided proportionally for each measure, and the MAC curve was created.

Figure7 shows the MAC curve in consideration of NEB. As a result of dividing indirect benefits proportionally for each measure against low carbon and re-creating a marginal abatement cost curve, CO_2 reduction cost of each measure decreased greatly, and average measure cost reduced to -127.62 [USD/t-CO_2].

5. Conclusions

From the results of this case study it became clear that the measures against low carbon of the community according to the characteristic of areas raised CO_2 emission reduction potential. The effective countermeasures were thermal transmission line using methane gas produced by the digestion of mixture of sewer sludge and kitchen garbage sludge, and use surplus steam from waste incineration plant. It was also found that taking NEB into consideration improved B/C greatly and increased feasibility.

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Study on Low Carbon Energy Supply to the District Heating & Cooling Plants and Buildings with a Waste Heat Pipeline in Yokohama City

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Abstract: District heating and cooling (DHC) in Japan's major cities are required to further lower their carbon emission. This study proposes to supply zero-carbon steam from a nearby waste incineration plant to the DHCs in the center of Yokohama, Japan's second largest metropolis by constructing a pipeline between them. To maximize environmental effects of the project, efficient cogenerations will also be integrated extending low carbon heat supply to large buildings along the pipeline. Construction cost of five alternative pipeline routes, revenue from steam sales and the environmental value of reduced CO_2 emission were estimated. Then the loan repayment period was calculated to figure out how to finance and manage the project. Because statistical data are used to calculate heat load, actual primary energy consumption and reduction of CO_2 emission may differ. Also, without a detailed field survey, assumed construction cost may not correspond to the actual amount to be financed. From the study it became clear that steam pipeline with cogeneration will reduce 3.6 PJ of primary energy use and 300,000 tons of CO_2 emission annually. The project will become feasible with loan repayment period of 8 and 10 years with and without subsidy by minimizing the construction cost.

Keywords: *district heating and cooling, low carbon, waste heat, CO_2 emission, steam pipeline*

1. Introduction

District heating and cooling (DHC) has been introduced to Japan's major cities from 1970s achieving efficient and reliable supply of energy compared to the installation of small appliances to the individual building. However, additional effort is being required to further lower the carbon emission nowadays. This study proposes to supply zero-carbon steam from a nearby waste incineration plant to the center of Yokohama, Japan's second largest metropolis, by constructing a pipeline between them. Environmental and economic benefits of the project have been examined in order to evaluate its feasibility.

1.1 Site review

Yokohama city center is one of most densely built up metropolis in Japan with good access to public transportation. Because density of energy consumption in the area is high, a few district heating and cooling plants are already in operation and most of the blocks have been assigned for urban renewal promotion area. Therefore it is easy to recognize that the area has a good potential of providing necessary heat more efficiently by networking the supply pipeline. If these networks are connected to the untapped low carbon heat sources, the entire city can reduce its energy use and CO_2 emission dramatically. This is why the study proposes to transport zero-emission heat source from a nearby waste incineration plant to two DHC plants and buildings in Yokohama city center. Following are the outline of the DHC plants.

1.1.1 Yokohama West DHC

It Started operation in 1998 with 6.5 hector of supplying land area and 350,152m^2 total floor area. Customers include department stores, hotels and a train station. Chilled water and middle pressure steam (0.8 – 1.0 MPa) are supplied by absorption chillers, boilers and two 1MW gas turbine cogenerations.

1.1.2 Minato Mirai 21 DHC

It Started operation in 1989 with total supplying floor area of 2,311,000 m^2 as of 2008. Major customers include 23 office and commercial buildings, hotels, public facilities and 6 apartments. Chilled water and middle pressure steam are produced by steam and electric turbo chillers, absorption chillers as well as boilers and delivered through utility tunnels.

2. Steam network pipeline

Besides above DHCs, the network will be extended to the separate buildings by to the following stages.
Stage 0: Waste incineration plant and DHCs are connected by a steam pipeline
Stage 1: Buildings over 10,000m^2 of floor area are connected to the pipeline
Stage 2: Buildings over 5,000m^2 of floor area are connected to the pipeline
Extension of pipeline will be planned by the distribution of the buildings (Fig.1). Because DHCs and most of the buildings use middle pressure steam as major heat sources for space heating, hot water supply and air conditioning (cooling), the network will deliver steam (up to 2.0 MPa) to them.

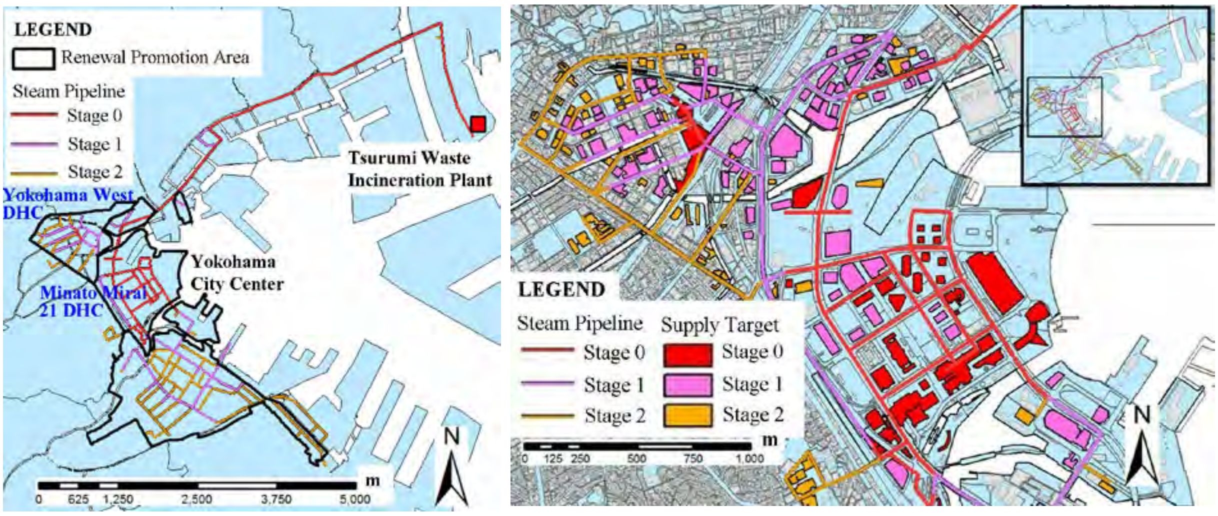

Fig. 1. Site map, steam pipeline and target buildings in Yokohama city center

2.1 Assumed heat supplying floor area by stage

Assumed floor area for supplying heat is 2,430,000m^2 at stage 0, 8,530,000m^2 at stage 1 and 10,620,000m^2 at stage 2. As for floor type shares, business, commercial and residential use rank top three with 36%, 33% and 19% of the total floor area respectively.

2.2 Assumed energy consumption

By multiplying assumed floor area and statistical unit energy consumption [1], energy consumption by purpose were calculated by hour, day, month and year. Because business and commercial floors with huge exhaust heat from appliances and human bodies prevail, annual cooling demand exceeds heating by about 50%.

3. Use of low carbon heat from waste incineration and cogeneration

3.1 Available heat from waste incineration

Three waste incineration plants are in operation in the vicinity of Yokohama city center. They are Kanazawa, Tsurumi and Asahi plants with 290, 270 and 120 thousand tons of annual handling amounts. These plants are equipped with total capacity of 66,000 kW of generators which produce 293GWh of electricity annually. These generators, however, have low efficiency ranging from 13 – 18% because of the temperature restriction to avoid corrosion of the equipment. Therefore the study proposes among other options to halt generation and to supply entire amount of available heat to the city center by steam pipeline. This alternative will enable the plants to send 5,243 TJ of heat to the city center. (Table 1)

Table 1. Garbage Incinaration Plants nearby Yokohama City center

Plant Name	Handling Amount (t/year)	Generation Capacity (kW)	Generation Efficiency (%)	Generated Electricity (MWh/year)	Garbage Calorific Value (kcal/kg)	Incinerated Heat Value (TJ/Year)	Available Steam (TJ/Year)
Kanazawa	289,187	35,000	18	144,660	2,468	2998	2098
Tsurumi	266,640	22,000	16	107,181	2,838	3178	2225
Asahi	125,631	9,000	13	41,199	2,492	1315	920

Considering heat demand gap among seasons and daily hours, it is necessary to set appropriate supply capacity according to the base demand in order to avoid excess heat supply. Therefore the study cases accept steam only from the Tsurumi incineration plant with shorter pipeline to be built than with other plants. Assumed amount of heat to be supplied from Tsurumi is 2,225TJ/year.

3.2 Covered rate and used steam rate

Efficiency of steam driven appliances such as absorption chillers are determined to calculate demand of steam to be supplied by the network. Then the ratio of network steam to the demand is defined as “covered rate”. Also, the ratio of the used steam to its supply is defined as “used steam rate”. Both rates are calculated annually and monthly (Tables 2 and 3).

Table 2. Covered rate and steam share (Annual)

	Heat Demand (TJ/year)	Available Steam (TJ/year)	Usable Steam (TJ/year)	Covered Rate (%)	Used Steam Rate (%)
Stage 0	1,702	2,225	1,690	99%	76%
Stage 1	5,872	2,225	2,225	38%	100%

Table 3. Covered rate and steam share (Monthly)

	April		August		January	
	Covered Rate (%)	Used Steam Rate (%)	Covered Rate (%)	Used Steam Rate (%)	Covered Rate (%)	Used Steam Rate (%)
Stage 0	100%	53%	94%	100%	100%	96%
Stage 1	60%	100%	26%	100%	31%	100%

Annual covered rate of Tsurumi plant is about 100% at stage 0, while it drops to 38% at stage 1. Looking by season, at stage 1, covered rate decreases to 26% in August while it increases to

60% in April, a off-peak month. With heat storage during night hours, used steam rates reach 100% at stage 1. Hourly heat demand and supply from three waste incineration plants are shown in Fig.2. During daytime hours network steam is not sufficient to meet the heat demand.

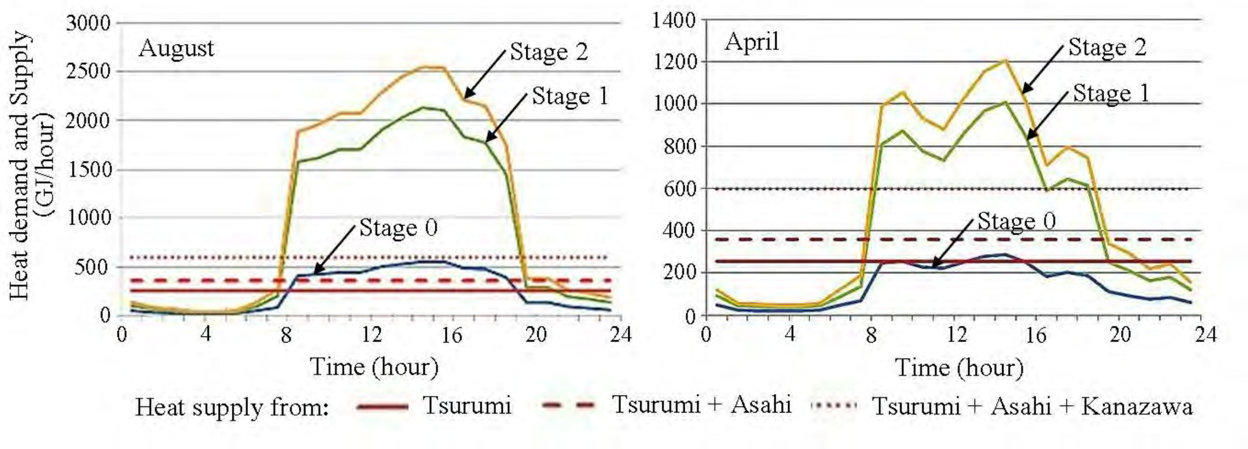

Fig. 2. Heat demand and supply from three waste incineration plants

3.3 Integrating cogeneration

Since daytime heat demand exceeds amount of steam supplied from Tsurumi throughout a year, it is appropriate to install and integrate cogenerations in the DHC plants and buildings along the network. To maximize the CO_2 reduction, gas engines with high generating efficiency and steam recovery capability from exhaust heat should be introduced instead of gas turbines. Capacities of gas engines were set so that they can meet most of the remaining steam demand at each stage. Covered rates will significantly increase by integrating cogeneration into the network.

4. Environmental effects expected by the network

Primary energy conservation and CO2 emission reduction by the network are calculated with following assumption.

4.1 Assumed condition for calculation

a) Priority of network steam use are: Cooling > Hot water supply > heating
b) Cogenerations operate to meet the electricity demand of the plants and buildings where they are installed. Priority of recovered steam use is same as a).
c) Chilled and hot water produced from excess steam during night hours are stored and used during daytime hours. Some steam accumulators, widely used in the factories, will be used too.
d) Marginal CO_2 emission factor is used for generated electricity by cogeneration. Flat emission factor is used for consumed electricity in the DHC plants and buildings as well as generated electricity at waste incineration plants.
e) Following alterative use of heat produced from waste incineration are compared
Case 0: discharged with no heat use
Case 1: exclusively used for electricity generation
Case 2: exclusively used for steam supply through network
Case 3: exclusively used for steam supply through network with cogeneration in buildings

4.2 Results

4.2.1 Energy conservation

At stage 0, primary energy conservation rate will be doubled from 18% to 35% by switching from electricity generation to steam supply. Also, if cogeneration is integrated in case 3, 3,616 TJ/year or 15% primary energy reduction will be attained at stage 2 compared to case 1 (Table 4).

4.2.2 Reduction in CO_2 emission

At stage 0, reduction in CO_2 emission will increase by 33% from 73,955 tons/year to 98,412 tons/year by switching from generation to network steam supply. By integrating cogeneration into the system, reduction will be increased by 36% or 252,595 tons/year at stage 1 and by 35% or 298,906 tons/year at stage 2 compared to case 1 (Table 4).

Table 4. Environmenal effects of the pipeline

		Stage 0				Stage 1				Stage 2			
		Case 0	Case 1	Case 2	Case 3	Case 0	Case 1	Case 2	Case 3	Case 0	Case 1	Case 2	Case 3
Primary Energy Consumption	(TJ/year)	5,776	4,723	3,765		20,869	19,815	18,630	16,621	25,144	24,091	22,927	20,474
Primary Energy Reduction	(TJ/year)		1,054	2,012			1,054	2,239	4,248		1,054	2,217	4,670
Primary Energy Reduction Rate	(%)		18	35			5	11	20		4	9	19
CO_2 Emission	($t\text{-}CO_2$/year)	216,340	142,385	118,197		776,137	702,182	672,991	449,587	937,389	863,434	835,597	564,528
CO_2 Emission Reduction	($t\text{-}CO_2$/year)		73,955	98,412			73,955	103,146	326,551		73,955	101,792	372,861
CO_2 Emission Reduction Rate	(%)		34	45			10	13	42		8	11	40

5. Business scheme and feasibility

5.1 Pipeline route alternative

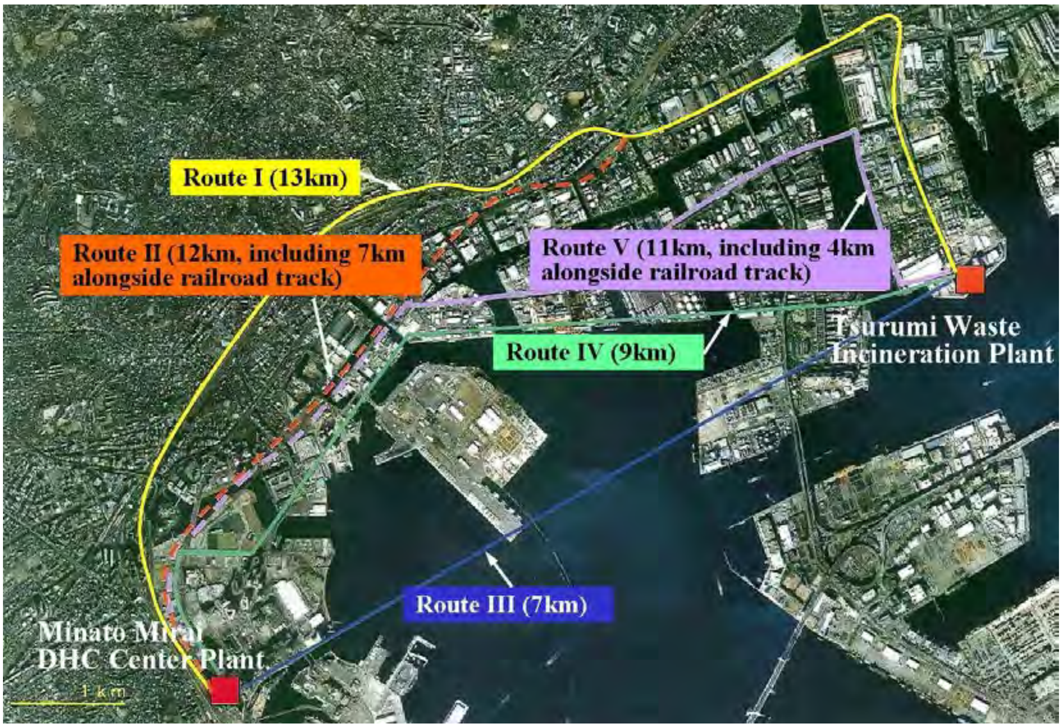

Fig. 3. Steam pipeline route study

Following alternative routes were proposed (Fig 3) and reviewed for case studies.
a) Route I: Laying pipes shallow underground along existing road (length: 13km)
b) Route II: Laying pipes shallow underground along existing road and railroad track (length: 12km)
c) Route III: Laying pipes deep undersea by excavating a tunnel (length 7km)
d) Route IV: Laying pipes under or over the private land on the waterfront (length 9km)
e) Route V: Laying pipes either under or over the green belt along the railroad track (length11km)

5.2 Assumptions for calculation

Costs and Prices in Japanese Yen are also converted to US dollars/cents using the rate of 1$US=82 yen as of February 4, 2011 and shown in parentheses.
a) Available amount of steam from Tsurumi Plant: 2,225 TJ/year
b) Acceptable amount of steam at DHCs and buildings: 1,690 TJ/year (Stage 0), 2,225 TJ/year (Stage 1)
c) Steam pricing: purchase price is set at 0.6 yen (0.73 cent) /MJ [2], 0.3 yen (0.37 cent)/MJ less than the base price assuming burning gas, wholesale price is set at 1.45 yen (1.77 cent)/MJ and 1.6 yen (1.95 cent)/MJ [3] assuming entire or a half of the surplus from the base price is to be refunded to the steam buyers respectively.
d) CO_2 emission reduction 24,188 tons/year for stage 0, and 252,595 tons/year for stage 1
e) Steam pipe size: 400 - 500mm in diameter for supply and 100- 150 mm for return
f) Construction cost [4]
Route I : 1,500,000 yen ($18,293)/m for underground shallow plumbing along conventional road
Route II : 800,000 yen ($9,756)/m for overground plumbing beside railroad track, 1,500,000 yen ($18,293)/m for u shallow underground plumbing along the conventional road
Route III: 2,000,000 yen ($24,390)/m for undersea shielded tunnel construction and plumbing
Route IV: 1,200,000 yen ($14,634)/m average for plumbing under and over the private land
Route V: 800,000 yen ($9,756)/m for plumbing under or over the green belt along the railroad track
g) Subsidy: none (Case A), 1/3 of construction cost (Case B) parallel to the ongoing subsidy by the Ministry of Land Transportation and Tourism
h) Carbon credit: 2000 yen ($24)/t-$CO_2$ or 3000 yen ($37)/t-$CO_2$ credit added to the revenue
i) Managing expenditure
- personnel cost: 6 million yen ($73,171)/year each for 4 operators, 8 million yen ($97,561) /year for a concu-
rrent manager
- road occupancy fee: 2,000 yen ($24)/m year
- pipeline management cost: 1% of the construction cost each year
- overhead expenses: 10% of personnel cost
- depreciation period: 30 years with remaining book value of 10%

5.3 Business scheme

Following alternative are assumed.
a) PFI (Private Finance Initiative): Yokohama municipal government sells steam to a PFI enterprise. It will construct the pipeline, transport and sell the steam to its customers.
b) Private enterprise: Private companies will construct the pipeline by an open bid. They will also buy steam from Yokohama municipal government and sell to its customers.

c) A joint venture company: Yokohama municipal government and private enterprises cooperate to establish a so-called "third-party company" to construct the pipeline and operate the business.

5.4 Specifications of the business

a) Construction cost:
Route I (shallow underground): 19,500 million yen ($238 million)
Route II (overground and shallow underground): 13,100 million yen ($160 million)
Route III (deep undersea): 14,000 million yen ($171 million)
Route IV (underground and overground) 10,800 million yen ($132 million)
Route V (shallow underground and overground) 8,800 million yen ($107 million)
b) Terms of construction: Three years for connecting Tsurumi plant and two DHCs after start of construction at stage 0, another 2 to 3 years for connecting to the buildings at stage 1
c) Funding: 70% of the loan to be raised by senior bonds with an interest rate of 3 or 4%, 30% by subordinated bonds with an interest rate of 5 or 6%.
d) Insurance premium: 0.25% of the construction cost to be budgeted
e) Property tax: 1.4% of the opening book value can be exempted for the BTO (Build-Transfer-Operate) case of the PFI scheme

5.5 Results

Based on the basic case with relatively strict conditions, business feasibility under various conditions are compared. Loan repayment period will be extended to 24 years from 17 years without subsidy suggesting its availability will give a significant impact to the feasibility of the project.

5.5.1 Basic and Alternative cases

a) Routes: Loan repayment period will significantly shorten with reduction in construction cost. 17 years for the basic case (Route I) will be shortened by half to 9 years for Route IV and 8 years for Route V.
b) Steam price: Loan repayment period will shorten by three years to 14 yeas if a half of 0.3 yen (0.37 cent)/MJ surplus obtained by the steam purchase from Tsurumi plant is reserved for the enterprise rather than giving all out to the end users
c) Carbon credit: Loan repayment period will shorten by one year if the carbon credit price will be increased from 2,000 yen ($24)/t-$CO_2$ to 3,000 yen ($37)/t-$CO_2$.
d) Subsidy: Loan repayment period will be extended to 24 years without subsidy. However, even in that case, retained earnings which is a sum of the profit after tax and depreciation will be kept in black suggesting it is possible to run the business if long-term loan can be raised at a low interest rate.
e) Property tax: BTO case of the PFI scheme, in which the pipeline and facilities will be transferred to the Yokohama municipal government after completion, property tax will be exempted shortening the loan repayment period by three years.
f) Interest rate: Loan repayment period will be extended by one year if the interest rate of both senior and subordinated bonds increase to 4 and 6%.
g) Schedule: Even if the start of operation for stage 1 is extended from 2 to 3 years after the completion of stage 0, loan repayment period will not change significantly.
h) Surplus: No significant effect will be expected by investing surplus with 3% annual gain.
All above alternative are listed in Table 5.

Table 5. Loan repayment period for basic and alternative cases

Condition Loan Payback Period	Deteriorating Cases	**Basic Case**	Improving Cases			
Route/Construction Cost (million Yen)		I/ 19,500 17years	II/ 13,100 11years	III/ 14,000 12years	IV/ 10,800 9years	V/ 8,800 8years
Steam sales price (Yen/MJ)		1.45 17years	1.6 14years			
Carbon credit (Yen/t-CO2)	None 19years	2,000 17years	3,000 16years			
Subsidy ratio to the construction cost	None 24years	1/3 17years				
Property tax on the opening book value		1.4% 17years	None 14years			
Interest rates of senior and subordinated bonds	4%,6% 18years	3%,5% 17years				
Stage 1 operation start (after stage 0 completion)	3years 17years	2years 17years				
Interest rate of surplus investment (%)		None 17years	3% 16years			

Currency rate: 1$US=82yen as of February 4, 2011

5.5.2 Combination of alternative cases

If most of the favorable alternative are applied together, loan repayment period will be shortened to 8 years. In that case, even without subsidy, the project will retain its profitability with loan payback period of 10 years.

6. Conclusions

A steam pipeline network is planned to transport zero-emission heat from Tsurumi waste incineration plant to the Yokohama city center. The study made it clear that by integrating cogeneration into the network, 3.6PJ or 15% of primary energy reduction as well as reduction of 300,000 tons of CO_2 emission will be achieved annually for the district heating plants and buildings over 5,000m^2 of floor area. The network will be able to provide inexpensive carbon-free heat with loan payback period of only 8 to 10 years by lowering the construction cost with an appropriate pipeline route selection. However, following limitations must be stated on the accuracy of above conclusions: (a) Because statistical data such as energy consumption by unit floor area are used instead of measured data to calculate heat load, actual primary energy reduction and reduction in CO_2 emission may decrease; (b) Without a field survey, assumed construction cost may not correspond to the actual amount to be financed, which may affect the feasibility of the project. These limitations should be cleared in a more detailed study to be followed.

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Study on the Non-Energy Benefit (NEB) of Area-Wide Energy Utilization and Evaluation of the Marginal Abatement Cost

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Abstract: To achieve the Kyoto Protocol target of carbon reduction in Japan, additional measures beyond individual building-scale are strongly required. Area-wide energy utilization is expected to play an important role, not only in improving energy efficiency, but also in enhancing utilization of renewable energy and unused thermal energy toward a low-carbon society. But so far there have been few initiatives that have been realized. One of the major hurdles is the lack of methods to convince stakeholders to collaborate towards implementation. This study focuses on non-energy benefits (NEBs), which are indirect benefits such as stimulating regional economies and environmental protection, as distinguished from the direct energy-benefit (EB) of utility costs reduction.

Through the development of methods to classify and quantify various NEBs and to assign monetary values in the marginal abatement cost (MAC), area-wide energy utilization has been deemed to be more competitive among various carbon reduction measures. Customized marginal abatement cost curve evaluation has proven effective for encouraging stakeholders to implement.

Keywords: *Area-wide energy utilization, Non-energy benefit, Marginal abatement cost, Cost benefit ratio, Payback time*

1. Introduction

1.1. Area-wide energy utilization of scale measures for carbon reduction

In the commercial and residential sectors, further reductions of carbon emissions are being sought toward the realization of a low-carbon society. To respond to this issue, area-wide carbon-emission reduction measures must be promoted for blocks of buildings, communities, districts and for cities, which go beyond individual buildings. The Kyoto Protocol Target Achievement Plan[1)] in Japan begins with area-wide energy utilization as its first measure, in terms of further energy saving beyond individual buildings and for promoting a large increase in the utilization of neighboring unused energy sources and renewable energy sources.

1.2. Necessity of evaluating measures from a middle-to-long-term perspective, considering local characteristics

In 2008, the Mid-term Targets Examination-Committee of the Cabinet Secretariat's Council on the Global Warming Issue (hereafter, the "Mid-term Targets Committee") discussed measures for the nation to reduce carbon emissions over the middle term through marginal abatement cost (MAC). [2)]
The image is shown in Fig.1.

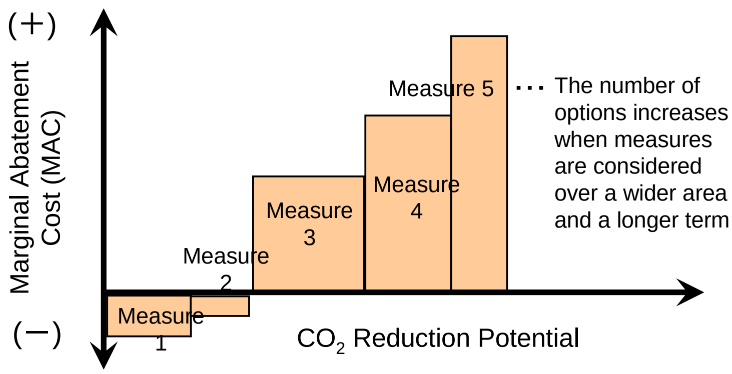


Figure 1 Marginal abatement cost curve (image)

MAC is defined as the cost required per additional unit reduction of CO_2 (e.g., per ton CO_2) from the present conditions, under a given area (e.g worldwide, nationwide, district-wide, etc.). McKinsey & Company[3)] and some other organizations have evaluated the MAC of a variety of carbon reduction measures and have published reports presenting MAC curves, which is a useful method to determine the selection of cost-effective measures. However, for discussions on area-wide energy utilization, the current evaluation method has some problems, as listed below;

1) Measures whose costs vary greatly due to distinct regional characteristics (such as differences in energy infrastructure and in access to locally generated, locally consumed energy) are too detailed to discuss on a nationwide scale.
2) Measures which require large initial investments, but which are effective for a long time (such as insulation of buildings and infrastructure development) are evaluated as comparatively expensive options if the payback time is set at a relatively short uniform period.
3) MAC has been defined as the net cost of measures, deducting direct energy benefits (EB) of energy-utilities cost reduction from the total costs. However, even if there are also diverse indirect benefits, such as stimulation of regional economies and environmental protection resulting from the measures, which some researches collectively refer to as "non-energy benefits" (NEBs)[4),5)], they have not been considered in the MAC evaluation.

1.3. Research objectives

The objective of this research is to establish methods of accurately determining area-wide energy utilization in comparison with other carbon reduction measures, and methods of evaluating cost-benefit ratios (B/C) and MAC, focusing on non-energy benefits (NEBs) in order to encourage stakeholders to implement.

2. Methodology

2.1. Estimation of CO_2 reduction potential considering the regional characteristics

Specifying the particular region where the measures for a low-carbon society will be advanced clarifies the specific figures concerning any unused energy sources (incineration-plant waste heat, etc.) that can be accessed in the concerned district, such as solar heat collectors and photovoltaic power generation equipment in accordance with heat and electricity-demand density and patterns according to time band, and on-site cogeneration. Those figures are then used to calculate the CO_2 reduction potential of the concerned district.
The initial and running costs of each measure are set referring to prior knowledge[2),6)] published by the Japanese government. The values for measures with different costs by region, by necessity, are set on a case-by-case basis. Subsidies and other grants are not included.

2.2. Setting the payback time considering the duration of the measure's effects

The MAC of each measure is calculated as the annual cost ([yen/year] / [t-CO_2/year]) under the following procedure; considering the initial costs (including renewal costs) for implementing each carbon-emission reduction measure, the running costs, and the reduction in utilities expenses gained from energy conservation. The expressions of the procedure are as follows, and Fig.2 presents an image of the MAC structure.

The payback time should be set appropriately for each measure from the viewpoint of the middle-term and long-term improvement of social capital and with consideration for the technology use conditions. Referring to the option that the National Institute for Environmental Studies proposed to the Mid-term Targets Committee (a setting of 50-70% of the functional lifetime of each measure)[2), McKinsey & Company report[3), in this study the payback time is set at a number of years equivalent to 70% of the lifetime of each measure.

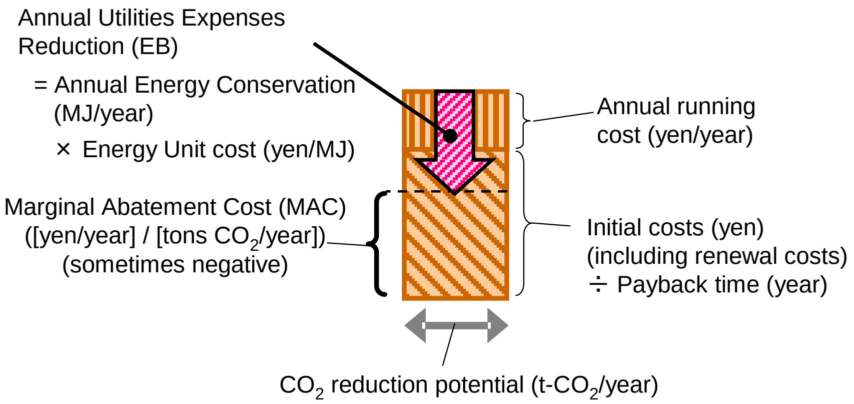


Fig. 2. Structure of marginal abatement cost (MAC) of a carbon reduction measure

Table 1 presents a summary of the classification of CO_2 reduction measures and their MAC.

Table 1. Carbon reduction measures and MAC setting by measures

Carbon reduction measures in this study (Set based on the 2008 Local Government White Paper (Japan) on the Environment)		MAC and payback time under prior Knowledge [2),6)]		Proposed MAC with payback time set at 70% of functional lifetime of each measure			
		MAC (yen / t-CO_2)	Payback time (years)	MAC (yen / t-CO_2)	Payback time (years)	References of lifetime	
Commercial Sector							
(1)	Air conditioning equipment efficiency improvements	- 24,000	3	- 24,000	10.5	15	*
(2)	Lighting efficiency improvements, etc.	- 25,000	3	- 25,000	14.0	20	*
(3)	Power and other efficiency improvements	19,000	3	- 16,491	17.5	25	*
(4)	High-efficiency water heaters	32,000	3	0	10.5	15	*
(5)	Improved insulation in newly constructed buildings	69,000	9	16,143	21.0	30	***
(6)	Improved insulation in existing buildings	69,000	9	35,964	14.0	20	***
(7)	Building and energy management systems (BEMS)	3,000	8	8,714	7.0	10	*
(8)	Use of solar thermal energy	2,000	10	2,000	11.9	17	***
(9)	Photovoltaic power generation	62,000	9	23,378	11.9	17	**
(10)	Changes in work styles	- 38,000	-	- 38,182	-	-	****
(11)	Commercial cogeneration	- 8,500	10	- 8,500	10.5	15	****
Residential Sector							
(12)	Heating-and-cooling efficiency improvements	- 30,000	3	- 30,000	4.2	6	**
(13)	Lighting efficiency improvements, etc.	- 28,000	3	- 34,789	14.0	20	*
(14)	Household appliances' efficiency improvements	28,000	3	10,629	4.2	6	**
(15)	High-efficiency water heaters	143,000	3	11,343	7.0	10	*
(16)	Improved insulation in newly constructed housing	430,000	9	239,870	15.4	22	**
(17)	Improve existing insulation	430,000	9	266,607	14.0	20	***
(18)	Home energy management systems (HEMS)	- 2,000	3	- 18,457	7.0	10	*
(19)	Solar water heaters	17,000	8	- 22,328	11.9	17	**
(20)	Photovoltaic power generation	78,000	10	59,319	11.9	17	**
(21)	Changes in life styles	- 38,000	-	- 38,000	-	-	****
(22)	Residential cogeneration	30,000	10	30,000	7.0	10	*
Community-Wide Energy Utilization							
(23)	Wind power generation	12,000	-	12,000	11.9	17	**
(24)	Woody biomass	4,000	20	4,000	14.0	20	****
(25)	Waste products power generation	2,000	-	2,000	14.0	20	****
(26)	Heat-and-electric power exchange among buildings*****	-	-	17,488	14.0	20	****
(27)	Incineration plant waste heat*****	16,616-28,329	20	9,890 - 14,925	31.5	45	****
(28)	Regional cogeneration*****	2,586	15	- 2,082	21.0	30	****

2.3. Definition and Monetizing NEBs

As described above, there are various NEBs among the carbon reduction measures received by the stakeholders. In terms of the way of estimating monetary value, the classification and quantification of the NEBs are proposed. Five major categories are defined (a - e), and they are additionally classified into fourteen categories. Table 2 shows the details.

Table 2. Monetization of EB and NEBs by category

Benefit	Monetization Outline	Referenceis
＜Energy Benefit (EB)＞		
Reduction in utilities expenses	Reduction in utilities expenses (yen/year) = energy reduction volume (yen/year) X energy unit cost (yen/MJ)	**Energy unit cost** set based on supply agreements and supplementary supply agreements from city gas and electric power utilities
＜Non-Energy Benefit (NEB)＞		
a. Benefit from creation of environmental value		
a1. CO2 reduction value	CO_2 reduction value (yen/year) = CO_2 reduction amount (t-CO_2/year) X CO_2 price (yen/ t-CO_2)	**CO_2 price** set (e.g., 4,000yen/t-CO2) "Point Carbon "Carbon 2009" (March 2009)"
a2. Green energy creation value	Green energy creation value (yen/year) = green energy use volume (MJ/year) X green energy unit price (yen/MJ)	**Green energy unit price** set (e.g., 15yen/kWh) "Examination Committee on VER Japanese Certification Standards Used in Carbon Offsets" (for photovoltaic power generation)
b. Benefit from the ripple effect on the regional economy		
b1. Economic ripple effect from infrastructure construction investment	Economic ripple effect from infrastructure construction investment (yen/year) = initial infrastructure construction investment (yen) X gross value added ratio ÷ ripple effect period (years)	**Gross value added ratio** set (e.g., 0.5) with reference to public investment gross value added estimates from various industry-related analyses by local governments **Ripple effect period** set at 70% of the lifetime of business facilities lifetime (e.g., 10.5 years ~ 31.5 years)
b2. Economic ripple effect on business operations	Economic ripple effect on business operations (yen/year) = business operating expenses (yen/year) X (ripple effect multiplier – 1)	**Ripple effect multiplier** set (e.g. 1.3) with reference to public works ripple effect multiplier, estimates from various industry-related analyses by local governments
b3. Increased real estate value effect (residential property)	Area real estate value increase effect (¥/year) = standard land price (yen/m^2) X subject land area (m^2) X (real-estate-value increase rate (%)/100) ÷ increase effect period (years)	**Standard land price** uses the figures from Ministry of Internal Affairs and Communications, Statistics Bureau, "2009 Statistics on Cities, Wards, Towns and Villages" **Real estate value increase rate** set (e.g., 0.5%) with reference to the rent increase rate (0-5% for model case rent) in the "CASBEE Real Estate Use Manual (provisional version) (July 2009)" **Increase effect period** set at 70% of the lifetime of business facilities lifetime (e.g., 10.5 years ~ 31.5 years)
b4. Increased real estate value effect (commercial property)		
c. Benefit from risk aversion		
c1. Contribution to the business and living continuity plan (BLCP); energy supply interruption aversion effect	Energy supply interruption aversion effect (yen/year) = energy supply interruption unit damage (yen/kW-hour) X decentralized power source capacity (kW) X supply interruption period (hours/interruption) X damage occurrence probability (times/year)	**Supply interruption damage** (yen/kW-hour), **Supply interruption period** (hours/interruption) **Damage occurrence probability** (times/year) set considering prior research[5]
c2. Risk aversion effect from stronger regulatory system, higher standards, etc.	Risk aversion effect from stronger regulatory system (yen/year) = utilities expenses (yen/year) X risk aversion expense ratio ÷ 100	**Risk aversion expense ratio** set with reference to "Sumitomo Trust & Banking Co. Ltd. "Outline of Business Awareness Survey Regarding Environmental Buildings" (July 2009)
c3. Health damage risk aversion effect (residential sector)	Health damage risk aversion effect (yen/year) = insurance benefits (yen/person) X subject population (persons) X occurrence ratio	**Insurance benefits** set using the figures from Japan Institute of Life Insurance "Nationwide Life Insurance Fact Survey" (e.g., 20.33 million yen/person for death benefits) **Occurrence ratio** set (e.g., 0.01%) Tokyo Medical Examiner's Office)
c4. Health damage risk aversion effect (commercial sector)	Health damage risk aversion effect (yen/year) = work absence ratio (days/person-year) X salary income (yen/year-person) ÷ work days (days/year) X affected persons (persons) X occurrence probability	**Salary income** uses figures from National Tax Agency "Fiscal 2005 Salary Income Survey" (e.g., nationwide average of ¥4.37 million/person [including bonuses, etc.])
d. Benefit from the diffusion and education effect		
d1. Leading model project public awareness and education effect	Public awareness and education effect (yen/year) = subject population (persons) X cost required for public awareness and education (¥/person-year) X effective period coefficient	**Subject population** is the population residing in the subject district **Cost required for public awareness and education** set (e.g. 3,000yen/person) referring to the costs for attending seminars implemented by non-profit organizations **Effective period coefficient** set (e.g., 3 years, 10 years) as the ratio of the periods in which projects are still leading projects
d2. Leading model project advertising and publicity effect	Advertising and publicity effect (yen/year) = costs required for the measure (yen/year) X advertising and publicity effect coefficient X effective period coefficient	**Advertising and publicity effect coefficient** set (e.g., 2%) referring to the cases (e.g., an effect equivalent to 2% of total environment-related costs) for company case studies "FY2005 Environmental Accounting Guidelines Reference Materials" **Effective Period Coefficient** set the same as in d1
e. Benefit from improving the living and working environment		
e1. Higher worker intellectual productivity effect	Higher worker intellectual productivity effect (yen/year) = affected persons (persons) X personnel expenses (yen/person-year) X productivity improvement coefficient X effective period coefficient	Productivity Improvement Coefficient set (e.g., average of 0.5%) referring to the case study analysis (16 environmental buildings in the U.K. with an intellectual productivity change ranging from -10% to +11%) in Diana Urge-Vorsatz, et al., "Mitigating CO_2 Emissions from Energy Use in the World's Buildings," Building Research & Information (2007) 35(4), pp. 379-398
e2. Resident health promotion effect	Residents' health promotion effect (yen/year) = subject persons (persons) X amount intended to spend (yen/person-year) X effective period coefficient	**Subject persons** are the number of residents in the subject district **Amount intended to spend** is set based on a questionnaire survey of the residents

3. Case study

A case study of implementation on a specific district was conducted using the evaluation policy presented above.

3.1 Overview of the case-study district

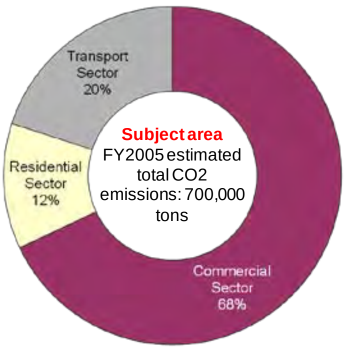
Fig.3 presents an outline of the case-study-subject district. The district (hereafter, "District A") is an existing mixed-use urban area centered around a large train station and offices, stores, housing, hotels, universities and other facilities, and an incineration plant located nearby. The case study assumes the following infrastructure arrangement of the District A energy system, as district-scale measures, together with other carbon reduction measures at the individual building level, considering the presence of the incineration plant, which is an unused energy source nearby, as well as area-wide energy utilization that is already being implemented in part of the District.

1) Area-wide utilization of unused high-temperature energy sources (incineration plant heat)
2) Development of area cogeneration as a foundation of an area-wide energy system, together with area-wide development within the district
3) Formation of a smart energy network for the effective use of heat and electricity in response to demand fluctuations, with linkage to the existing district heating and cooling infrastructure

District A Overview

District with a high concentration of large-capacity, primarily commercial buildings

- District area: 398ha
- Building floor space: 8.8 million m^2
- Population: 40,700 persons
- Households: 22,000



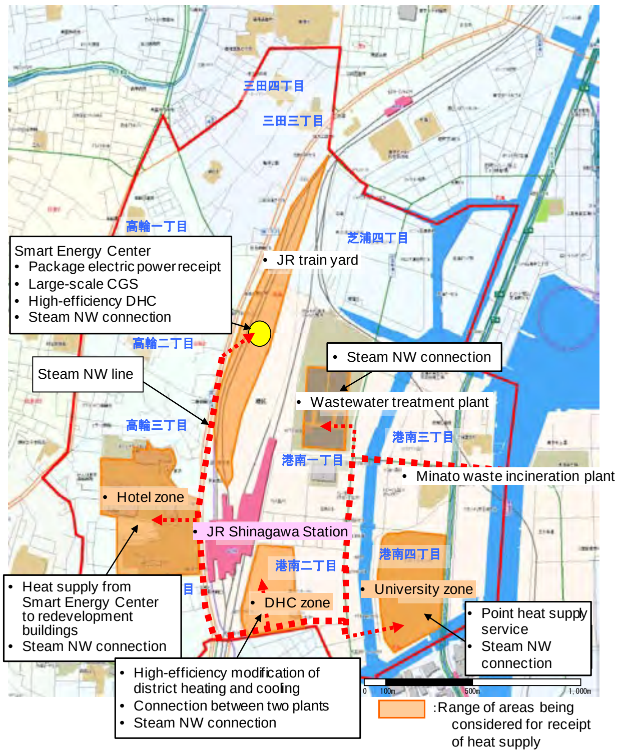


Fig.3. Case study district characteristics and annual CO_2 emissions breakdown

3.2 Carbon reduction measures and CO_2 reduction potential

Carbon reduction measures and the CO_2 reduction potential considering that the characteristics of District A are estimated based referring the 2008 (Japanese) Local Government White Paper on the Environment[7]. The total CO_2 reduction potential of all the assumed carbon reduction measures is approximately 160,000 t-CO_2/year.

3.3 Results - Cost-benefit ratio (B/C) considering NEBs

Fig.4 presents the cost-benefit ratio (B/C) trial calculation results for District A, considering NEBs. The total cost when all the measures are implemented is about 4.8 billion yen/y, the EB is approximately 3.7 billion yen/y, and the total monetized NEB is about 4.3 billion yen/y. The B/C is just 0.77 when only the EB is included, but rises to 1.7 when the NEBs are also considered.

3.4 Results – Marginal abatement cost curve considering NEBs

Fig.5, Fig.6 and Fig.7 present the results of estimated MAC curves. Fig.5 shows the MAC calculated with uniform payback time of 3 years, or of about 10 years. Fig.6 shows the results calculated by use of payback time set at 70% of the functional lifetime of the measures. Fig.7 is the result by considering the NEBs allocated to MAC of each measure in addition to Fig. 6.

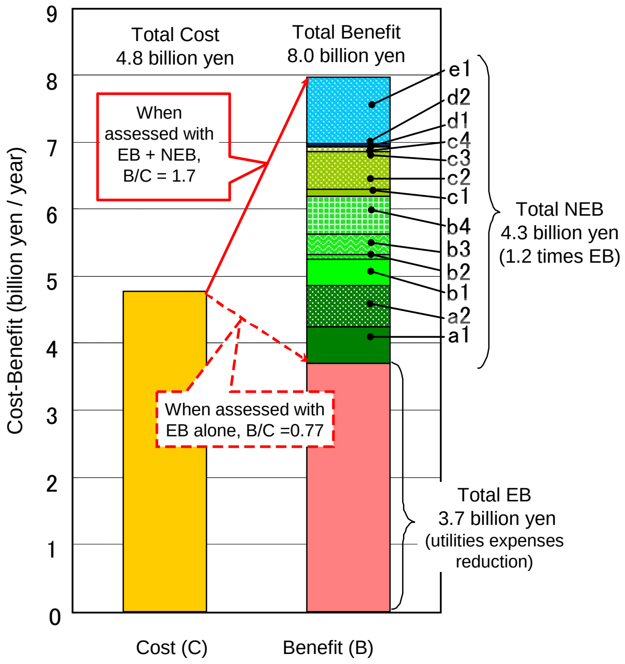


Fig.4. Total cost-benefit ratio (B/C)

As shown by the cross-hatched sections of each figure, in District A, arranging community-wide energy utilization by making use of the regional characteristics (including the effective use of incineration plant waste heat and the existing district heating and cooling network) has a high economic priority.

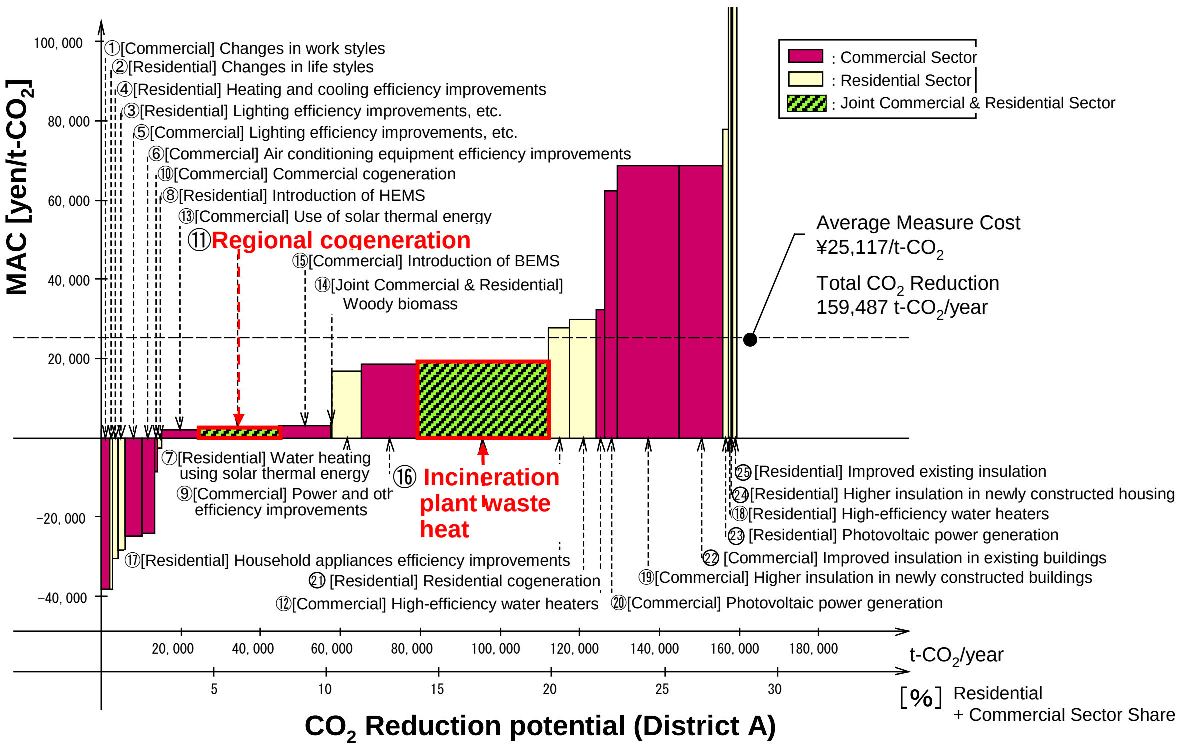


Fig.5. District A's marginal abatement cost curve
(Uniform payback time of 3 years, or of about 10 years)

Comparison between Fig 5 and Fig6, it is clearly shown how setting the payback time appropriately for each measure greatly decreases the average cost of the measures (25,117 -> 6,739yen/t-CO_2).

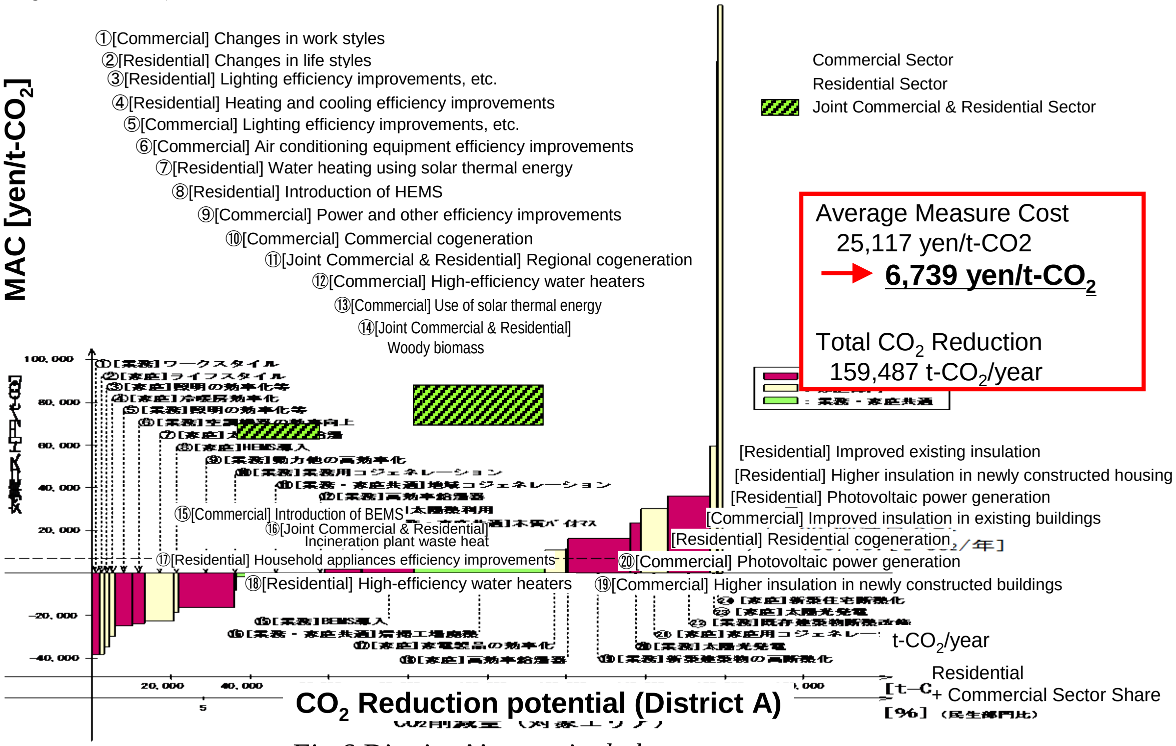


Fig.6 District A's marginal abatement cost curve
(payback time set at 70% of the measure lifetime)

In addition, by reflecting the NEB to Fig.6, as Fig.7 shows, the MAC becomes negative for most measures (i.e., the benefits exceed the expenses over the payback time), and the average measure cost is estimated at around (+6,739 -> -20,006 yen/t-CO_2).

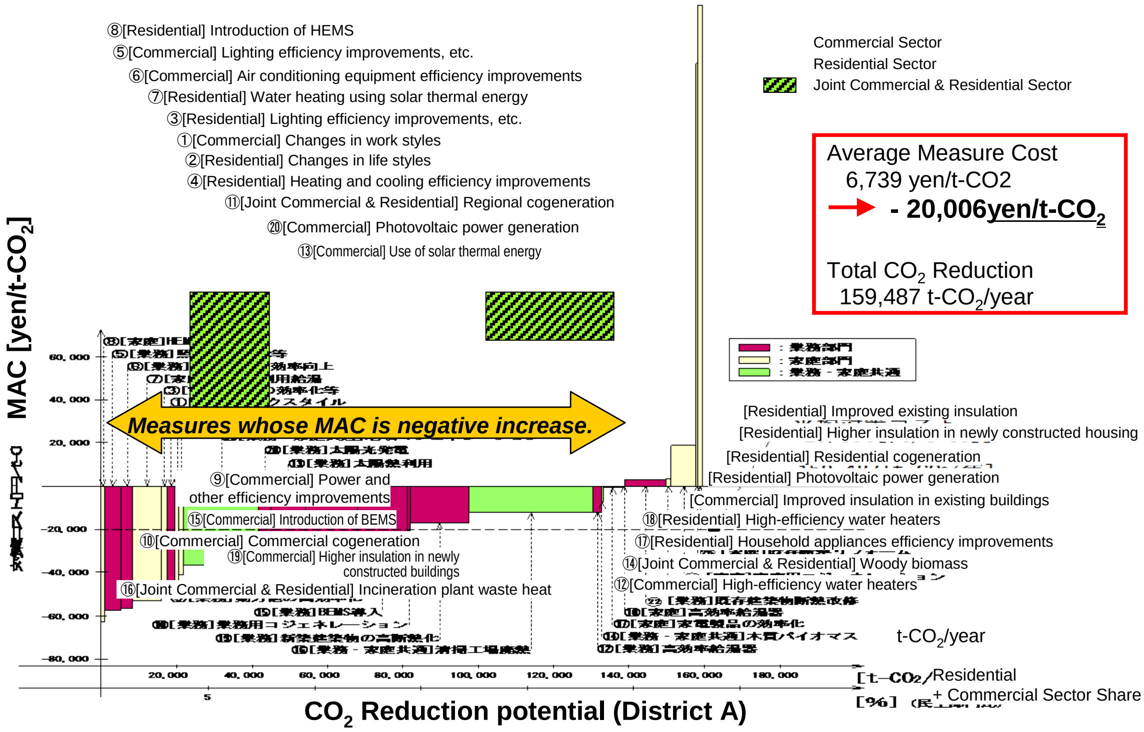


Fig.7 District A's marginal abatement cost curve
(reflecting payback time set at 70% of the functional lifetime and NEB of each measure)

4. Conclusion

To promote area-wide energy management, this study proposes the approach of using a marginal abatement cost (MAC) from a middle-term and long-term perspective and conducting cost-benefit ratio (B/C) calculations considering the non-energy benefits (NEBs) generated from various carbon reduction measures. The findings are as below:

1) It was clarified that the CO_2 reduction potential of area-wide energy utilization and the utilization of unused energy sources are much competitive measures in the marginal abatement cost curve for a specific district. This was verified through a case study on utilization of incineration-plant waste heat.
2) It is proposed that evaluation of the MAC for each measure should should be used to set the payback time appropriately from the viewpoint of the middle-term and long-term improvement of social capital, with consideration for the conditions under which the technology is used. 70% of the functional lifetime of the measures is proposed as the payback time. Through a case study, it was clarified that this improves the MAC assessment for measures with high initial investments, such as improving building insulation and area-wide utilization.
3) This study presents an approach to monetizing the non-energy benefits (NEBs) that result from area-wide energy utilization, which can explain a higher B/C. This study also proposes an approach to revising MAC through allocation of the NEBs to each measure, and demonstrates through a case study how this results in the assessment of more of the measures within the subject areas as economically promising.

Acknowledgements

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Regional climate and energy strategies: actors, responsibilities, and roles

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Abstract: Since 2008, the Swedish regional authorities, i.e., the County Administrative Boards (CABs), have been exhorted to produce regional climate and energy strategies indicating how sustainable energy systems might develop in the future. I analyze the CAB role and mandate to coordinate and promote the development of regional climate and energy strategies. How do other regional and local actors perceive the CAB role, mandate, and legitimacy in relation to work on regional climate and energy strategies? Case studies were conducted in two counties where CAB representatives, municipal politicians, municipal climate and energy consultants, and Regional Energy Agency and Regional Cooperation Council representatives were interviewed in-depth.

The results of the interviews indicate that it was difficult for interviewed actors to explain how the tasks and responsibilities differed between the CAB, Regional Energy Agency, and Regional Cooperation Council; the representatives of these three bodies also experienced this difficulty. The CAB's leading role in the energy strategy work was accepted by the other stakeholders, but only because the other regional actors currently lacked the resources to take on such work. In the future, the Regional Cooperation Councils will be the main legitimate CAB competitors, willing to take over the strategic energy work.

Keywords: *regional planning; strategy; accountability; legitimacy, network; planning theory, governance*

1. Introduction

In Sweden, the regional administrative level has generally been weak while the municipalities have been in a strong position. However, since 2008 the Swedish regional authorities, i.e., the County Administrative Boards (CAB), have been exhorted to produce regional climate and energy strategies indicating how sustainable energy systems might develop in the future. In this paper, I will discuss these strategic plans in relation to questions concerning their legitimacy and accountability.

The central government wants to strengthen the role of CABs in developing sustainable energy systems, and accordingly chose to assign them coordination responsibility [1]. The CAB role and tasks were debated by the Committee on Public Sector Responsibilities (Ansvarskommittén). From 2003 to 2008, this Committee was commissioned to analyze the current system of public administration and to determine whether changes were required in the division of responsibilities and in structural arrangements in order to meet the challenges public sector services will face in the future [2]. To remedy these structural deficiencies, the Committee proposed a new regional system of public administration with clearer roles and a clearer division of responsibilities, and regionalization that is the same for the state and the local government sector. As regards regional development, development tasks characterized by self-governance were distinguished from tasks that were more purely a matter of carrying out government agency mandates. Consequently, it was proposed that County Councils be replaced by directly elected regional authorities with overall responsibility for regional development and health and medical care.

The Committee on Public Sector Responsibilities wanted this regional development mandate to be assigned to the newly established regional authorities. At the same time, the CAB tasks and mandate would be concentrated, focusing on central government coordination, supervision, permits and other legal applications, follow-up, evaluation, and cross-sectoral knowledge creation. The Committee’s proposals were, however, not realized. As we will see, their investigation has had consequences for how local and regional actors reason about their responsibility and legitimacy in relation to developing regional energy and climate strategies.

In this context, I will analyze the CAB role and mandate to coordinate and promote the development of regional climate and energy strategies. How do other regional and local actors perceive the CAB role, mandate, and legitimacy in relation to work on regional climate and energy strategies? Over the past decade, several public actors in the regional arena have wanted to take responsibility for regional energy issues. These include the Regional Cooperation Council, organized by the municipalities in a county, which wants to assume overall responsibility for regional development. In addition, more regions have acquired a Regional Energy Agency with a regional focus on energy issues. Then we have local officials and politicians who want to keep their power of self-government on these issues. This paper will examine four actors: municipal politicians, municipal climate and energy consultants, Regional Energy Agencies, and Regional Cooperation Councils. I am interested in how these actors perceive the division of issues and responsibilities between actors at the regional administrative level in the energy system.

1.1. Methodology and material

Two case studies were conducted in two counties, Dalarna and Östergötland, where I interviewed regional and local actors concerned with the CABs’ ongoing work on regional climate and energy strategy.

I interviewed one CAB representative in Östergötland and two in Dalarna. The CABs are state-controlled regional authorities that, among other tasks, are commissioned by the central government to develop regional climate and energy strategies.

In Dalarna, I also interviewed one representative of the Regional Energy Agency (REA). REAs are financed by the Swedish Energy Agency, EU, CABs, and Regional Cooperation Councils. They are commissioned to promote energy efficiency and the use of renewable energy sources.

The Regional Cooperation Councils (RCCs), mentioned above, handle regional cooperation between the municipalities in a county and the County Council (landstinget). RCCs are a politically controlled municipal interest organization commissioned to support the municipalities and facilitate cooperation and coordination between them. I interviewed one RCC representative from Östergötland and one from Dalarna.

I also interviewed nine municipal climate and energy consultants from Östergötland and five from Dalarna. They provide municipal energy guidance, disseminating objective knowledge of environmentally friendly energy sources, energy distribution, and energy use. We also interviewed six municipal politicians from Östergötland and five from Dalarna. Altogether, 31 interviews were conducted.

Interviews were used to gain an understanding of actor perceptions of the process and outcomes of developing regional energy strategies. I am interested in the background stories of and in-depth information on participants’ experiences of this process. In the analysis, I compare the actors’ descriptions of the process and search for patterns. While quantitative data concern differences in degree of aspects of a studied entity, qualitative data concern similarities or dissimilarities between studied entities. Interview analysis is descriptive, and aims to go beyond merely describing the responses to the interview questions. The analysis entails the researcher, through reflection, abstracting from the descriptions and seeking patterns and dysfunctions in light of earlier studies or theories [3]. Taking the particular conclusions relating to Östergötland and Dalarna and generalizing them to other regions is not of interest; what is of general interest is analysing the actors' roles, responsibilities, legitimacy, and inclusion in and exclusion from the process. In other words, analytical generalization is of interest here, not statistical generalization [3].

2. Regional strategic planning: legitimacy and responsibility

Swedish CABs have been commissioned to develop regional climate and energy *strategies*. The meaning of *strategic planning* is an empirical question, and depends on what efforts particular actors put into it. Healey [4] emphasizes that strategic work aims to change the direction of an activity (in this case, a technical system), open up new possibilities and potentials, and move away from previous positions. These strategies are social products embedded in the governance cultures of particular regions [4,5]. A regional strategy functions by articulating an orientation shared by many stakeholders in a regional development process. Because strategies are social products formed in networks within governance structures, questions concerning legitimacy and accountability are vital for working strategies that influence the direction of regional energy systems.

According to CAB budget documents, regional sustainable energy systems are to be developed by creating arenas and processes where regional actors can meet and develop common strategies and goals. Such processes are often collectively labelled governance. Theories of governance often draw attention to how and why actors that are not part of the political sphere participate in forming politics in the broad sense, and to how new arenas and coordination forms are created and used [6,7].

Democratic legitimacy concerns how the governed are interested in and understand political legitimacy. A policy is seen as legitimate by concerned actors if there is principal consent, i.e., if concerned parties think the policy is legitimate and if they agree on norms and values. Legitimacy can also be conferred by active consent, referring to acts indicating approval, such as actor participation in projects, reference groups, etc., initiated by the actors seeking legitimacy [8].

In a government context, accountability is generally regarded as a chain extending from the electorate to the elected politicians and from the politicians to the public administration. The new localism and complexity of governance structures make accountability intertwined and multiple [9], imbuing it with new meanings. The role of government then changes: it becomes just one player among many [10]. Governance structures have developed in response to the state's increased need to mobilize actors, and their resources, outside their formal contexts to formulate and implement public policy [11].

Mitchell and Shortell [12] argue that accountability is "defined as a process by which a party justifies its actions and policies and is a key aspect of governance". The increasing complexity of governance through partnership permits a broader understanding of accountability, including bureaucratic/hierarchical, legal, professional, political, and moral/ethical dimensions [13].

In developing sustainable energy systems, CABs have been commissioned to establish strategic planning initiatives at the regional level. In practice, this means that they are responsible for promoting the issue; they should not do everything on their own, but work in cooperation with other actors. I will next discuss how this is done in practice.

3. Dalarna and Östergötland counties work on regional climate and energy strategies

Dalarna is often portrayed as a pioneer in regional energy work. Even before the government's 2008 budget document, it had worked to coordinate regional actors to deal with various energy issues. A regional energy programme had been developed from 2004 to 2005, "Energy Intelligent Dalarna – programme for regional energy coordination",[1] in which representatives of municipalities, industries, and organizations in the region participated. Dalarna's first climate and energy strategy was completed in October 2008. The strategy is supposed to integrate visions and goals from Energy Intelligent Dalarna and provide a common overview of the entire region [14].

Östergötland's climate and energy strategy was developed in 2008, also in consultation with external stakeholders. In Östergötland, a special advisory group was formed, including the CAB, RCC, and the County Council, which met several times [15].

3.1. Actor perceptions of roles, tasks, and responsibilities

The representatives of the CABs of both Östergötland and Dalarna said that they were happy that the CABs had been responsible for working on the climate and energy strategies, saying that the work was in line with the CABs' long-standing commitment to environmental issues. The Östergötland representative offered one reason why the CABs had been assigned this task:

> The CABs are the outstretched arm of the state in the regions, so that it is not so surprising, really. And the CABs have a coordination function in other contexts, too, and also in this cross-sectoral work.

Another option would be to allow the RCCs to coordinate regional energy planning. One representative of the Dalarna CAB, however, said that it could be difficult for the government to give an assignment to an RCC, which is funded by and works on behalf of the county's municipalities. If the state wanted to commission the RCCs to develop regional planning, it would also need to fund the assignment; that was not necessary when the assignment went to the CABs.

It can generally be concluded that the vast majority of interviewees were aware that their CAB had worked on a climate and energy strategy. However, the actors had difficulties specifying what the CAB had worked on more exactly or the objectives associated with the strategy. The answers were more general, the CAB's work being described thus: "they should take a holistic approach", "review the region's energy balance", and "work on sustainable development". The Dalarna CAB's work was slightly better known by the regional actors than was the Östergötland CAB's work. The regional actors in Dalarna could more easily cite concrete examples of the content and aims of the Dalarna energy strategy. The participants best remembered matters on which they had worked specifically with the CAB, for example,

[1] EnergiIntelligent Dalarna – program för regional energisamverkan

when the CAB had developed a template text for municipal energy plan, or held a seminar on a specific issue.

A common opinion among the municipal politicians was that the climate and energy strategy would convey the state's views on energy issues. Several also emphasized that the CAB was a *state* rather than a regional actor, and that it acted mainly as a supervisory authority.

3.2. Division of tasks between regional actors

The Östergötland CAB representative said that issues concerning both responsibility and implementation in relation to the strategy's goals and vision were not easy to sort out:

> This is not easy – if one looks at the control, control over the actions, since there are many who must do things.

The CAB representatives from both Östergötland and Dalarna stressed the importance of cooperation and that a diversity of actors, for example, the business community and the university, needed to be coordinated. The Dalarna CAB established a legitimation process in which actors could participate by creating a steering committee that included the county governor, RCC president, and key sector representatives. This committee was a way to create legitimacy and commitment by involving regional actors.

The division of responsibilities between the various regional actors, such as the CABs, RCCs, and REAs, was not very clear to any of the interviewees. One of the municipal climate and energy consultants commented on the difference between the CAB and the REA's GDE-Net:

> No, I don't know. They're the same … I cannot see any distinct difference. (Climate and energy consultant Dalarna, 5)

In addition, a more integrated strategy was asked for at the regional level:

> There are so many players now who work in the same direction. First, there's now the County Administrative Boards in general. Then we have the Environmental Protection Agency, with climate coaching, and then comes the Energy Agency with their 'sustainable municipality' programme. Actually, I think there are too many players. There should probably be just one regional player. (Climate and energy consultant Dalarna, 1)

3.3. The difference between the CAB and the RCC

The two regional players that were the biggest competitors in formulating and developing regional climate and energy strategies were the CAB and the RCC. According to the representative of Dalarna's RCC, the difference between the RCC and the CAB was that the CAB was a "clearly defined authority"; the RCC, on the other hand, "takes responsibility for regional development" in general, which is similar to the arguments of the Committee of Public Sector Responsibilities.

The representative of Östergötland's RCC Östsam said that the difference between the CAB and the RCC was unclear, but that they dealt with this periodically by recurring negotiations:

> It is never clear who is doing what, but the point is that you need to talk to each other and inform each other of what you are doing at the moment. And sometimes we can engage them in our activities and vice versa. But it isn't anything cast in stone, where you can say that this is the CAB's task and that is Östsam's. It may evolve over time, but now it's more that people talk to one another.

The municipal politicians discussed the problem of having two regional players, both driving the energy issue:

> Yes, I'm one of those who may feel that, as it is today, it has become a little bit like parallel actors, with both Östsam and the County Administrative Board. And it has become a kind of dual control, which I find a bit unnecessary. (Municipal politician Östergötland, 1)

The politicians would like to see the roles streamlined, and said that the CAB's role should be to monitor issues, and that a different kind of regional player should be responsible for regional development.

The RCC representatives from both Dalarna and Östergötland wanted to run the climate and energy strategy in the future, as this was seen as an important development issue for the Council. Even the elected municipal politicians advocated an increased role for the RCCs. In Östergötland, all the politicians wanted the CABs to be mainly regulatory in function in the future, and wanted Östsam to be solely responsible for regional development. The same was true in Dalarna, but here the politicians wanted to see a clearer distinction between supervision and development in the long run.

Dalarna's RCC representative felt that energy was an important development issue for which they should be responsible; that, however, would require that the Council receive additional resources. In the current situation, the RCC lacked sufficient resources, and until the financial situation was resolved, the representative thought it was positive that the CAB was responsible for developing a regional energy strategy.

Östsam would like to see a trend towards greater responsibility being transferred to the RCC, and would like to see this transfer start immediately.

4. Conclusions

By means of a government directive in the 2008 budget document, the state indicated that regional energy strategic planning was important. The CAB's mission was made clear, and the CABs in Dalarna and Östergötland have taken initiatives to develop common goals, visions, and strategies in the regions.

In the current situation, the CAB has no real "competitor" in either Dalarna or Östergötland. In the future, it is primarily the RCCs that might compete with the CABs and would like to assume responsibility for energy strategy work. Both the RCCs and leading local politicians identified the RCC as the party that should handle this strategic work. This is because local politicians and RCCs would like to see development handled in line with the recommendations of the Committee on Public Sector Responsibilities, according to which

CAB activities are limited to control issues and the RCCs would be responsible for regional development. This division of responsibilities can only be realized in the future due to the current lack of resources for RCCs. This lack also means that local politicians will continue to accept the CABs' current work and role until viable alternatives are available.

The roles of these actors, including the REA, are unclear. It was difficult for the interviewed actors to clarify their tasks and responsibilities. The representatives of the RCCs and CABs said that they divided tasks and responsibilities through ongoing dialogue with each other. When a question entered the agenda, they simply contacted each other to see how the issue could best be handled and by whom. This pragmatic system, however, is not very transparent to the actors excluded from the informal dialogue. With such an informal system, it is unclear how decisions are made and for what reasons, or who is accountable for a given decision. In addition, issues can fall through the cracks when no one is explicitly responsible for them.

Other issues raised are what will happen when the climate and energy strategies are to be acted on and the goals implemented. What legitimacy does a CAB strategy have in a county? Will it be just another document, among others, that the municipalities must take into account, and that will disappear among all the other documents? Assuming that a strategy reaches out to stakeholders, the problem of putting the goals and measures into practice remains. Another obstacle is that a CAB strategy may lack legitimacy and only be accepted because of lack of alternatives. The municipalities would like to see other agencies develop and implement regional goals and visions; it is too early to say what significance this might have for implementation, but it is an obvious hindrance and threat to united action in a region.

Local politicians are involved in the RCCs, which gives the Councils legitimacy and direct access to the municipal decision-making processes. In a situation of competition regarding future policies, CAB strategies will probably not attract support, because CABs are perceived as representatives of the central government rather than the regions. The RCCs, on the other hand, are working to create regional identities from below and represent local interests and not the state, which will benefit them in any future competition.

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Wave Power Resource in Iran for Electrical Power Generation

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Abstract: This paper presents the physics of ocean waves and its governing mathematical equations. The potentials of the Seas in Iran for wave's energy conversion into electrical energy using linear permanent magnet generators are discussed. The characteristics of the Seas and the useable regions for wave energy conversion are recognized. Finally economics of this energy conversion is analyzed.

Keywords: *Wave Energy, Electrical Power Generation, Iran*

1. Introduction

Direct-driven linear permanent magnet generator (LPMG) is a wave energy converter which has a simple structure, easy fixing, low volume, high efficiency and capability of converting the calm waves into electrical energy [1-4]. Falnes [5] introduced several theories for direct wave energy conversion systems and studied different forms of buoys for such energy extraction. LPMG consists of a movable and a fixed part. The magnetic field of the generators is provided by permanent magnet fixed on the moving piston. As shown in Fig. 1, the generator is fixed at the bottom of the sea and its piston is connected to a buoy on the sea level by a rope. The waves move the shaft, induce voltage in the armature windings and it is rectified and transmitted to the coasts by underwater cables.

Different techniques for converting wave's energy into electrical energy are categorized into three parts based on the distance from the shore as 1) shoreline, 2) near shore and 3) offshore. The shoreline systems have advantages such as easy fixing and low maintenance and they do not need very deep water or underwater cables; however, their generated power are too low because of low energy of the waves approaching the shore. Therefore, it is sometimes non-economical to install such system for wave energy conversion. The offshore systems enable to convert more wave's energy due to the stronger waves in the deeper water. LPMGs are considered as offshore devices which must be installed deeper than 15 m in order to gain an optimal efficiency. The existing wave energy depends directly on the wave height and its time period. One of the most important stages in the design, simulation and analysis of LPMG is the wave characteristic and modeling for the region in which the generator is fixed.

This paper considers the physics of the ocean waves and their stored energy. Characteristics of the seas in Iran are investigated. The attempt is made to recognize the regions in which the use of LPMG is suitable based on the sea depth, distance from shore and waves height. Also these characteristics can be included in the process of the design of LPMG. Finally, economics of the wave energy conversion is studied and compared with other forms of renewable energies.

2. Ocean Waves Energy

The total waves energy in the world coasts is estimated to be 10^6 MW and if only 2% of this energy is extracted it can supply the total world energy demand [1]. Generally ocean waves are categorized into wind-sea and swell waves. The wind-sea is used for the waves that generated by the local winds, and waves move in the direction of these winds. The waves with long period generated in the stormy regions are called swell waves. The swell waves with very low energy losses spread from coast to coast. The typical wave length of swell waves, particularly in deep water, is 100-500 m, while the wind-seas are few meters up to 500 m depending on the wind velocity. In the installing LPMG in the deep water those waves are taken into account that has the depth larger than a half wave length **[5]**. In the deep water, the bottom of sea has no noticeable influence on the waves and their effects are ignored. Normally at a specific time, many waves' pulses are generated over offshore in different directions and periods. Wind-sea and swell may present simultaneously. A real ocean wave consists of the waves with different frequencies and directions. The mean stored energy in the unit area of the sea surface is as follows [1-13]:

$$E = \rho g H_{m0}^2 / 16 = \rho g \int_0^\infty S(f)\, df \tag{1}$$

where ρ=1030 kg/m^3 is the sea water density, H_{m0} is the water height in the natural case and g=9.81 m/s^2.This stored energy is equally divided into the kinetic and potential energies. In (1), $S(f)$ is the wave spectrum in m^2/Hz. Integration of $S(f)$ shows the effects of frequencies of different waves upon the waves energy. In practice, (1) is substituted by sum of the limited number of waves frequencies. For sinusoidal waves having amplitude of 0.5H (H is the height of the wave, vertical distance between the lowest and highest points of the wave) H_{m0} is substituted by $H\sqrt{2}$ in (1) to calculate E. The approximate natural wave of $S(f)$ is defined using Fourier analysis by measuring the wave at a given time. To obtain the long-term statistics, measurement and analysis are taken every three year. For growth wind seas, the empirical Prison-Moskowitz spectrum agrees well with the practical spectra and calculated as follows:

$$S(f) = (A / f^5) \exp(-B / f^4) \tag{2}$$

where $A=BH_{m0}^2/4=0.0005m^2Hz^4$, $B=(5/4)f_P^4=0.74g^4/(2\pi U)^4$. $f_P=1/T_P$ is the peak frequency and U is the mean velocity of the wind at height of 15 m above the sea level. For a low reaction between the wind and sea level, the use of JONSWAP spectrum is more common; the band width of this spectrum is narrower than that of the Prison-Moskowitz spectrum. The torque of j-order wave moment is $m_j = \int_0^\infty f^j S(f) df$. Therefore, the significant wave may be defined versus 0-order torque spectrum as $H_{m0}=4\sqrt{m_0}$. To simplify the investigation it is assumed that the wave is propagated in x direction. For a sinusoidal wave with frequency f, the energy of the wave is transferred with velocity c_g (group velocity). The wave power level, defined as transferred energy over every unit width of the propagating front wave, is equal to $J=c_gE=c_g\rho gH^2/8$. For real sea waves, the level of wave power versus wave spectrum is:

$$J = \rho g \int_0^\infty c_g(f) S(f) df = \rho g^2 m_{-1} / 4\pi = \rho g^2 T_J H_{m0}^2 / 16 \tag{3}$$

Eqn. (1) is true in deep water, where $c_g=gT/4\pi=g/4\pi f$ and energy period as $T_J=T_{-1,0}=m_{-1}/m_0$. The level of the wave power can be estimated by integrating the power density flow: J=$\int I(z)dz$ in z direction (direction of water flow). The peak wave power density is as follows:

$$I(0) = 2\pi \rho g m_1 = (\frac{\pi}{8}) \rho g H_{m0}^2 / T_{0,1} \tag{4}$$

under water level z=0, the wave power density has its maximum value and it is more decreased by moving lower sea level. For perfectly growth wind-seas, we have the following based on Prison-Moskowitz spectrum:

$$I(0) = 0.0325\rho\, g^{3/2} H_{m0}^{3/2} = 5I_{wind} \tag{5}$$

where I_{wind} is the peak wind energy. For a sinusoidal wave in deep water, H_{m0} is substituted by $H\sqrt{2}$, T_J and $T_{1,\,0}$ by T in (4) and (5). The power density varies proportional with z. $I(z)=I(0)\,exp(2kz)$ where $k=2\pi/\lambda$ is the wave number, and $\lambda=gT^2/2\pi=(1.56m/s^2)T^2$ is the wave length. 96% of J is calculated from integrating between z= $-\lambda/4$ and 0. Decreasing water depth means approaching the wave near shore. In this case wave length reduces uniformly. However, c_g rises 20% compared with the deep waters. Value of c_g *is* decreased by reduction of h and it nearly diminishes when approaches the shore (zero wave energy). In the shoreline, the wave energy is used to overcome the friction between the waves and shore bottom and depth-induced braking force.

In latitude of 40-50 degrees, the average annual wave's power levels in off-shore water are between 30 and 100 kW/m. The low power level waters are mostly in the north and south. In most equatorial waters, the average wave power level is lower than 20 kW/m. The offshore wave power levels are between kW/m up to MW/m (in the case of variable storm). Finally, a general equation for estimation of the stored energy in the real sea waves, propagated in different directions, is as follows:

$$E = \rho\, g\, H_{m0}^2 / 16 = \rho\, g \int_0^{\infty}\int_{\beta_1}^{\beta_2} S(f,\beta)\, df\, d\beta \tag{6}$$

where *S(f, β)* is the oriented energy spectrum, and *β* is the propagation angle in respect to x-axis. The transferred power density from the waves to a floating cylinder with diameter equal to 1 m and normal (vertical) path in θ direction is as follows:

$$J_\theta = (\rho g^2 / 4\pi) \int_0^{\infty}\int_{\beta 1}^{\beta 2} f^{-1} S(f,\beta) \cos(\beta-\theta)\, df\, d\beta \tag{7}$$

For sinusoidal waves in deep waters, the transferred power density from the waves to 1 m diameter floating cylinder and its wave length are as follows;

$$J = \rho g^2 T H^2 / (32\pi) \quad W/m \tag{8}$$

$$J_\theta = (\rho g^2 / 4\pi) \int_0^{\infty}\int_{\beta 1}^{\beta 2} f^{-1} S(f,\beta) \cos(\beta-\theta)\, df d\beta \quad W/m \tag{9}$$

3. Characteristics of Sea Waves in Iran

3.1. Persian Gulf

Persian Gulf is situated between the north attitude of 25 and 32 degrees and between east attitude 49 and 56 degrees. The Persian Gulf area is about 850 km^2 which has been connected to the Oman Sea by the Hormoz Channel. The depth of the Persian Gulf increases from north-west to south-east and reaches to 100 m and lower depth in the Hormoz Channel. The water depth in Khozestan and Saudi-Arabia shores is very low and at most 10 m along tens km of the shores; while in the east of Khozestan, particularly in Kangan Port up to Gheshm Island, the average depth is larger. The average depth of the Persian Gulf is basically about 40 to 50 m and is lower toward to the shores. There are sometimes high depth in the shores (around 40 m) which are small and a limited number of cavities and they cannot be considered as the real depth of the shore. The common depth in the shores is 18 to 29 m. So the Persian Gulf shores are generally flat and at the same time the deeper shores are in the north of the Persian Gulf [14, 15].

Fig. 2 exhibits the Persian Gulf map [16]. It shows that the depth of water over tens km of the shore is not larger than 10 m, this is the reason that most parts are not suitable for installing LPMGs. Because, the regions deeper than 15 m are very far from the shore and this increases the energy transmitting cost to shore. Also due to the limitation of deep areas in Persian Gulf, most of these areas are used as path for passing the large ships. However, in Asaloyeh, Gavbandi and particularly Hormoz Channel the deep regions are closer to the shore and suitable for installing the generators.

Fig. 3 shows the waves height in the Persian Gulf during 100-year period [17]. The stored energy in the waves has a direct relationship with the wave height. As indicated in Fig. 3, the waves height in areas close to the shores of Iran are higher than other points. According to Fig. 3, the west regions of the Persian Gulf up to the Gheshm Island and particularly Hormoz Channel with wave height of 4.5-5 m, up to 5 km of the shore are suitable regions for installing LPMGs. Considering sinusoidal waves with period of 4 s, the peak energy of the waves in these regions is estimated by (4), which is between 79.74 and 98.44 kW/m.

3.2. Oman Sea

Oman Sea is part of the Indian Ocean and is only open Sea of Iran. Persian Gulf in connected to Oman Sea via Hormoz Channel. The tropic of cancer passes the north of Oman Sea. It is one of the warmest seas on the south-west of Asia. The minimum water temperature in August is 33 and minimum in January 20 degrees. The area of the Oman Sea is 903 square km. This Sea is deeper than Persian Gulf particularly in the shores of Iran. Its depth around Chabahar Port is around 3380 m. There are many notches in the Oman Sea forming small Gulfs locally such as Chabahar Gulf and Govatr Gulf. However, most of these small Gulfs have low depth and they are not useable for large ships because their shores are sandy For this purpose, it is necessary to establish docks [14, 16]. Fig. 4 exhibits the map of Oman Sea [17]; which includes the depth of the Sea in different regions. Fig. 5 shows the peak height of the wave in the Oman Sea over 100-year

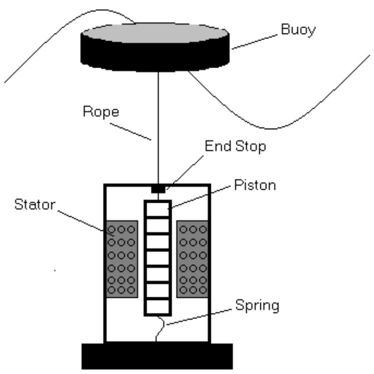

Fig.1. Direct wave energy conversion system

Fig. 2. Map of Persian Gulf

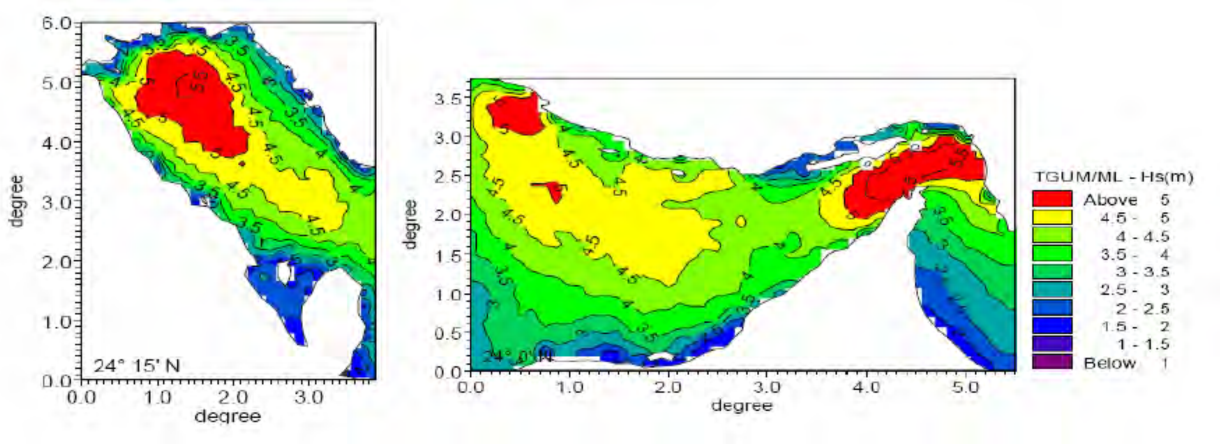

Fig. 3. Peak waves energy in Persian Gulf in 100-year period [17].

period [17]. In this Sea the deep areas (deeper than 15 m) are closer to the shores. However, the peak height of the waves is lower than that of the Persian Gulf and is between 3 and 4 m.

Considering sinusoidal waves with period of 4 s, the peak energy of the waves in these regions based on (9) is estimated between 35.44 and 63 kW/m. The advantages of deeper Sea close the shores are that the cost of transmitting the generated electrical power to the shores is lower. Finally most of the shores particularly Chabahar shores are suitable to install LPMGs.

3.3. Caspian Sea

Caspian Sea in the north of Iran has 424000 km^2 area and is the largest lake of the earth and that is why it is called the Sea. This is the largest remaining portion of the ancient Sea of Tetis which extended from the North Pole to Indian Ocean in the 1st to 3rd geology ancient time. The depth of the Caspian Sea in the north region is very low and about its 4/5 area has lower than 10 m depth. The peak depth of this Sea in the north is 15 m and in the south is 1000 m. The average depth of this Sea is 325 m. Basically, Caspian Sea is not a calm Sea. It is in the path of the air flow in many days of the year and is wavy. The waves created by the north which extended from the North Pole to Indian Ocean in the 1st to 3rd geology ancient time.

Fig. 4. Map of Oman Sea [16].

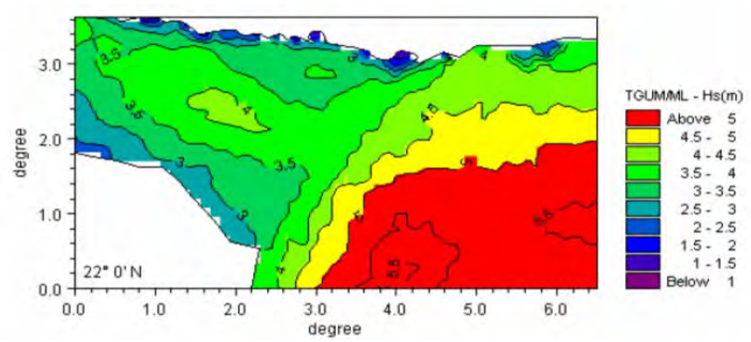

Fig. 5. Peak height of the wave in the Oman Sea over 100 years period [17]

The depth of the Caspian Sea in the north region is very low and about its 4/5 area has lower than 10 m depth. The peak depth of this Sea in the north is 15 m and in the south is 1000 m.The average depth of this Sea is 325 m. Basically, Caspian Sea is not a calm Sea. It is in the path of the air flow in many days of the year and is wavy. The waves created by the north winds often have 25 m/s velocity, 11 to 12 m height and 200 m wave length. The major part of these waves is formed by these waves. The frequency of the waves is larger in the west and middle parts and therefore these parts are more non-calm compared with other parts [18, 19]. This wavy Sea has large potential for waves energy conversion. Fig. 6 and Fig. 7 show the Caspian Sea map and the peak height of the waves in 100-year period respectively [16, 17]. Referring to Fig. 7, the height of the waves particularly close to the shores in Iran is very large which indicates the large potential of this Sea for converting the waves energy into electrical energy. In Caspian Sea the regions with high wave height and depth larger than 15 m are close to the shore and their distances to the shore are less than 5 km. This feature reduces the cost of electrical energy transmission. Considering sinusoidal waves with period of 5 s, the peak energy of the waves in these regions is estimated between 123 and 315 W/m by (9).

4. IV. Economics of Wave Energy Conversion

To estimate the economics of the available renewable energy conversion the following merit index has been defined:

$$\alpha = \frac{P_{ave}}{P_r} = \frac{W}{8760 P_r} \tag{10}$$

where α is the merit index, P_r is the rated power, P_{ave} is the mean developed power in kW, W

Fig. 6. Caspian Sea map

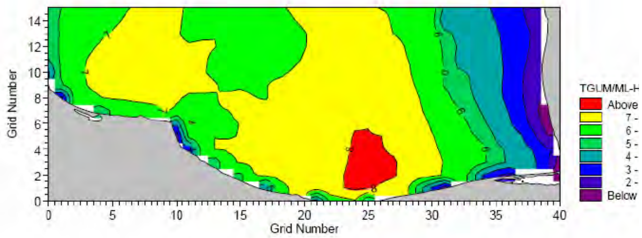

Fig. 7. Peak height of the wave in the south of

Caspian Sea over 100 years period

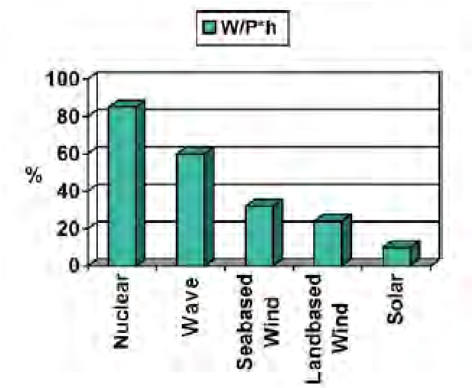

Fig. 8. Merit index for different types of renewable energies [20].

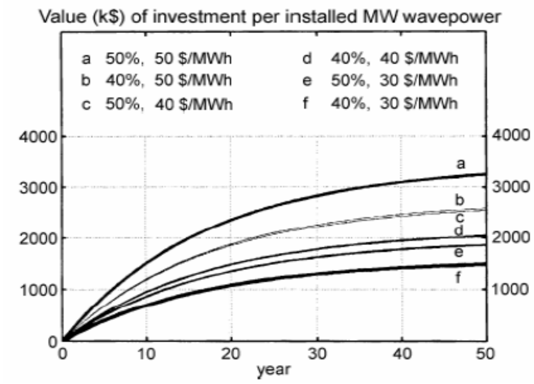

Fig. 9. Value of investment per installed MW wave power for different values of the utility factor and electricity price [20]

is the generated energy over one year in *kWh* and 8760 is total hours of the year [20]. Fig. 8 shows the merit index for different renewable energy systems. It shows that the waves energy has 60% merit index and places in the second rank after the nuclear energy. The wave energy is superior to the wind energy from generation time period and generation level points of view. The wave's energy is damped very calmer than that of the wind energy. Also the peak power density of wave under the sea level is 5 times of $I_{wind}=(\rho_{air}/2)U^3$ at 19.5 m above the Sea level. For wave energy density of 3.2 kW/m^2 and the mean wind velocity of U=10 m/s, the wind power density at 19.5 m above the Sea level is 0.6 kW/m^2 [14]. Fig. 9 shows that the investment for converting the waves energy into electrical energy is 40-50 $/MWh [20] where 3 $/MWh is for the maintenance. Of course direct conversion systems have not been included in this table. If direct conversion system is used a lower investment is required.

5. Conclusion

Physics of Seas waves and their governing equations were studied and then conditions of these Seas for wave's energy conversion into electrical energy were investigated. Persian Gulf is not suitable to install LPMGs due to its very low depth and its deep regions are far from the shore. The Oman Sea is deep and the deep areas are close to the shores and it is capable to generate electrical energy from the wave's energy using LPMGs. The Caspian Sea is wavy due to the path of the air flows in many days of the year and the height of the waves approaches 12 m and its wave length is very long. Also the depth of water in the south and west sides in Iran is high, therefore Caspian Sea has more potential to convert the waves energy into electrical energy using LPMGs. In order to include the characteristics of the Seas in Iran in simulation and design of LPMGs, it is necessary to have data about the wind velocity, average height of annual waves, and average wave length and time period of the waves. The mentioned data are required to use equations in section 2 of the paper and estimate the power level of these waves and design the generator suitable for this power level.

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Effects of environmental taxation on district heat production structures

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Abstract: In this study, we explore how different environmental taxation regimes influence the design of cost-optimal district heat production systems and the primary energy use for district heat production. Our calculations are based on the heat load duration curve of a district heat production system in Östersund, Sweden. Using the system's measured daily district heat load curve from 1st May 2008 to 30th April 2009, we model four cost-optimal district heat production systems based on four environmental taxation scenarios. The design of the district heat production under the different taxation scenarios is based on expected utilization time and on the production units which give the lowest heat production cost. We find that primary energy use varies strongly when different technologies and fuels are used under the different environmental taxation scenarios. However environmental taxation has a minimal effect on district heat production cost for optimally designed district heat production systems. Fossil fuels become less competitive as the environmental taxation increases. However, light fuel oil boiler for the peak load production remains viable due to low utilization time and investment cost.

Keywords: *District heat production, CHP, Boilers, Fossil fuel, Biofuel, Environmental tax, Primary energy, Cost*

1. Introduction

Energy security and the impact of energy systems on the global climate are important energy policy concerns in the European Union, including in Sweden. Several strategies can be used to address these concerns, including promotion of more efficient energy production technologies, and conversion to renewable and low carbon fuels. District heating based on combined heat and power (CHP) production is primary energy efficient [1], and can use biomass-based fuels.

In Sweden, district heating with CHP is increasingly common, and is the main source of heat for multi-story residential and non-residential buildings [2]. In 2008, district heating accounted for 50% (about 50TWh) of the total space and tap water heating [3]. The energy input for the Swedish district heat production is dominated by biomass, which accounted for 48% of total input in 2008 [4]. The Swedish government energy policy aims at further increasing the share of biomass. Policy instruments to realize this include environmental taxes on fuels, tradable green electricity certificates (GEC) and obligated quota mechanism of GEC for customers [2].

The utilization time of district-heat production units varies and is very small for the units that cover peak-load demand. Therefore, the investment costs of these units are much more important than the operation costs. Low investment fossil fuel-based technologies are often used even though they are associated with higher external cost. Environmental taxation can be an important policy instrument to restructure district heating systems into more sustainable form. Such policy instrument may influence the choice of technologies and fuels for district heat production units.

In this study we explore how different environmental taxation regimes influence district heat production structures. We investigate the choice of production units and fuels for cost-optimal district heat production for the different environmental taxation scenarios, and calculate the primary energy use and the cost of district heat production.

2. Method and assumptions

Our analysis is based on the measured daily district heat load curve of a district heat production system in Östersund, Sweden from 1st May 2008 to 30th April 2009. Figure 1 shows the measured heat load of the production system during this period, arranged in descending order. During this 12 month period, the output of the production system was 210 GWh electricity and 612 GWh heat. Based on the district heat load curve, we model four cost-optimal district heat production systems based on four environmental taxation scenarios. Figure 2 presents a schematic diagram of the study.

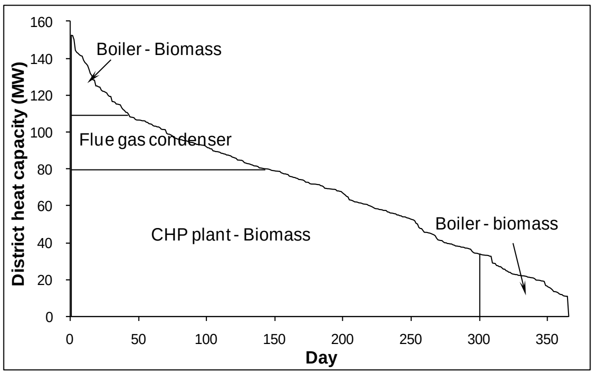


Fig. 1. Reference heat load duration curve

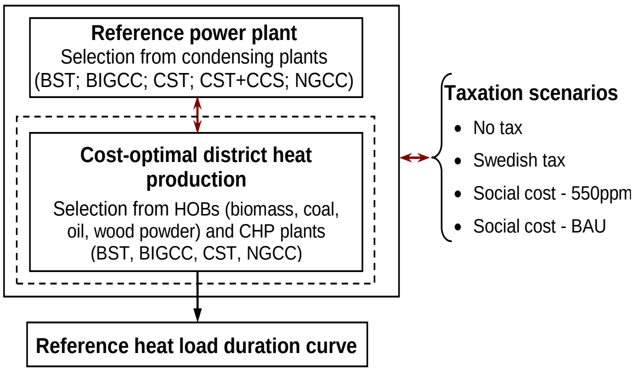


Fig. 2. Schematic diagram of the analysis

We use four environmental taxations scenarios to explore their effect on the structure of district heat production. The taxations scenarios are: (i) the *No tax* scenario with the year 2008 Swedish price of fuels with zero taxes; (ii) the *Swedish tax* scenario with the year 2008 Swedish prices and taxes on fuels, comprising of a carbon tax of €386/t CO_2 for emissions related to non-electricity production, an energy tax that varies for different fossil fuels used for non-electricity production, and an average green electricity certificate (GEC) benefit of €12.5/MWh_e of produced green electricity [5]; (iii) the *Social cost-550 ppm* scenario with the year 2008 fossil fuel prices excluding taxes, plus a carbon damage cost of €20.55/t CO_2 (\$30/t CO_2) corresponding to the 550 ppm emission scenario by Stern [6]; (iv) the *Social cost-BAU* scenario with the year 2008 fossil fuel prices excluding taxes, plus a carbon damage cost of €58.23/t CO_2 (\$85/t CO_2) corresponding to the business as usual (BAU) emission scenario by Stern (2006). The costs of the fuels under the various scenarios are shown in Table 1.

Table 1. Fuel costs under the various scenarios (€$_{2008}$/MWh)

	Scenarios			
Fuel type	No tax	Swedish tax	Social cost-550 ppm	Social cost - BAU
Fuel oil	29.7	62.9	36.1	47.7
Coal	8.0	46.3 (17.4)[a]	15.5	29.3
Forest fuel	16.3	16.3	16.5	16.8
Natural gas	33.7	37.6 (37.9)[a]	37.9	45.6
Wood powder[b]	26.1	26.1	26.4	26.9

[a] CHP plant.
[b] Estimated based on forest fuel cost.

We select the district heat production units for each taxation scenario based on the utilization time and lowest district heat cost. We consider the fuels and technologies shown in Table 2. The technologies consist of CHP plants and heat only boilers (HOB). The CHP plants are based on biomass steam turbine (BST); biomass integrated gasification combined-cycle (BIGCC); coal steam turbine (CST); and natural gas combined-cycle (NGCC) technologies.

Table 2. Investment cost, fixed and variable costs and conversion efficiency of different technologies. The data is based on lower heating values (LHV).

Technology	Capacity	Investment cost	Fixed O&M cost	Variable O&M cost	Efficiency (%) Heat	Elect.
Heat-only boiler (HOB):	*(MW_{heat})*	*(€/kW_{heat})*	*(€/kW_{heat})*	*(€/MWh_{fuel})*		
Biomass[a]		646	12.92	1.95	110	-
Wood powder[b]		430	8.6	1.95	95	-
Oil[a]		300	4.5	0.65	90	-
Coal[c]		690	17.3	2.59	90	-
CHP plants:	*(MW_{heat})*	*(€/kW_{heat})*	*(€/kW_{heat})*	*(€/MWh_{fuel})*		
BST[c]	80	1150	17.3	2.6	80	30
BIGCC[a]	80	1700	42.5	3.1	47	43
NGCC[a]	80	950	23.8	1.0	43	46
CST[c]	80	1350	33.8	3.1	59	30
Condensing power plant:	*(MW_{elec})*	*(€/kW_{elec})*	*(€/kW_{elec})*	*(€/MWh_{fuel})*		
CST[c]	400	1200	24.9	3.12	-	47
CST with CCS[c]	400	1900	74.8	5.2	-	37
NGCC[c]	400	620	18.7	1.04	-	58
BST[d]	400	1200	20	2.39	-	45
BIGCC[a]	100	1680	42	3.12	-	47

[a] Encompasses forest fuels; estimated from [7] with adjustment for the difference in investment cost between [8] and [7]
[b] Swedish Wood Fuel Association and Swedish Energy Agency [9], with 170% adjustment
[c] Hansson et al. [8]
[d] Estimated from CEC [7]

The calculation of the heat production cost is based on the following equation from Gustavsson [10]:

$$C_{heat} = \frac{C_{vom}}{\eta_{heat}} + \frac{C_{fuel}}{\eta_{heat}} - V_{elec} \times \alpha + \frac{CRF \times C_{cap} + C_{fom}}{t} \qquad (1)$$

where C_{heat} is the heat production cost (€/MW_{heat}), C_{vom} is the variable operation and maintenance (O&M) costs of the plant (€/MWh_{fuel}), η_{heat} is the efficiency of heat production of the plant, C_{fuel} is the fuel cost of the plant (€/MWh_{fuel}), V_{elec} is the value of produced electricity (€/MWh_{elec}), α is the electricity-to-heat ratio of the plant, *CRF* is the capital recovery factor of the plant, C_{cap} is the capital cost of the plant (€/MW_{heat}), C_{fom} is the annual fixed O&M costs of the plant (€/MW_{heat}), and t is the utilization time of the plant.

For district heating systems with CHP production, the production cost of heat may be determined by subtracting the value of the cogenerated electricity from the total production cost of the CHP plant [11]. We calculate the value of cogenerated electricity using the subtraction method, where we consider the cogenerated electricity as by-product and assume its value to be equivalent to the cost of electricity produced with a reference condensing power plant [12]. We calculate the cost of the cogenerated electricity as the lowest production cost from the condensing power plants (Table 2) for each taxation scenario. We assume the same technologies as for cogeneration but also add carbon capture and storage (CCS) for the CST technology. Data for condensing power production from CST with CCS is from Hansson et al. [8]

We calculate the primary energy use and the heat and electricity generated by the cost-optimal district heat production systems based on the operation schedules, production units and fuels. We consider fuel cycle energy inputs in our calculations.

For all the production units, we assume a discount rate of 6%, an economic plant life of 25 years and a maximum operating period of 7200 hours per year. We use exchange rates of EUR/SEK = 9.62 and USD/SEK= 6.59, based on the average rates for 2008.

3. Results and discussion

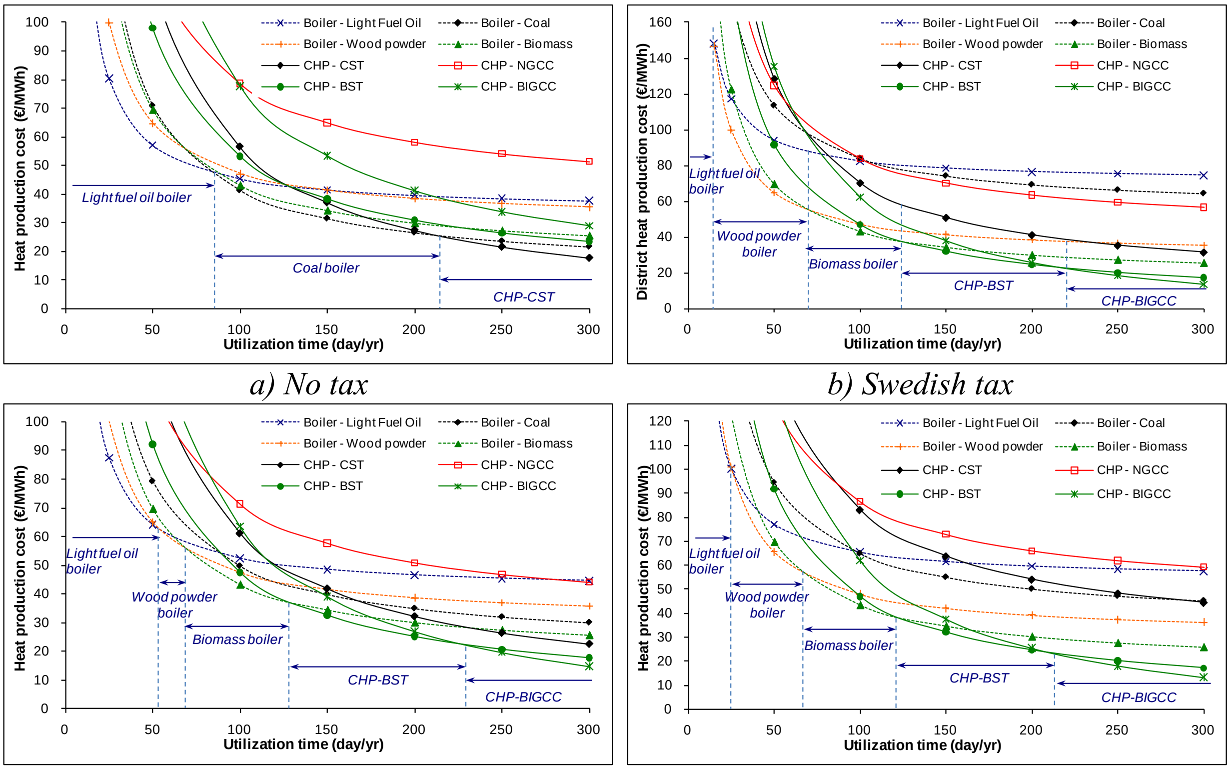
The calculated cost of electricity from the condensing power plants under the various taxation scenarios is shown in Table 3. The numbers in bold show the lowest production cost for each taxation scenario, and hence become the reference condensing power plant for each scenario. CST emerges as the reference condensing power plant for electricity production in all scenarios except for the *Social cost-BAU* scenario. For the *Social cost-BAU* scenario, BST emerges as the reference condensing power plant. However, the cost difference between BST and CST is small for the *Swedish tax* and *Social cost-550 ppm* scenarios.

Table 3. The cost of electricity production for the various taxation scenarios (€/MWh).

Technology	*No tax*	*Swedish tax*	*Social cost-550 ppm*	*Social cost-BAU*
CST	**40.2**	**44.6**	**56.1**	85.4
CST, CCS	66.7	66.7	68.9	72.9
NGCC	69.2	76.5	76.4	89.7
BST	57.4	44.9	57.8	**58.6**
BIG/CC	65.4	52.9	65.8	66.5

Figure 3(a-d) shows the cost of district heat production units as a function of the utilization time under the different taxation scenarios. The units with the lowest heat production cost are applied to the heat load profile to minimize the overall heat production cost (Figure 4a-d). For the *No tax* scenario a CHP-CST for base load, coal boiler for medium load and light-fuel oil boiler for peak load give the cost-optimal system (Figure 3a). Five different units give the cost-optimal system for the *Swedish tax* scenario (Figure 3b), including CHP-BST and CHP-BIGCC for base load, wood powder boiler and biomass boiler for the medium load, and light fuel oil boiler for the peak load. However, the CHP-BIGCC may not be technically feasible as the technology is still at the demonstration stage and is not yet commercialized [13]. Therefore we select the CHP-BST plant for the base load production but show the results if CHP-BIGCC is used in a sensitivity analysis. During periods when the base load unit is shut down (after 300 days) heat demand has to be met by the medium load unit, increasing the utilization time for that unit. If this utilization time is also considered, the wood powder boiler becomes less competitive than the biomass boiler for the medium load production. Therefore a combination of CHP-BST plant for base load, biomass boiler for medium load and light fuel oil boiler for peak load gives the minimum heat production cost for the *Swedish tax* scenario

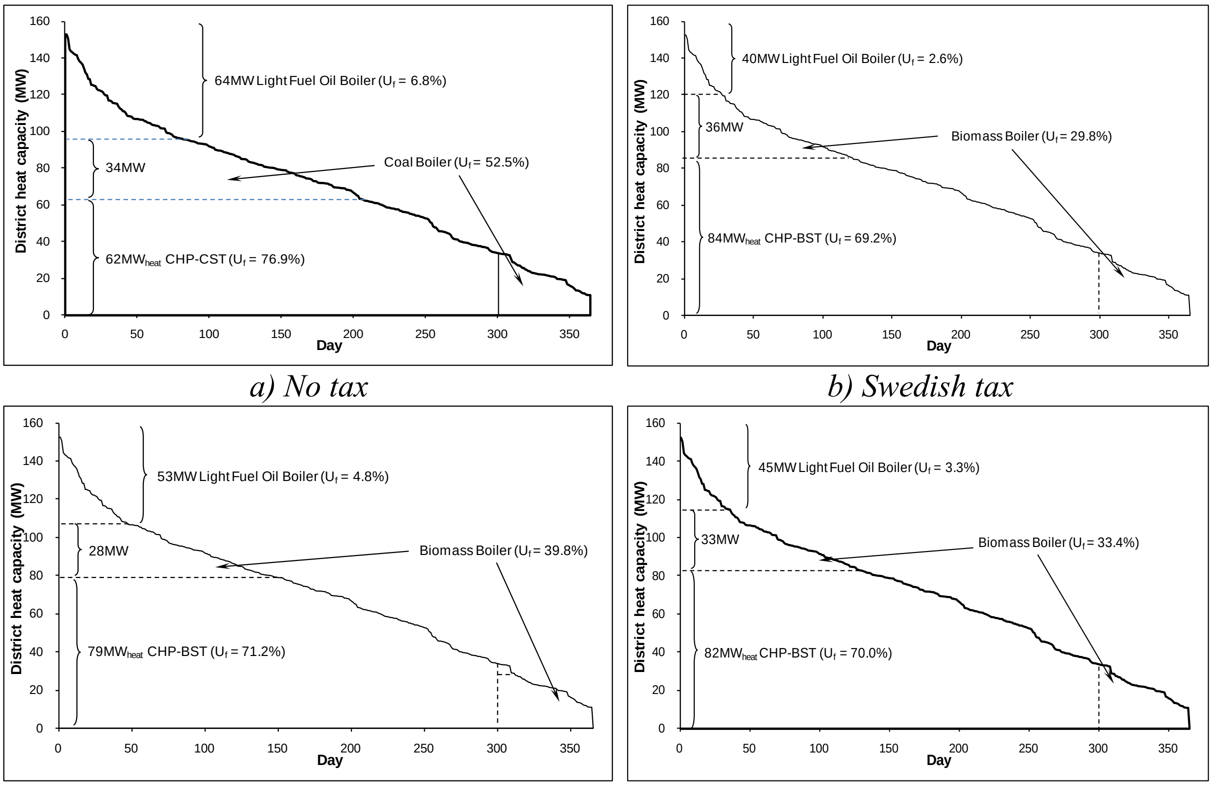
(Figure 4b). Similar analyses for the *Social cost-BAU and Social cost-550 ppm* scenarios give the selections the production units shown in Figure 4c and d.



a) No tax *b) Swedish tax*

c) Social cost – 550ppm *d) Social cost – BAU*

Fig. 3. Performance of district heat production units under different taxation scenarios



a) No tax *b) Swedish tax*

c) Social cost – 550ppm *d) Social cost – BAU*

Fig. 4. The cost-optimal production units satisfy heat load demand under different taxation scenarios

Table 4 shows the production units and the capacities of the cost-optimal district heat production systems as well as the annual heat and electricity production and the annual primary energy use. District heat production is based on only fossil fuels under *No tax* scenario whereas in the other scenarios district heat production is based mainly on biomass, accounting for 96.4% in *Social cost-550ppm* scenario and 98.5% in *Swedish tax* scenario. Hence fossil fuels become less competitive as the environmental taxation increases. However, light fuel oil boiler for the peak load production remains viable due to low utilization time and investment cost.

Table 4. The cost-optimal district heating systems under different taxation scenarios.

Production unit of district heat	*Capacity (MW_{heat})*	*Heat generation (GWh)*	*Elect. generation (GWh)*	*Primary energy use (GWh)*
No Tax:				
CHP-CST	62	418.0	212.0	793.0
Boiler-coal	34	156.0		159.0
Boiler-oil	64	38.0		47.0
Swedish tax:				
CHP-BST	84	509.0	191.0	658.0
Boiler-biomass	36	94.0		88.0
Boiler-oil	40	9.0		11.0
Social cost - 550ppm:				
CHP- BST	79	492	185.0	637.0
Boiler-biomass	28	98		92.0
Boiler-oil	53	22		27.0
Social cost - BAU:				
CHP- BST	82	503	188.0	650.0
Boiler-biomass	33	96		91.0
Boiler-oil	45	13		16.0

Table 5 shows the district heat production cost and primary energy use for heat production under the different scenarios. The district heat productions with CHP-BST have similar district heat production cost, ranging from €25.6 to €25.8 per MWh regardless of taxation scenarios. This is slightly higher than that of the cost-optimal system under *No tax* scenario, which is €25.0 per MWh. The primary energy use is about 50% higher in the *No tax* scenario compared to the other scenarios. This is mainly because CHP is less cost-effective without any taxation, resulting in a higher use of the less efficient boilers.

Table 5. District heat production cost and primary energy use of cost-optimal systems.

Scenario	*District heat production cost (€/MWh)*	*Primary energy for heat production (GWh)*
No tax	25.0	440.6
Swedish tax	25.8	325.8
Social cost – 550ppm	25.6	335.9
Social cost – BAU	25.6	311.6

4. Sensitivity analysis

To demonstrate the potential of CHP-BIGCC technology if it is commercialized, the CHP-BIGCC plant is used for the base load production for the *Swedish tax, Social cost-550 ppm* and *Social cost-BAU* scenarios as it gives the lowest district heat production cost. The optimal capacities for the production units with CHP-BIGCC are given in Table 6. The capacities of the production units and the heat generated decrease when CHP-BIGCC is used instead of CHP-BST. This is because the CHP–BIGCC system is more efficient than the CHP–BST but also more capital intensive. However, the cogenerated electricity is about twice as much for CHP- BIGCC than for the CHP-BST.

Table 6. The cost-optimal district heating systems under different taxation scenarios if CHP-BIGCC is used.

Production unit of district heat	*Capacity (MW_{heat})*	*Heat generation (GWh)*	*Elect. generation (GWh)*	*Primary energy use (GWh)*
Swedish tax:				
CHP-BIGCC	74	473	433.0	1042.0
Boiler-biomass	46	130		122.0
Boiler-oil	40	9.0		11.0
Social cost - 550ppm:				
CHP-BIGCC	72	465.0	425.0	1024.0
Boiler-biomass	33	124.0		117.0
Boiler-oil	55	23.0		29.0
Social cost - BAU:				
CHP-BIGCC	75	477.0	437.0	1051.0
Boiler-biomass	36	118.0		111.0
Boiler-oil	49	17.0		20.0

Table 7 shows the district heat production cost and primary energy use if CHP-BIGCC is used. The district heat production cost is 5-8% lower than when CHP-BST is used. The primary energy for district heat production is also significantly reduced compared to when CHP-BST is used. This is due to the benefits from the increased cogenerated electricity.

Table 7. District heat production cost and primary energy use of cost-optimal systems if CHP-BIGCC is used.

Scenario	*District heat production cost (€/MWh)*	*Primary energy for heat production (GWh)*
Swedish tax	24.0	254.7
Social cost – 550ppm	24.3	288.6
Social cost – BAU	23.6	247.1

5. Conclusions

In this study, we explore how different environmental taxation regimes influence the design of optimal cost district heat production system. We find that primary energy use varies strongly when different technologies are used under the different taxation scenarios. CHP is less cost-effective without any taxation, resulting in a higher use of the less efficient boilers. Fossil fuels become less competitive as the environmental taxation increases. However, light fuel oil boilers for the peak load production remains viable due to low utilization time and investment cost. Varying the environmental taxation has a minimal effect on the heat production cost when the biomass-based district heat production is designed for the given taxation.

CST emerges as the reference condensing power plant under all taxation scenarios except for the *Social cost–BAU* scenario, in which BST is the reference condensing power plant. CHP-BIGCC is an emerging technology for efficient use of biomass for district heat production as this technology increases the power-to-heat ratio of CHP-based district heat production. Policy instruments that provide incentives for and eliminate barriers against this technology may be needed to implement the technology. Hence, environmental taxation can be an important policy instrument to increase the competitiveness of biomass-based CHP.

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Energy Neutral Districts ?
Key to Transition towards Energy Neutral Built Environment !

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Abstract: The Dutch project 'Transition in Energy and Process for a Sustainable District Development' focuses on the transition to sustainable, energy neutral districts in 2050, particularly in energy concepts and decision processes. The research results in six innovative energy concepts for 2050.
Firstly, fourteen variations of six general energy concepts have been developed and calculations conducted on the energy neutrality by means of an Excel model designed for this purpose.
Three concepts are based on the idea of an energy hub (smart district heating, cooling and electricity networks, in which generation, storage, conversion and exchange of energy are all incorporated). Calculations show the energy neutrality ranges from 130 % to 164% excluding transport of persons within the district.
In this approach, different districts have different sustainable energy potentials that have their peak supply at different times. The smart approach therefore is not an autarkic district, but an exchange of surplus sustainable energy with neighbouring districts and import of the same amount of energy in case of a shortage.

Keywords: *Energy neutrality, District, Energy concept, Energy hub, All-electric*

1. Introduction

One third of the current Dutch (and European) energy demand is caused by the built environment. The target of the Dutch government, in accordance with the European targets, is to reach 20% renewable energy supply in 2020 [PEGO, 2009]. The document [New Energy for the Netherlands, 2009] contains a plea of the leading political parties in favour of a completely renewable energy supply in 2050.

A characteristic of the built environment is that it changes very slowly. Each year, 1% of the floor area of existing building stock is added to the total building stock. With a minimal lifespan of buildings of one hundred years we need to take action today to reach this vision before 2050 or even this century if we wish to break our addiction to fossil fuels. We need to develop innovative and integral energy concepts for renovation and new housing and apply them to entire districts.

Energy neutral houses are already demonstrated mainly as villa's or special designs [1]. In ordinary cities, existing buildings and newly built districts it is impossible to reach energy neutral houses on a large scale with these common technologies. For offices it is even more difficult to gain energy neutrality [2]. Only within district energy neutrality can be achieved. It can be concluded that there is a need for using sustainable sources on an district scale.

2. Future Energy Housekeeping

The starting point for establishing the energy demand of the energy neutral concepts is based on the Building Future Potential Study 2050 [2] and [4]. According to this study, the main features of a energy neutral district are as summarized below (Fig. 1):

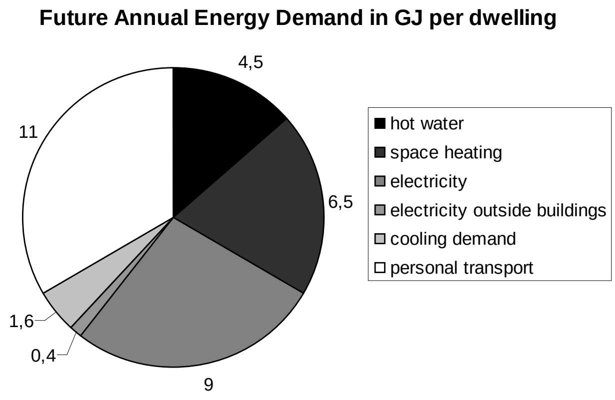

Fig. 1: Annual energy demand of a house in GJ, assessed for 2050 [ECN, 2009]

The energy demand of a district separated into the following components: (1) Buildings, (2) Transport for persons within the district and (3) the surroundings of the district. Due to a far-reaching reduction of demand in future, the total average energy demand of a dwelling will be approximately 33 GJ annually, separated into:
- Domestic Hot water (4.5 GJ or 185 m^3 natural gas)
- Space heating (6.5 GJ or 300 m^3 natural gas)
- Space Cooling (1.6 GJ or 300 kWh_e)
- Electricity for lighting and household appliances (9 GJ or 2,450 kWh)
- Electricity demand for street lighting etc (0.3 GJ)
- Transport of persons (11 GJ).

Energy losses due to distribution of heat:
- high temperature (90-70 C): 5 GJ per meter with high performance insulation
- low temperature (50-30 C): 2.5 GJ per meter

The energy demand for transportation of persons within a district is established as 34 GJ primary energy use of 11 GJ electricity [5].

3. Understanding energy neutral districts

An (energy neutral) district, as defined in this research, follows the boundaries of the built area and consists of a mix of residential and commercial buildings. This implies that energy sources from outside the district, such as wind turbines (for example offshore) and biomass (forests, agricultural sources) are not taken into account. It is assumed that the energy for industry and transport other than personal transport is generated outside the district boundaries. One exception is waste heat from large-scale incineration and combustion plants, which process mainly waste from the district such as domestic and company refuse.
We consider a district as energy neutral if, on a yearly base, no net energy import is necessary from outside the district. An energy neutral district is not an autarkic district that does not exchange any energy with its surrounding districts. Surplus of energy can be exported and, in case of energy shortage, the same amount of energy can be imported from the surrounding districts. It is better to import or export electricity than to store it. This definition is according to PEGO [6].

3.1. Technologies used in energy neutral concepts

Technologies needed to be deployed in energy neutral concepts can be classified as existing, future (on the market within app. 10 years) and still to be developed technologies (market ready after 2020). Existing renewable technologies comprise of high and low temperature district heating networks, geothermal sources, heat and cold buffering in storage tanks, Aquifer Thermal Energy Storage (ATES), flat plate and vacuum tube solar collectors, heat pumps, heat-driven cooling, PV (photovoltaic modules), urban wind energy and biomass CHP. The future technologies are, among others, organic rankine cycle (ORC), heat pump booster, electricity hub, heat and power matcher, thermal chemical heat storage (TCS) and hydrogen as carrier and storage of sustainable energy. Still to be developed technologies are, among others, bi-directional district heating networks, heat/cold hub and energy hub.

In addition to this it is assumed that the primary energy use per produced kWh electricity delivered to the power grid will decrease. Nowadays the energy-efficiency has an average of about 39%. This efficiency will increase in 2050 towards 50%.

3.2. Energy hubs

An energy hub is defined as a central point in a district where all energy distribution systems come together and energy can be converted to other energy carriers. In addition vehicles can be refuelled with (bio)gas or liquid bio-fuel there, for example. (Bio)-gas can be used for combined heat and power systems in order to generate heat and electricity. Electricity can be used to charge electric vehicles and to generate heat or cold with heat pumps. Energy hubs will probably be equipped with seasonal storage of heat and cold. Energy management, based on the PowerMatcher™ (Figure 2a) and HeatMatcher (Figure 2b, under development) technology will be used to coordinate the generation, supply and demand of all energy flows and conversions. The energy hub makes sure that the entire renewable energy generation potential of all connected systems will be exploited to its maximum.

Fig. 2a: Supply and demand matching with the PowerMatcher™ [ECN, 2009]

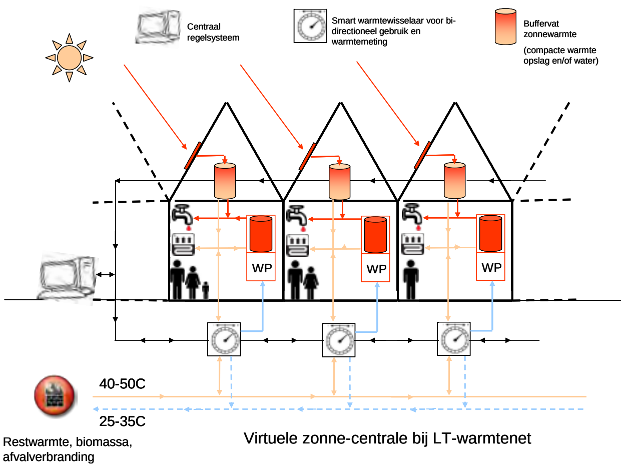

Fig. 2b. Part of a smart heat grid with solar collectors (under development; Willems, 2010)

4. Quantification energy neutrality and sustainable energy surplus

The results are expressed in terms of "degree of energy neutrality" (or energy self-sufficiency). The degree of energy neutrality is defined as the renewable energy generated in a district, divided by the energy demand of that district. If the degree of energy neutrality is higher than 100%, this means that the district can export energy surplus in terms of heat, cold or electricity. Values under 100% mean that the district needs to import renewable (or fossil) energy in order to meet its annually energy demand. Shortage and surplus are expressed in primary energy. It can be shown that the energy neutrality is not strictly depending on the energy demand but of the combination of demand en supply of sustainable energy.

5. Six concepts for energy neutral districts

Six types of energy concepts on a district scale have been developed by means of well considered combinations of the above mentioned technologies. The names of the concepts are derived from its main sustainable energy source: Geo hubs, Bio hubs, Solar hubs, All-electric Natural gas concepts and Hydrogen concepts. Within these six general concepts, fourteen variations have been elaborated. The energy performance, as expressed as the degree of energy neutrality, has been calculated for each concept variation for the years 2020, 2035 and for 2050. These steps give as an example insight in what steps de maximum energy performance can be increased in time.

5.1. Description and performance

The first step in all energy concepts consists of limiting the energy demand by means of refurbishing or renovating according to the passive house standard for existing buildings (Renovated houses have a higher heat demand: 28 kWh/m^2 of floor area annually.). Newly built buildings reach the passive house standard by an excellent building envelope (insulation and air tightness), low temperature space heating and heat recovery from ventilation air. The heat demand for newly built passive dwellings is 15 kWh/m^2 of floor area annually. Both types of dwellings also have heat recovery from waste water. The average roof area suitable for solar energy generation systems such as solar collectors, PV and PVT (combined thermal solar collector and PV) is assumed to increase in time up to 28.1 m^2 per dwelling. This increase mainly is caused by making use of southern orientation of the roofs or other construction possibilities that provides the use of solar energy. On the supply side the main sustainable district sources are thermal energy: geo, bio and solar; electrical energy through PV-panels and urban wind turbines.
In view of the aspiration of an imaginary municipality, concept 4 (all-electric) combined with concept 3 (low temperature storage with ORC or heat pumps) is given as an example of the applications of the developed concepts (Figure 3).

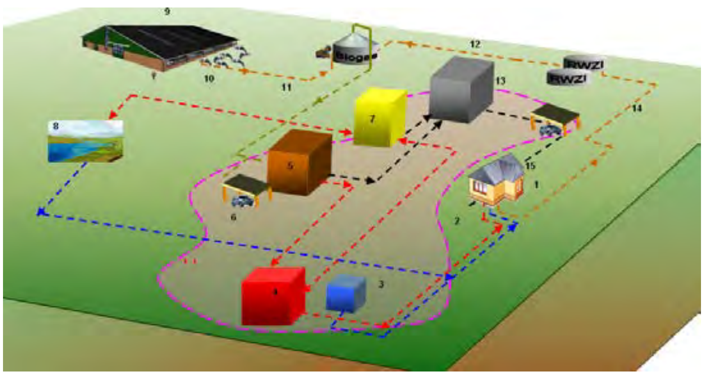

Fig. 3: Energy flows in an imaginary district

1 – Dwellings
2 – Solar heat
3 – ABS chiller
4 – Heat hub
5 – CHP
6 – Fuel tank
7 – ORC
8 – Canal/surface water
9 – Stables
10 – Fertilizer
11 – Biogas
12 – Sludge
13 – Electricity Hub
14 – Sewage
15 – PV-panels

The energy performance of the energy concepts has been calculated in an Excel model.

The performance of the main energy concepts and their related variations are presented in Table 1 below.

Table 1: Degree of energy neutrality of the concepts in 2020, 2035 and 2050 [ECN]

	ENERGY CONCEPTS	Individual or collective	Cooling	Degree of energy neutrality [%] 2020		2035		2050	
				Transport excl	incl	excl	incl	excl	incl
1	**Waste Heat and/or Geothermy (Geo-Hubs)**								
	High temperature waste heat utilization or geothermy	District heating	Compression cooling by PV or sorption cooling by solar	96	61	120	73	**164**	**96**
2	**Waste Heat and/or Biomass (Bio-Hubs)**								
	Moderate temperature waste heat utilization	District heating	Compression cooling by PV or sorption cooling by solar	93	60	119	72	**163**	**95**
3	**All-Solar concepts (Solar-Hubs)**								
	High temperature storage of solar heat	District heating	Compression cooling by PV or sorption cooling by solar	53	34	73	45	**130**	**76**
	Low temperature storage with ORC or heat pumps			47	30	72	43	**131**	**76**
4	**All-Electric concepts**								
	Individual electric heat pumps, PV and solar collectors	Individual	Free cooling by ground heat exchanger	71	45	102	61	**150**	**87**
	Individual electric heat pumps and PV			73	47	106	64	**157**	**92**
5	**Conventional concepts with PV**								
	Individual gas boilers with PV	Individual	Compression cooling by PV	36	23	64	38	**112**	**65**
	Individual gas boilers, solar collectors and PV		Compr. or sorpt. cooling by solar	38	24	65	40	**114**	**67**
6	**Hydrogen concepts**	Individual	Free cooling by ground heat exch.	15	7	57	30	**115**	**54**

In 2050, all concepts can provides in a energy surplus, unless personal transport in the district is included.

5.2. Interaction between district energy concepts and scale

The actual size of a district is determined by the energy losses of the heat transport grid. Too long transportation pipes (heat) give high losses (about the same quantity) compared to the energy demand. Several energy concepts together perform energy neutral districts on a larger scale than apart due to energy exchange by energy hubs where a meso scale develops. On a macro scale we can imagine geothermal energy and large scale wind turbines. The areas between the built environment (e.g. agricultural land, oceans) can provide in wind, bio mass and hydro power for other purposes than the built environment (industry transport etc). Examples are given in table 2.

Table 2. Techniques per scale of energy concepts

Micro level (1-40 houses)	Meso level (40-4.000 houses)	Macro level (> 4.000 houses)
Solar energy	Bio mass	Bio mass
ATES / ground source heat pump	ATES	Mine water energy
PV-panels	Geothermal energy	Geothermal energy
Urban wind turbines		Large scale wind turbines

In figure 4 visualisation of the interaction between energy neutral concepts is given. Smallest circle is representing the scale of an energy concept on micro level. In this vision energy concepts based on natural gas only have a function if only a part of the built environment is energy neutral. Through energy hubs the surplus of sustainable energy can be used in other districts. In case of only energy neutral districts except one there is a surplus on renewables and still using natural gas, an unwanted situation.

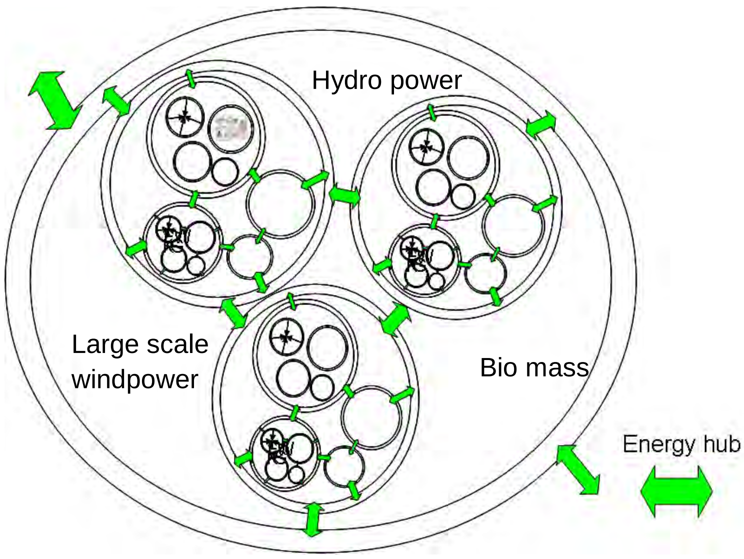

Fig. 4.Visuliasation of the scale and interaction between energy neutral district concepts (Willems 2010 [7]).

5.3. Robustness and sensitivity

Sensitivity analysis are grouped in three classes: screening methods like OAT-method (One-Parameter-At-a-Time), local sensitivity methods and global sensitivity methods [8]. In the sensitivity analysis of the Excel tool, a screening method is used, because is a relatively simple method that can identify and qualitatively rank the parameters that has the most influence of the tool's outcome. To evaluate the robustness of the calculations on the energy concepts energy performance a short sensitivity analysis is performed. These values are specified in Table 3 as averages per dwelling.

Table 3. Input parameters used in the sensitivity analysis, including the stratified samples per parameter

Parameter	Unit	Discrete values				
ATES efficiency	[-]	*20%*	*40%*	*60%*	*80%*	*100%*
Space Heating	[GJ_t]	4.5	6.5	8.5	10.5	12.5
Domestic electricity usage	[GJ_e]	*70%* 8.8	*85%* 10.7	*100%* 12.6	*115%* 14.5	*130%* 16.4
Percentage renewables national generation	[GJ_{pe}/GJ_e]	*20%* 1.6	*30%* 1.4	*40%* 1.2	*50%* 1.0	*60%* 0.8

The sensitivity index is defined as a percentage of the output difference of the extreme values according to:

$$SI = \frac{\text{Emax - Emin}}{\text{Emax}} x100\% \qquad (1)$$

where the maximum and minimum degree of energy neutrality are represented by respectively E_{max} and E_{min}. The results of the screening analysis are illustrated in Table 4.

Table 4. Sensitivity Index of the varied parameters per concept first impression analyses

Parameter	Concept													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ATES efficiency					56%	57%	30%	30%						
Space heating	16%	16%	16%	16%	25%	16%	25%	24%	19%	20%	39%	37%	37%	19%
Domestic electricity usage	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	40%
Percentage renewables national generation	13%	13%	13%	13%	4%	3%	3%	4%	9%	11%	29%	21%	21%	1%

Energy concepts with heat hubs have a surplus in sustainable heat. They are less sensitive to energy demand of heat. Energy concept that have a surplus on electricity are very sensitive to de efficiency of the power grid as well as very sensitive to de heat demand. The figures in table 4 show that de heat-hub concepts are more robust than the all-electric and natural gas concepts.

6. Conclusions

The aim of a built environment without any need of fossil fuels is still ambitious but becoming a realistic goal. Building techniques and energy storage will become market ready in 10-20 years an will provide the missing links in the energy concepts.

Based on the conducted research the following conclusions can be drawn:
- Energy neutrality of the built environment can only be reached by an extensive reduction in energy demand. Sun oriented new buildings and new and renovation building development according to the passive house standards and development of high-performance heat recovery from warm waste water are essential.
- In 2050, energy neutrality is feasible with several energy concepts. The geo and bio hubs and the all-electric concepts lead to the highest degree of energy neutrality, followed by solar hubs. Conventional and hydrogen concepts realise the energy neutrality only barely. The fact that all elaborated concepts lead to energy neutrality in 2050 or earlier means that the transition based on the current energy infrastructure is possible. This way, the investments already made can remain profitable.
- Based on the assumptions made here, energy neutrality of the built environment including personal transport is not feasible within a district. Because the production of renewables in maximized only energy neutrality with personal transport can be reached by reducing transport or increasing efficiency of transport vehicles.
- Energy concepts with sustainable heat form local sources (ground, biomass, solar) are more robust due to changes in energy demand and efficiency of the power grid. It can be derives that diversification of sustainable energy sources is preferred above all-electric.

7. Follow-up steps

The research will be continued on various aspects of the above-mentioned energy concepts. The energy hub concepts seem very promising. It would be interesting to elaborate various types of energy hubs to a level of preliminary design for certain cases in communities and districts as presented by ECN [9].

An energy hub will be dynamically simulated in order to prove the added value of the exchange, conversion and storage of the energy flows within a district.
Next to the energy and CO_2 reduction, a further research can be done on clever utilisation of temperature levels of energy flows within an energy hub.

For future investigation it appears that the availability of sustainable sources becomes more important than the specific efficiency rates in energy conversion. In case of complete energy neutral districts only availability of the appropriate cost effective energy carrier for a specific energy demand is of importance, not the way it is generated or converted.

Acknowledgements
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A Forecast of Effective Energy Efficient Policies for the Building Sector in Shanghai through 2050

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Abstract: Currently in China, the energy consumption of buildings is increasing rapidly. In this study, we used a macro-model to forecast the energy consumption of buildings in Shanghai through 2050. Total energy consumption from 2000 to 2050 and the potential energy savings were projected for both the residential and commercial sectors. For urban residential buildings, we developed a forecast model for 2050 to estimate the potential energy savings of residential measures. Compared to the business-as-usual (BaU) scenario, implementation of residential measures achieved a 24% reduction in energy consumption. The reduction rate rose to 65% by combining the implementation of residential and electrical measures. For commercial buildings, we first used official statistical data to determine the energy intensities of air conditioning, lighting, computing, and other thermal uses for the base year 2000. Then, estimates of the labor force, GDP, and floor area were predicted through 2050 according to past growth patterns and the literature. Likewise, estimates for energy intensities through 2050 were projected. Energy-saving scenarios also were integrated into the commercial model. Compared to BaU scenario, implementation of commercial measures achieved an 80% reduction in energy consumption. The reduction rate increased to 99% by combining commercial and electrical measures.

Keywords: *Shanghai, Energy consumption, Buildings, Forecasting*

1. Introduction

At the UN Climate Conference in Copenhagen in 2009, the European Union formulated the goals that temperature increase by no more than 2 °C, that global emissions peak no later than 2020, and that by 2050 global emissions be reduced to a level that is at least 50% below the figure for 1990. These goals require action by both industrialized nations and developing countries (Gaines and Jager, 2009). In the Copenhagen Accord, the Chinese government announced mitigation action to reduce CO_2 emissions per unit of GDP by 2020 to 40-45% of the 2005 level. This target was reaffirmed at the 2010 UN Climate Conference in Cancun. However, the most efficient way to achieve this reduction goal remains an unsolved problem.

In recent years, the economy of China has developed rapidly, which encourages demand for higher living standards and energy consumption. In this paper, we focus specifically on urban buildings in Shanghai, which is one of the biggest cities in China and has the highest GDP among all Chinese cities. First, we investigated the environmental performance of both residential and commercial buildings in Shanghai. Then, to quantify their sustainability, we developed macro-models to forecast CO_2 emissions for both residential and commercial buildings. The forecasts include global warming countermeasures and are intended to support decision making for determining reasonable CO_2 emission reductions.

2. Methodology

2.1. Residential Projections

2.1.1. Summary of the macro-model

The macro-model used for the residential sector has been modified from the "Estimation Macro-model for Residential Energy Consumption" (Ikaga, 2004). The flow chart in Fig. 1

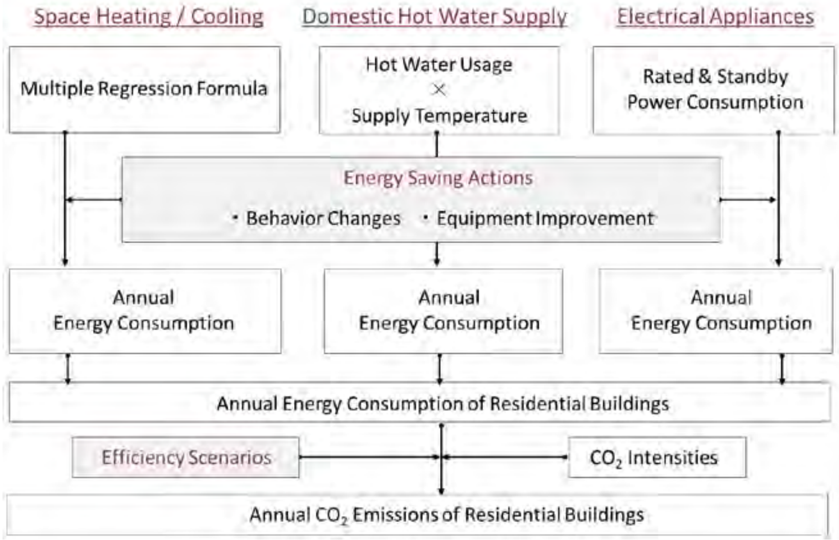

Fig. 1. Flow chart of the residential sector macro-model.

provides an overview of the model. It is a simulation model that estimates changes in energy consumption on the basis of family type, application, and energy source for each year. Estimation methods are described below.

Space heating/cooling: Annual load per household was calculated using a multiple regression equation for heating and cooling load. The annual total load of each city was computed multiplying the number of households of each household type by the energy use for the respective household type and taking the summation.

Domestic hot water supply: The total load of each city was calculated using the frequency of hot water use, the number of households and the average temperature of tap water for each month. Furthermore, energy consumption was calculated using the ratio of owned equipment and the average coefficient of performance (COP) by fuel type.

Other electrical appliances: Energy consumption was calculated as the product of the cumulative energy consumption per household per day and family type, the number of households, and the number of days in each month.

Total CO_2 emissions: By totaling the results of the three functions calculated above and multiplying by the CO_2 intensity of electricity for each energy source, we calculated the annual total CO_2 emissions.

2.1.2. Model parameters

The present model is based on a macro-model that was used to calculate the national residential CO_2 emissions in Japan. For the case of Shanghai, we switched the entire calculation database. The parameters that were set include the number and size of households, average gross floor area, and several pieces of household data. The parameters come either from official statistics or are based on the Chinese government development plan.

There were several parameters for which we could not find a source. To set these parameters we referred to data for the Japanese city of Fukuoka in place of Shanghai, as the two cities have similar latitudes and climates.

2.1.3. Scenarios

In this study, two scenarios are examined: one for residential measures and another for electrical measures. In the residential scenario, we recommend behavioral changes and equipment improvements as global warming countermeasures, having taken into account the social conditions and citizens' lifestyles in China. All the measures are listed in Table 1.

Table 1. Residential measures.

Scenario	Measure	Implementation rate (by 2050)
Behavioral changes	1. Regulation of room air temperature (Heating: STD -2 °C; Cooling: STD +1 °C) 2. Regulation of space heating and cooling operation time (STD×0.75) 3. Reduction of hot water supply temperature (STD +1 °C) 4. Reduction of hot water use 5. Using cold water during summer 6. Unplugging electrical equipment when not in use 7. Only washing clothes when there is a large load 8. Washing clothes using shorter cycles 9. Closing the lid of warm-water cleaning toilet seats 10. Adjusting the temperature setting of warm-water cleaning toilet seats	Implemented by 50% of all households
Equipment improvement	1. Old air conditioners replaced by energy-efficient models	Increase of COP: Heating from 3.0 to 8.0; Cooling from 4.0 to 8.0
	2. Enhancement of thermal insulation level	All houses meet new standard
	3. Water heaters replaced by heat pumps	Increase of COP: 3.0 → 6.0
	4. Use of water-saving shower heads	Implemented by 50% of all households
	5. Kerosene water heaters replaced by heat pump models	Electrification rate increases 2.5% every 5 years
	6. Replacement of incandescent bulbs with compact fluorescent lamps	Implemented by 50% of all households
	7. Accelerating the adoption of eco-appliances	Reduction of power consumption: 70% reduction of refrigerators, 75% reduction of TVs (compared to 2005)

As for electrical measures, the electric utilities made contributions to global warming mitigation. The CO_2 intensity of electricity in Shanghai was 1.027 kg-CO_2/kWh in 1990, which we use as the baseline figure (100%). The NDRC scenario was based on data from the National Development and Reform Commission (NDRC) of China. According to NDRC, the emissions rate will decrease to 80% of the baseline amount by 2030. The METI scenario was proposed by the Ministry of Economy, Trade and Industry (METI) of Japan. In the METI scenario, the reduction rate of the CO_2 intensity of electricity will be even larger, to 40% of the baseline amount by 2050.

2.2. Commercial Projections

2.2.1. Summary of the macro-model

Figure 2 shows the estimated flow chart of the macro-model applied to the commercial sector. Total energy consumption was divided into two parts: air conditioning and other electrical appliances. Air conditioning includes cooling and heating; other electrical appliances include lighting, computers, and other heating devices. The macro-model is a simulation model that estimates changes in energy consumption according to building type (retail space and hotels, office buildings, warehouses, education facilities, hospitals, and personal services facilities and others) and application (air conditioning, lighting, computing, and others) over a 5-year period.

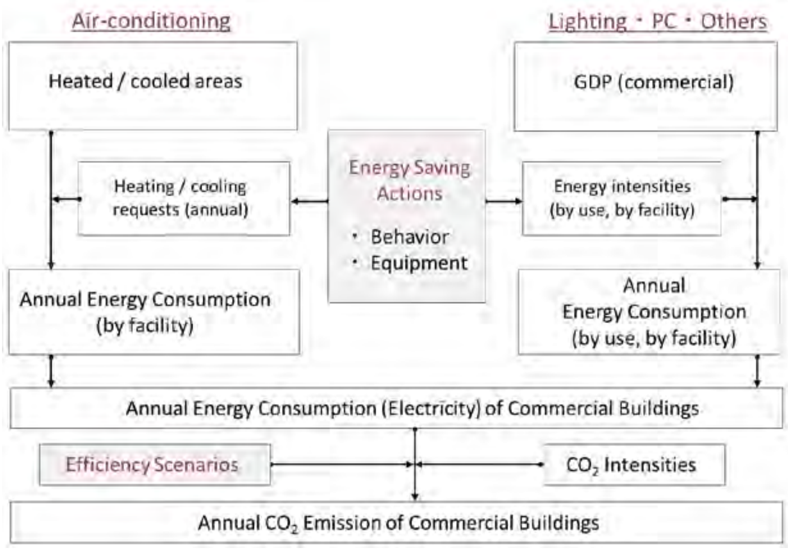

Fig. 2. Flow chart of the commercial sector model.

The commercial model is also a bottom-up engineering model that estimates energy consumption similarly to the residential model. Hence, we analyzed the connection between GDP and penetration rates of electrical appliances in the past 10 years to project penetration rates though 2050.

2.2.2. Model parameters

Because this is prediction research, every parameter was set through 2050. The data for 2000 and 2005 were primarily from the *Shanghai Yearbook*. Parameters for future years were based on relevant literature and the author's assumptions.

For the GDP projection, we referred to research results from the Department of Foreign Affairs and Trade (Wu, 1997) that suggested Chinese GDP will continue growing sharply and overtake the GDP of the United States by 2020. We then looked at the historical growth patterns of another Asian country, namely, Japan. Japan has also been through a period of high growth and development, starting with the "Golden Sixties" and ending with the "Lost Decade." After this period, growth became stable and the trend line became flat. China is now going through a period of high growth. On the basis of the two perspectives above, we assumed that this unusually high growth in China will last until 2030, at which time it will start slowing down. The GDP of Shanghai's service sector was projected through 2050 using this same trend line, as shown in Fig. 3 (left). Using a similar approach, we also projected the labor force and gross floor space for the next 40 years. For the labor force projection, we referred to the population projection by the Shanghai Municipal Population and Family Planning Commission (SMPC) and calculated labor force as a share of the overall population. For gross floor area, we analyzed the growth pattern over the past 10 years (Xing, 2010) and projected future gross floor area through 2050, as shown in Figure 3 (right).

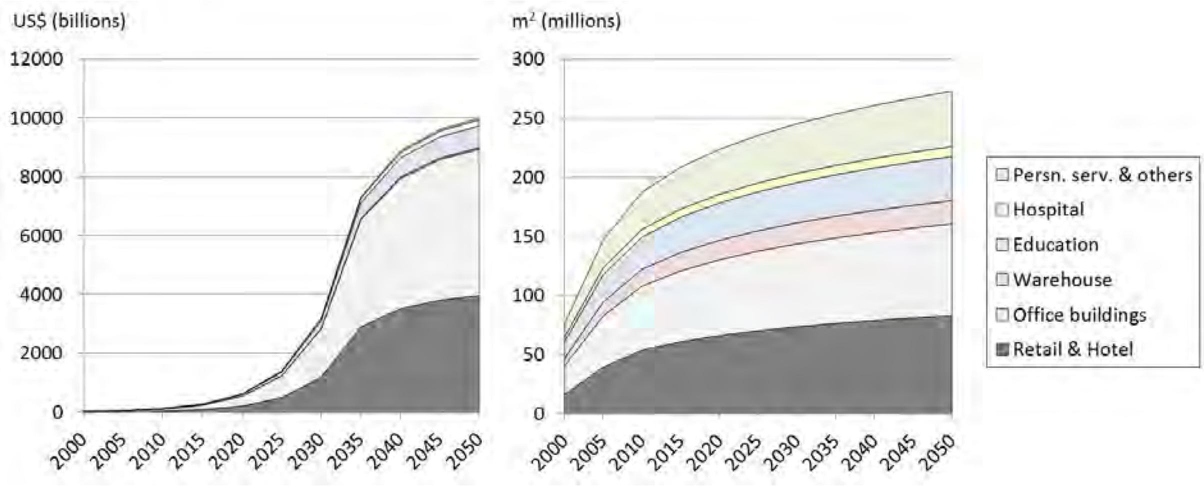

Fig. 3. Projected GDP (left) and floor space (right) through 2050.

Table 2. Commercial measures.

Electrical application	BaU	Energy saving scenarios	
		Behavioral changes	Equipment improvement
Air conditioning	Heating 18 °C, cooling 26 °C COP: 3.54	Heating 17 °C, cooling 27 °C Operational time × 0.75	COP: 3.54 → 8.0
Lighting	Lighting is used all day	Turn off the lights when away	Adoption of LED lighting
Computer	PC enters sleep mode after work	Shut down PC after work	Adoption of ECO-PC
Other heating devices	Waste of standby power	Unplugging electrical equipment when not in use	None

COP: Coefficient of Performance

2.2.3. Scenarios

Two projection scenarios for the commercial sector were also examined: one for commercial measures and another for electrical measures. As for the residential sector, we recommend behavioral changes and equipment improvements as global warming countermeasures for the commercial sector. Table 3 shows the operating power settings for electrical applications by building type under different energy use scenarios. In the Global Energy Assessment (GEA) electrical scenario, the CO_2 intensity of electricity will decrease to 10% of the baseline amount by 2050.

Table 3. Operational power settings by application and building type

	Air condition (COP)		Lighting (W/m^2)	
	BaU	Energy saving	BaU	Energy saving
	(DAIKIN, ZEAS 2000)	(METI)	(GB50189)	(Hitachi Lighting)
Retail and hotel	3,54	6,00	16,00	1,60
Office building			15,00	1,50
Warehouse			5,00	0,50
Education			15,00	1,50
Hospital			15,00	1,50
Personal services & others			12,00	1,20

	Computer (W/hour)				Other heating devices (W/hour)	
	BaU (NEC standard)		Energy saving (NEC eco model)		BaU	
					(GB50189)	(LBNL)
	In use	Sleep	In use	Sleep	In use	Standby
Retail and hotel	300	30	240	24	15,00	0,98
Office building					20,00	
Warehouse					5,00	
Education					20,00	
Hospital					20,00	
Personal services & others					12,00	

METI: Ministry of Economy, Trade and Industry, Japan; GB50189: Design Standard for Energy Efficiency of Public Buildings, China Construction Division, July 2005; LBNL: Lawrence Berkeley National Laboratory

3. Results

We first compared the estimation results with government statistics to verify the reliability of the macro-model (Fig. 4). In the years 1990, 2000, and 2005, total annual energy consumption estimated by the macro-model was very close to the government's statistics, suggesting that this model is reliable.

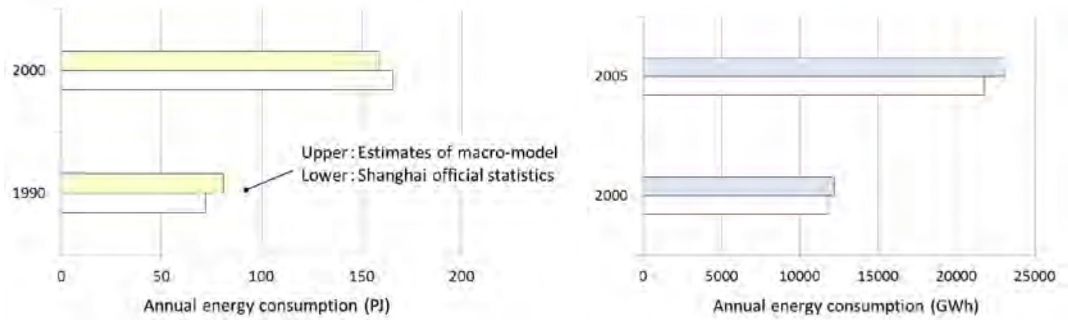

Fig. 4. Macro-model estimates and official statistics for the residential sector (left) and the commercial sector (right).

3.1. CO_2 Emission Reduction of Residential Buildings

The BaU scenario showed a 2.7 fold increase in CO_2 emissions above the 1990 level by 2050. Under the scenario where residential measures are adopted, behavioral changes caused a 6% reduction in CO_2 emissions by 2050 c ompared with BaU. Equipment improvements contributed an additional 18% reduction, which increased the total benefit of residential measures to 24% below the BaU scenario for 2050. When we combined residential measures with the NDRC scenario, the total emissions reductions reached 40%. Residential measures combined with the METI scenario reduced emissions by 65%. Figure 5 (top) shows the projected CO_2 emission reductions for the residential sector by electrical application.

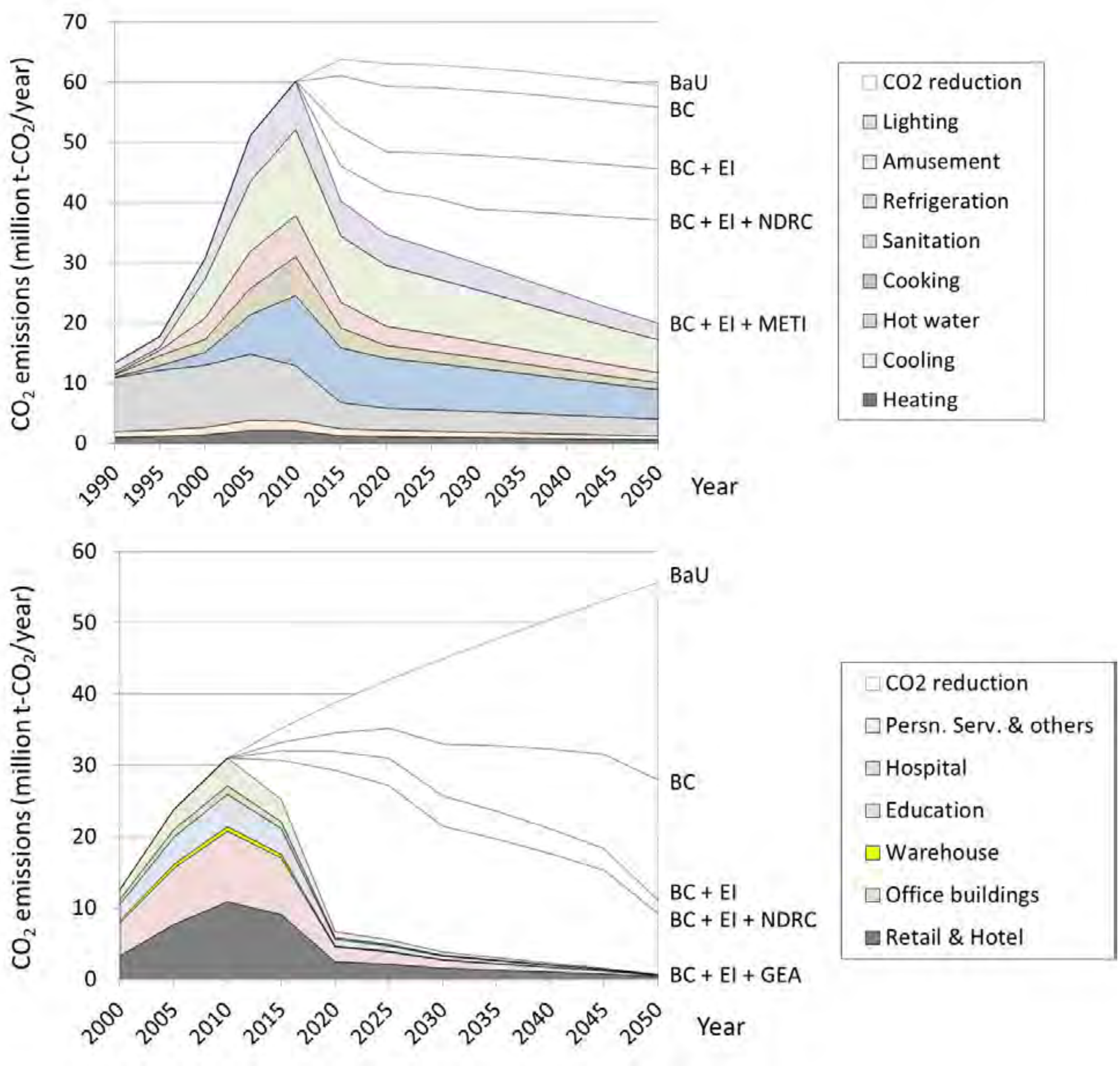

Fig. 5. Projected CO2 emissions for residential buildings (top) and commercial buildings (bottom). BC: Behavioral Changes; EI: Equipment Improvement; NDRC: National Development and Reform Commission of China; METI: Ministry of Economy, Trade and Industry of Japan; GEA: Global Energy Assessment, High case, CPA, WiP 0.5.1

3.2. CO_2 Emission Reduction of Commercial Buildings

Similar to the residential sector, the BaU scenario saw a 3.43 fold increase in CO_2 emissions by 2050 for the commercial sector above the 2000 level. The CO_2 emission estimates for commercial buildings were projected by building type and electrical application. Figure 5 (bottom) shows the results for commercial buildings by building type.

Under the scenario where commercial measures are implemented, behavioral changes caused a 50% reduction of CO_2 emissions compared with the BaU scenario by 2050. Equipment improvements contributed an additional 30% reduction, which increased the total benefit of residential measures to 80%. When we combined commercial measures with the NDRC scenario, total emissions reductions reached 83%. Commercial measures with the GEA scenario reduced emissions by 99%, which means near-zero contributions of CO_2 emissions from commercial buildings.

4. Discussion and Conclusions

In this study, we developed a model to predict the CO_2 emission reduction potentials by 2050 for diverse climates and policy scenarios. For energy savings in commercial buildings, we found that behavioral changes appear to be more efficient than equipment improvement. This finding will likely be appreciated in a developing country like China, since there is a limited budget for large-scale replacement of equipment.

In general, the projections in this research are theoretical. There is no evidence showing that all the suggested energy saving actions could be fully implemented as described in the scenarios projected. However, we hope the results of this research will help decision makers when they look for solutions to achieve CO_2 emission reduction goals in the future.

For the model parameters, we generally relied on the literature and official statistics. In future research, we will schedule local surveys and field measurements in Shanghai. These efforts are expected to improve the accuracy and reliability of the projection model.

Acknowledgment

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The Institutional dimension of rural electrification in the Brazilian Amazon.

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Abstract: The Brazilian government aims at providing complete electricity coverage for all citizens as a means to achieve development and reduce poverty. More than 2 million people living in the Amazon have benefited from the rural electrification program Luz Para Todos (LPT – Light for all), mainly through a grid-extension approach. Yet, there is general agreement on the need for an off-grid scheme in order to supply isolated areas. How can the actual institutional framework support the process of supplying electricity to these communities so that the trend of improving electricity access and quality of life continues? We aim at exploring the existing institutional dimension connected to LPT and identifying potential forms of organization for decentralized solutions in the Amazon region. Our analysis is based on current energy policy in Brazil, existing institutional framework, achievements of LPT and potentialities of the isolated areas in terms of resources. Our conclusions draw attention to potential approaches for the next step within LPT context. We argue that the off-grid approach must be based on the uniqueness of the isolated areas in the Amazon. We emphasize the relevance of renewable energy sources in the process of supplying electricity and securing inclusion of isolated areas in universal access.

Keywords: *Rural electrification, off-grid solutions, renewable energy*

In Brazil, significant governmental efforts have been put in place to enhance electricity access in rural areas since the 1990s. The last of these initiatives is called Luz para Todos (LPT – Light for all). It was launched in 2003 and has so far benefited about 11 million people, two of which live in the Amazon region. In general, grid-based systems have been used for the purpose of providing electricity to new users in Brazil, and the interconnected national grid supplies the majority of the population. Hydropower has been the most important energy source for electrification in the country. Despite its continental dimensions, Brazil has been successful in its program for electricity provision and has achieved about 88% of electricity access in rural areas. This makes Brazil the leader of universal electricity access in Latin America [1]. Traditionally, the availability of huge hydro resources and the search for economies of scale for power generation has promoted the development of a centralized electricity system. The fact that the government has allocated exclusive service territories for concessionaires has further promoted this centralized system [2]. Also the results obtained through the recent development of LPT are in line with the centralized approach, and mainly associated with grid extension for electricity provision. These results have not benefited yet an important group of people living in the Amazon region.

The Amazon region is assimilated hereby to the North region, as per defined in the macro-region division of Brazil. This has been usual practice in studies on the Brazilian Amazon. The Amazon region is the home of nearly 14 million people. and covers about 4 million km^2. This implies a population density of less than 4 inhabitants/km^2. The region is also characterized by a very sensitive eco-system. Extending the grid in this area is neither realistic because of the local topography and natural conditions, nor cost-effective because high investments would be required to benefit a few citizens with low income and consumption rates. Within this context, the target remaining in the Amazon is to provide electricity access to one million people who are still not connected [3]. Current challenges in terms of energy access are related to the exhaustion of the grid-extension model and mainly associated with the provision of services in isolated areas where grid extension is not economically viable. Though a very small percentage of the Brazilian population, the dispersed inhabitants of the Amazon serve the important role of guaranteeing the sustainability of this rich and very sensitive eco-system. Poverty exposure can jeopardize their task. Thus reaching this population in their local environment is important. But here, a different scheme is required, based on decentralized systems and the exploration of renewable energy resources. The decentralized approach is characterized by the generation of power in a location closer to the final users, focusing essentially on meeting local energy needs. But, how to organize the electricity delivery institutionally, and guarantee its technical, economic and environmental sustainability?. There is a well-structured institutional framework which has proved effective for the purpose of improving energy access in Brazil. This institutional framework has successfully provided electricity access to 11 million people throughout the country in a short period of time [3]. However, these results have been achieved through grid extension. The government has recognized the need for developing an off-grid approach in order to provide electricity to the dispersed rural communities living in the Amazon region. Nevertheless, there is a gap between the institutional arrangements in place, which are focused on a model of centralized electricity provision, and the institutional capacity required to develop an off-grid, decentralized model of electrification. This gap needs to be overcome if universalization is to be achieved in the Amazon region [4].

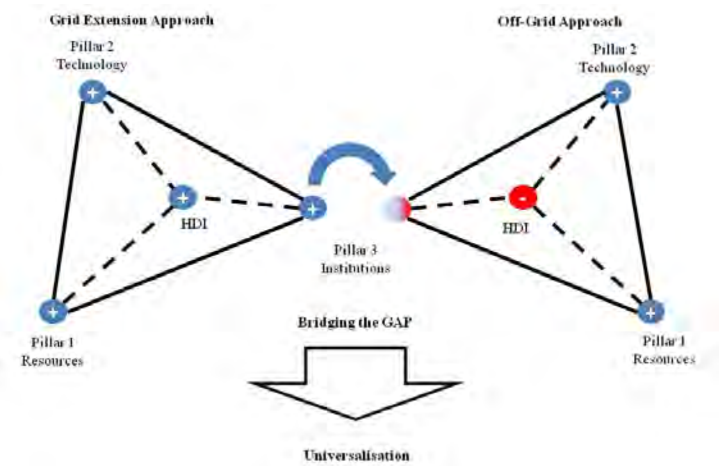

Fig. 1. Bridging the institutional gap for universalization in the Amazon region.

This paper explores the institutional characteristics of LPT and identifies improvements needed for the purpose of implementing decentralized solutions in the Amazon region. Our study has evolved around the analysis of three pillars of the electrification models applied based on grid-extension and off-grid approaches: (i) the resource availability; (ii) the technology applied and (iii) the institutional framework created to support the efforts (See Figure 1). How can the actual institutional framework support the process of supplying electricity to isolated communities so that the trend in improving electricity access and quality of life continues? The three pillars are crucial for the purpose of achieving human development. (see Figure 1). They are analyzed for both grid extension and off-grid approaches in the Amazon region. The isolated systems in the Amazon consider those electricity systems that are not connected to the national interconnected system. Though not interconnected, the majority of these systems have followed a centralized model that replicates, at a smaller scale, the national scheme. Electricity is provided through different approaches: (i) sub-grids that provide the main capital cities and nearby villages, also called Capital Isolated Systems and being developed through a grid-extension approach; (ii) mini-grids that provide electricity to small and remote villages and (iii) stand alone systems. The extension of the sub-grids corresponds, for the purpose of this paper, to a grid-extension approach. On the other hand, the off-grid approach is related to minigrids and stand alone systems.

1. Pillar 1. The Amazon region: the potential of available resources

In face of the unfeasibility of extending the national interconnected grid, smaller but also centralized power plants were installed in order to provide electricity to the main cities in the Amazon. The grid extension approach has relied mainly on fossil resources and today about 60% of the installed power generation in the Amazon is based on diesel power plants. At a lower scale (less than 1 MW capacity per unit), suitable for off-grid applications, about 80% of the generated power is produced using diesel. The remaining 20% is produced using hydro resources [14]. Thus, while offering an opportunity to provide energy access without significantly impact the environment in the Amazon region, renewable sources have not been explored enough. In terms of hydro resources, the Amazon basin shows the largest potential for electricity generation in the whole country, corresponding to about 106 GW, that is, 42 % of the national potential [5]. But a nominal potential of about 1,7 GW has been quantified as appropriated for using small, off-grid hydro power plants [4]. According to the National Electricity Agency –ANEEL, 15 small hydropower plants are already installed. This implies a total installed capacity of just 12 MW in the region and illustrates the magnitude of the unexplored potential [14]. A number of opportunities connected to biomass resources have also been identified and actually implemented. For example, floating residual wood being carried by the rivers is already being collected in order to avoid danger for navigation. It might be used for power generation [15]. The possibility of using vegetable oils either in natura or processed as biodiesel has also been studied and applied at the level of pilot projects [6]. Though seven biomass-based power plants with an installed capacity of about 72 MW are in place in the region, just two of them have an installed capacity of less than 1 MW [7] A wide variety of native species are yet to be explored. Regarding solar radiation, the potential for every location is not well known yet due to the extension of the area and the difficulties in terms of accessibility. However, there is evidence of an average radiation of 5.5 kWh/m^2. This potential has low inter-seasonal variability, which makes it suitable for the purpose of implementing hybrid systems [10]. Finally, wind resource is found mainly in the coastal area and in Roraima, close to the border between Brazil and Venezuela. The average annual wind speed there is higher than 5m/s, suitable for the installation of small scale wind turbines with capacity at the order of 100kW [4].

To summarize, the grid extension and the off-grid approaches in the Amazon have relied on fossil fuels. Given the sensitiveness of the eco-system in the Amazon, widely available renewable energy sources offer an opportunity for fulfilling universalization goals that is still to be explored.

2. Pillar 2: technologies to provide electricity in the Amazon

The traditional grid-extension is not self-sustainable and does not promote sustainable development [10]. Some estimation exist that reveal the need for an additional installed capacity of between 456 MW and 1 GW for the purpose of attending isolated systems [11, 12]. Unlike the majority of the national inhabitants, most of the Amazon population is today supplied through the Isolated Systems. They are characterized by (i) the predominance of diesel-driven power plants; (ii) consumers that are highly dispersed; (iii) the inexistence of economies of scale and; (iv) significant difficulties of logistics for fuel supply in the region

Thermal and hydropower plants have been the main technologies used for both, the grid extension and the off-grid approach in the Amazon. The most significant difference between them is the scale. Since the grid-connected power plants supply the main cities and nearby villages, they usually have a capacity higher than 1 MW. On the other hand, the off-grid options, that is, mini-grids and stand alone systems, are related to power plants with a smaller capacity. The number of installed diesel-based power plants with a capacity inferior to 1 MW is more than ten times that of small scale hydro power plants (Figure 2). Regarding stand alone systems, diesel-based systems with capacities ranging from 10 to 66 kW are the most common. In most of the cases, communities are responsible for the installation and operation of these power plants. Some estimation exists that reveal the presence of about 3000 small-scale diesel driven power generators just in the Amazonas state. Unfortunately, these power plants are not registered in the official records [11, 12].

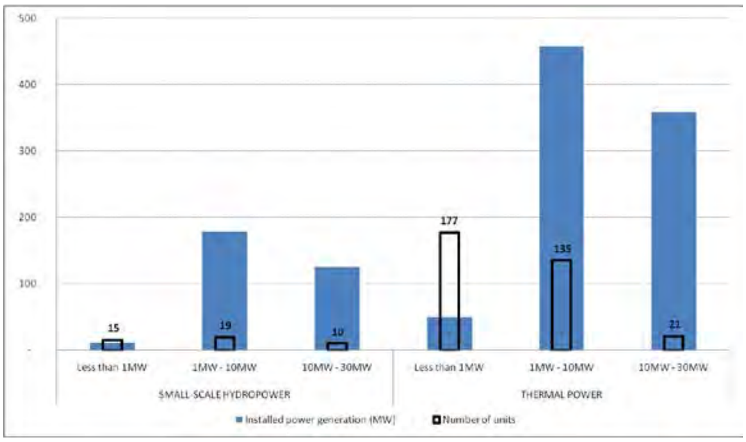

Fig. 2. Installed capacity and number of thermal and hydropower units in the Amazon (Less than 30 MW of installed capacity per unit). Source: [11]

Renewable technologies have in many cases proved cheaper and more appropriate than national grid extension when used in rural electrification [4, 13, 15, 21]. However, except for small hydro power plants, they are not used in the Amazon. The official records register just one photovoltaic system of 20 kW [14]. Biodiesel-based power generation has already shown its feasibility in stationary engines and gains importance in face of the vast biomass resources [6]. Photovoltaic technologies are suitable for lower demands than small hydro or biomass technologies. They have proved effective to provide services such as lighting and clean drinking water. On the other hand, wind energy technologies offer a good cost-competitive opportunity, in some cases with prices below those of PV, particularly effective for hybrid systems (PV-diesel) [10]. In any case, the simplicity, reliability, robustness, environmental aspects and low costs of operation and maintenance are key factors for the selection of the proper technology or mix of technologies (in the case of hybrid systems) to be implemented in a specific location.

3. Pillar 3: The existing institutional framework

LPT has obtained remarkable results in terms of poverty alleviation and human development, measured through the Human Development Index (HDI). These results have been achieved through a significant mobilization of political will and a precise definition of policies to promote full coverage [3] Resource availability, proven and mature technologies for electricity provision and a proper institutional framework have forged the success of LPT under a grid extension model. Isolated areas too have plenty of renewable energy sources that can be explored for electricity generation such as solar power and biomass. But the challenges here are different to harness the resources and provide the technology at the local level. Can the achievements of the grid extension approach serve as the foundation for developing a decentralized approach?. If so, how can the institutional gap be covered so that the goal of universalization can be reached?.

LPT is a national program reflecting a national goal. It has created an institutional structure in which the roles of diverse players are specified at regional and local levels. Along this institutional line of action, responsibilities are attributed to organizations at the various levels, and activities are defined from planning to monitoring. At national level, a National Commission of Universalization (NCU) is in charge of defining the policies that lead to full coverage in the country and use electricity access as a driver for development. The multi-sectorial support of the policies, as per exemplified by the participation of as many as 13 ministries, together with the operationalization of the policies guaranteed by the regulator (The National Energy Agency -ANEEL), and the financial support of Brazil's major development bank are noteworthy. The National Management Committee (NMC) acts transversally, coordinating, supervising and monitoring the actions of the programme throughout the country. The coordination role is in the hands of the Ministry of Mines and Energy (MME). Eletrobras, a federal company controlled by the Brazilian government, is responsible for the Operational Secretariat and administers the financial resources provided by the corresponding sectorial funds At the regional level, the Territorial Committee accompanied by the State Management Committee (SMC) identifies and prioritizes electricity demand. The SMC receives and analyzes the demand requirements that are provided by the communities. At the local level, the concessionaires, together with the civil society act in the implementation of the program through specific projects. They work in close cooperation for the purpose of identifying actual energy needs. [8] .The monitoring activities have received particular attention and institutions at three levels have been designated to develop them. Eletrobras and ANEEL are in charge of watching over the statement of commitment signed between the Federal Government, states and implementing agents

Table 1 shows the main competences of the existing institutions involved in the development of LPT. Whilst this matrix does not show the entire spectrum of competences in every institution, it does give a good illustration of the main capabilities that serve the LPT at three different levels, national, regional and local, with the purpose of accomplishing 100% electricity coverage in the country. It also shows the preponderant role of the concessionaires at the local level, as they are the only ones directly involved in the implementation activities. This is the result of the regulation considering exclusive service territories for concessionaires. It also emphasizes a strong connection between existing technologies and implementing agents. In other words, concessionaires' expertise has grown based on the implementation of hydro and diesel-based power plants. In the search for universal access and based on the existing interconnected electricity system, Brazil has built a well structured rural electricity policy that is anchored at national, regional and local levels. However, the traditional and strongly grid-oriented approach has reached physical and economic limits in the Brazilian Amazon. It cannot be further developed. In terms of institutions, this approach has enhanced a concession model that is in its nature exclusive and creates difficulties for new stakeholders to come into the system. There is a need for a new approach focused on the demand-side and a decentralized approach, requiring different technologies and a different institutional framework. How will that be delivered?

In the process of providing universal access, the government has recognized the need for these new players and has taken action, creating some possibilities for them to be active. The government has started the process to close the existing gap and the law has allowed the participation of new players within the existing concessions, where the concessionaires are not able to fulfill universalization targets. These possibilities are restricted where exclusivity contracts have been signed and further action from the government is limited by this fact. Yet, it is also possible for the concessionaires to establish commercial agreements with technology providers [2].

Table 1. Main competence of the institutions connected to LPT.

		Competences							
Level of action	Institutions	Policy	Regulation	Coordination	Integration	Prioritization	Operational Secretariat	Implement.	Monitoring
National	National Commission of Universalization NCU)	x							
	National Agency of Electricity (ANEEL)		x						
	Ministry of Mines and Energy			x					
	National Management Committee				x				x
	Eletrobras						X		x
Regional	Regional Coordinators			x		x			x
	State Management Committee								x
Local	Implementing Agents (concessionaires)							x	

Prepared by authors based on [8, 9]

4. Bridging the gap. Discussion and conclusions

The need for an off-grid approach has been generally recognized. Yet, the institutional framework for promoting the electricity access has not been modified or complemented for the purpose of appreciating the peculiarities of the isolated communities in the Amazon [9]. The Amazon is rich in renewable energy sources and various technologies can be applied for the purpose of providing electricity to isolated communities. These technologies have been identified by the government as critical for the purpose of reaching universalization [1, 18, 19].but the concessionaires do not have knowledge related to their installation and operation. This means that knowledge on a wide range of technologies could be better adjusted to the off-grid needs. The question is then if this implies the need for new agents for implementation, operation, maintenance and monitoring of the new off-grid systems. In this context, technology providers, community organizations and academic institutions, knowledgeable on specific renewable technologies, could add to the capacity that has been built by concessionaires in terms of management and operation of small scale thermal and hydropower plants. However, their action is limited by the existence of long-term contracts that give exclusivity to concessionaires.

Nevertheless, the concessionaires do have valuable information on the location and energy consumption trends in some of the isolated areas where they have been active and have worked in cooperation with local communities. This communication channels have been opened thanks to LPT. Local organizations, closer to the isolated communities, could then be responsible for some of the activities that today are in the hands of the concessionaires and that imply costly operation, maintenance and after-installation activities, due to the fact that concessionaires are located far away from the final users.

Thus, in order to reach universalization, the involvement of the concessionaires needs to be complemented with actions from other agents that can provide their expertise. An opportunity for existing institutions and new agents emerges for the purpose of providing electricity to the isolated areas. Actions from these new agents integrated with those from existing stakeholders could enhance the development of the required off-grid approach. Clear responsibilities for both private and public stakeholders are required to generate, distribute and supply electricity to rural inhabitants under a decentralized approach. Now, the need for a clear set of rules for new comers arises. It also does for concessionaires in connection to their new role. They could work at local level in cooperation with organizations with knowledge on the required new approaches and technologies. Technology providers, international entities and universities are examples of this type of organizations. The fact that communities are isolated and usually located far from the concessionaires raises the need for the participation of community organizations that are closer to the communities and can communicate with them easily. Such is the case of NGOs or cooperatives that have not been very active due to the existing centralized approach. Further, due to the size of the off-grid systems, management and operational skills requirements are less strict than those required to operate and manage centralized facilities. This could encourage the participation of local communities using local skills to operate the off-grid systems.

The design and implementation of the required institutional framework is complex due to the intervention of diverse public and private actors such as electricity companies, final users, funding, controlling and regulating institutions, national and local governments among others. Each of these agents has particular goals and creates the need for a clear set of rules to act. In this sense, actions from the government are crucial. There is no unique solution rather a combination of solutions that can be adopted. There are strengths that can support the process of universalization if properly complemented with the action of existing agents and new comers to be considered within the framework of LPT. Yet, clear rules are needed in order to build an enabling framework that brings together potential institutions and stakeholders when it comes to off-grid electrification of isolated villages. The governmental commitment exists and the recognition of the role that electricity access can play in addressing and achieving development goals is already in place. Now, the time has come for leading the establishment of a clear set of rules that facilitate action from the required agents and can support the development of a new and urgently needed approach.

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The Mágina Project. The renewables potential for electricity production in the province of Jaén, southern Spain

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Abstract: Nowadays, the global energy generation system relies mostly on fossil fuels. However, their foreseen depletion for the forthcoming decades puts at risk the current schema and suggests a gradual transition to a more self sustainable system. Consequently, the European Union (EU) committed in March 2007 to set a binding target for 20% of the EU's total energy supply to come from renewables by 2020. In this work, we tackle the study of the renewables' potential for electricity production in the province of Jaén (southern Spain), which has a pronounced unbalance between its inner electricity production and consumption. The potential of biomass from olive trees, solar photovoltaic (PV) and wind power has been analyzed using Geographical Information System tools. As a preliminary result, it has been proposed the installation of 5 biomass facilities, with an estimated production of 735 GWh per year, 10 PV facilities, with an estimated production of 534 GWh per year, and 50 windmills, with an estimated production of 172 GWh per year. Overall, these three resources together would be able to increase the rate of produced to consumed electricity in the province from a 30% to a 77%.

Keywords: *renewable energies, electricity, distribution grid, regional development*

1. Introduction

The foreseen depletion of fossil resources is forcing us to seek for new energy springs. However, the climate change issue claims for non-pollutant solutions that help in mitigating the global warming. Even more, due to the world's economic development, it is expected that the worldwide demand for electricity will increase by 80% between 2006 and 2030 [1]. This global scenario makes unavoidable the transition to more and more renewable energy shares.

Therefore, promotion of renewable energies will play a major role as it is also indicated by the European Union (EU) objectives by 2020. They set a binding target for 20% of the EU's total energy supply to come from renewables by 2020 (6.5% in 2007). Furthermore, they set a firm target of cutting 20% of the EU's greenhouse gases emissions by 2020 relative to 1990. Additionally, Europe has a marked dependence on outer energy imports (50%) provided its lack of own fossil resources. In Spain, particularly, the dependence is even higher, reaching the 85%. Hence, the national government has promoted in the last years the renewables through various ambitious national plans [2] which, additionally, pretend to accomplish with the EU's commitments through, among other, a 30% target contribution of renewables for electricity production.

The province of Jaén is situated in the southern part of the Iberian Peninsula (Fig. 1). It occupies an extension of roughly 13 500 km^2 with a population totaling 669 000 inhabitants. Its economy is principally based on the olive oil industry. Actually, the olive oil production in Jaén is the 20% of the worldwide production and the 50% of the Spanish one. Its territory is divided in two different topographic regions: the south-eastern and the northern façades, which are traversed by mountainous systems, and the region in between, a well-flat area which houses the higher part of the Guadalquivir river basin. The highest peak is the Mágina Peak, in the southern façade, with 2 167 meters above sea level.

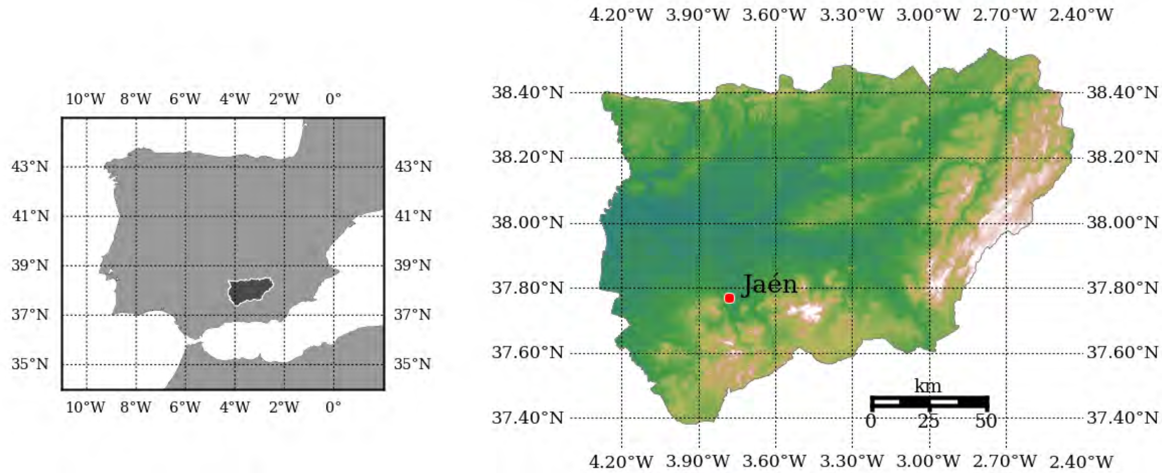

Figure 1. Geographical location and topography of the province of Jaén.

As the rest of Europe and Spain, Jaén has a high dependence on fossil fuels. As far as electric energy concerns, the region has a negative balance in production/consumption. Particularly, in 2008 the actual inner production of electricity was only about 940 GWh, against a consumption of about 3 080 GWh in this same period [3]. This situation strongly contrasts with the rest of Spain, where the electricity production/consumption is well-balanced. Particularly, in 2008, total production and consumption were about 296 000 and 275 000 GWh, respectively [3].

In order to correct this unbalance in the province, fossil fuels should not be a choice. Instead, local renewable resources are a real alternative with huge potential still to be developed. However, in spite of the high potential, currently, about 84% of the electricity is produced in thermal plants, most of them, combined heat and power plants. Out of this 84%, only a small rate comes from biomass residuals. The rest of the electricity share is produced by hydro-power stations (9%), solar photovoltaic (PV) (4%) and wind power (3%) [3].

Biomass is an important energy spring in the province, mainly, from agricultural residuals as prune wastes and olive stones, for instance. Currently, it represents around a 20% of the primary energy consumption, mainly for heating [4]. However, just the biomass from the olive prune is estimated to be about 3 tons per hectare and year [5]. Hence, the more than 600 000 ha of olive crops in the province are a resource that deserves to be exploited. Additionally, the province also has a considerable potential from solar and wind resources. Particularly, Jaén is one of the sunniest regions in Spain, with more than 1 700 sunshine hours a year. The electric production from wind farms is also a feasible approach as it has been already demonstrated by some plants that operate in the region.

In this work, we intend to tackle an estimation of the real potential for electricity production in the province of Jaén from local renewable resources: biomass, solar PV and wind power. It pretends to be a solid background to develop an optimum plan for a massive intervention in the electric grid that correct the current unbalance between electricity production and consumption based purely on renewable energies. We here propose a preliminary distribution of the production plants based on multiple criteria as the resources distribution, availability of feed-in points in the grid or even distribution of the plants along the region. However, this initial distribution is still subject to modifications based on on-going tasks, as a deeper investigation of the current state of the local electric grid or environment and economic issues.

2. Methodology

Firstly, the different resources availability has been independently evaluated using a suitable approach in each case. Afterwards, they have been jointly analyzed by using geographical information systems (GIS) tools. With these tools, digital models with the spatial distribution of the resources have been created considering restrictive criteria as topographic features or soil type and use. These maps allow estimating the real potential for electricity production from renewable resources and a subsequent analysis based on environment, social and economic criteria; currently, an on-going task.

2.1. Biomass potential from olive tree residuals

This part of the study has involved two different stages: (i) the evaluation of the total amount of biomass residuals available from olive trees and, (ii) the evaluation of the electric performance that could be achieved.

The first stage required an intensive use of GIS tools. Firstly, soil use maps of the province were used to isolate the olive crops in the region. Among them, only those areas with a terrain slope less than 20% were considered as useful for exploitation. The rationale behind is that terrains with higher slopes make difficult the use of agricultural machinery, thus considerably increasing the management and transport costs of the residuals. Once the total (useful) area of olive crops available for exploitation was determined (S_{crops}), the total amount of residuals (*BR*, biomass residuals in kg per year) was evaluated based on the biomass residuals production index (*BRI*) for olive trees. It indicates the biomass residuals availability per ha and per year. Therefore:

$$BR = S_{crops} \times BRI. \quad (1)$$

The value of the *BRI* parameter for olive trees was extracted from previous research works conducted by the Andalusian Energy Agency and the Agricultural Department of the Regional Government of Andalusia [6, 7]. Following the recommendations of these studies, two different *BRI* values were used for irrigated and dry lands. This terrain classification was conducted based also on the soil use maps of the region.

In order to assess the potential electricity that can be generated from these biomass residuals, we were based in the operation data accumulated in some biomass plants that are already operating in the province and the rest of Spain.

2.2. Photovoltaic potential

The solar PV potential assessment also implied a two steps procedure: (i) the evaluation of the solar resource potential and, (ii) the electricity potential generation based on the resource availability.

In order to evaluate the solar resource, the clear-sky solar radiation model of the European Solar Radiation Atlas (ESRA) was used in its version implemented in the GRASS GIS platform [8]. The ESRA model has been profusely used in practical applications as the determination of solar radiation maps from satellite imagery [9] or the generation of databases from ground measurements as the PVGIS web platform. This model parameterizes the effect of the atmosphere based on the Linke turbidity coefficient (T_L), which represents the number of Rayleigh atmospheres radiatively equivalent to the actual atmosphere. The Linke turbidity is a climatic and dimensionless parameter which has been traditionally calculated on a monthly basis from satellite and ground measurements. It is freely available in wide databases as the SODA dataset.

The second step involved the assessment of the potential electricity produced from this solar resource. The evaluation was based on a traditional fixed PV system with panels inclined 30º degrees over the horizontal and permanently oriented to the south. This reference configuration is close to the optimal for the latitudes of the region, thus enabling us to estimate the real PV potential. The recovered energy, E_{PV}, was estimated considering the practical rule that installation of 1 MW_p requires approximately a parcel of 2 ha. Therefore:

$$E_{PV} = \frac{G}{G_p}\frac{1MW_p}{2ha}P_R, \tag{2}$$

where G is the total irradiance that strikes the PV panel, G_p=1000 Wm^{-2} and P_R is the performance ratio, which accounts for the different system losses. Based on our own experience, we took P_R = 75%.

The use of this methodology presents various advantages. On the one hand, as the model is integrated within a GIS, it is able to account for the topographic shading effect of surrounding terrain elevations. On the other hand, it allows us to calculate the solar radiation components with a high temporal resolution (in this case, every 12 minutes) which is essential to evaluate the total solar radiation on the tilted plane of the PV panels. Nevertheless, note that the clear-sky model is not accounting for the extinction caused by clouds. Thus, an evaluation of the model has been carried out based on long-term measurements of global solar radiation in the study region.

2.3. Wind potential

As in the former cases, the assessment has involved two steps: (i) the evaluation of the wind potential in the region and, (ii) the evaluation of the potential electricity that can be obtained from this resource.

Wind is a highly fluctuating resource both in space and time. This makes very difficult its estimation over a wide region exclusively from ground measurements since it would be required too many experimental stations which, additionally, should also record the wind at different altitudes above surface (typically, from 20 to 80 meters). Overall, this approach is often prohibitive from the economic point of view. Therefore, nowadays, the use of numerical weather prediction models is a common practice. They are able to generate comprehensive long-term data bases of the state of the atmosphere at high spatio-temporal resolutions. To do it, they make a spatial and temporal disaggregation based on physical laws (known as dynamical downscaling) over the previously assimilated datasets from worldwide measurements of the atmosphere.

In this study, we have used the Weather Research and Forecast (WRF) model [10], one of the most profusely used models for regional weather studies. A simulation over the southern half of the Iberian Peninsula was conducted for the whole 2007, thus avoiding boundary effects over the province of Jaén. The output was saved every 9 km and every hour. In the vertical, which is very important for wind assessment, the atmosphere was described based on 27 unevenly-distributed layers. A higher layers-density was set near the surface in order to achieve a better description of the turbulent transport processes that occur in these regions, which give rise to a high variability of the wind profile near the ground. Since most of the current windmills install their turbines at, roughly, 80 meters above surface, the output for wind speed from WRF was interpolated every hour at this vertical level. Afterwards, a refinement of the maps was carried out by spatial interpolation up to a grid spacing of 3 arc minutes (approximately, 5.4 km).

Finally, the wind potential for electricity generation was based on the power curves of two standard commercially available windmills developed by Gamesa (http://www.gamesa.es). If the power curve, *P(v)*, of the wind turbine is known, the potential energy generated, E_W, can be easily calculated from the local wind speed distribution, $\Phi(v)$, as:

$$E_W = \int_{v_s}^{v_c} \Phi(v) \mathrm{P}(v)\, dv, \tag{3}$$

where v_s is the velocity at which the turbine starts to work and v_c is the cut-off velocity, above which it is locked for safety. Usually, the performance and suitability of a windmill in a given placement is measured based on the number of equivalent hours, H_e, which represents the number of hours that the wind turbine must be working at maximum power, P_n, in order to produce the actual energy which is produced along a natural year. It is calculated as E_W/P_n.

3. Results

Results will be presented separately for each resource: biomass, solar PV and wind power.

3.1. Biomass energy

The total area of olive crops in the province amounts to 680 000 ha and, up to 482 000 ha of them correspond to useful terrains for exploitation (terrain slope below 20%). The *BRI* values, given as a function of the terrain slope and for irrigated and non-irrigated lands, are shown in Table 1.

Table 1. Biomass residuals production index for olive crops in tons per ha per year.

Terrain Slope	Dry crops	Irrigated crops
less than 10%	1.6	1.7
greater than 10%	1.4	1.6
greater than 20%	excluded	

According to these values, the total potential volume of biomass residuals from olive crops was found to be about 720 000 tons per year. After revising the historical production records of some biomass power plants which are already operating in Spain, it was concluded that facilities with a power of 16 and 25 MW consume around 120 000 and 170 000 tons per year, respectively. Therefore, multiple number and size of facilities, as well as different distribution layouts, could be selected. In this case, using GIS techniques, three different schemes were evaluated considering multiple criteria as: volume of biomass residuals available in the proximities of the plant, ease access to the facilities with heavy machinery, ease access to feed-in points in the grid or distance to cities. Particularly, the different layouts tested were: (i) 4 plants of 25 MW, (ii) 6 plants of 16 MW and (iii) 2 plants of 16 MW and 3 plants of 25 MW. The latter probed to be the best one according to the criteria established. Table 2 shows the operating details for each plant and Fig. 2 shows their geographical distribution and influence area.

Table 2. Installed power, biomass consumption and electricity production of the biomass power plants proposed in this study.

Facility (nearest city)	Installed Power (MW)	Biomass consumption (tons/year)	Production (GWh/year)
Linares	25	167 411	187.5
Vva. del Arzobispo	16	115 349	120.0
Peal del Becerro	16	115 349	120.0
Arjonilla	16	115 349	120.0
Martos	25	167 411	187.5
Total	98	680 867	735.0

3.2. Solar PV energy

The solar radiation potential was estimated using the ESRA's clear-sky model, which does not account for the very important role of the clouds. In order to evaluate the validity of this approach, the clear-sky estimates were compared against a 5 years-length record of global solar radiation data registered at the experimental station of the University of Jaén. During spring and summer months, when the solar resource is higher, the difference between the measurements and the model keeps always below 1 $kWhm^{-2}$. During the 5 years record, the experimental station registered an average daily value of 5.95 $kWhm^{-2}$, while the corresponding simulated value was 5.50 $kWhm^{-2}$. Interestingly, the simulated value is below the observed one. This seems to indicate that SODA database reported an excessively high value in the province over the whole year. Anyway, the annual error is below 8%.

Figure 2. Proposed distribution of the biomass, PV and wind power plants.

The difference between the maximum and the minimum yearly sum of irradiance over the whole region is a 5%. This is attributable to the topographic spatial variability caused by the mountains. In the flat area over the Guadalquivir river basin, the solar resource is relatively homogeneous around 2 075 $kWhm^{-2}$, which is equivalent to a PV generation of 78 $kWhm^{-2}$. Extended over the whole province, the PV potential is more than 300 times higher than the annual consumption of electricity in the region.

Based on these results, we propose the installation of 350 MWp spread over 10 PV facilities. Overall, these power plants would produce 534 GWh per year, occupying around 70 km^2, the 0.5% of the province's extension. Again, GIS tools have been used to delimitate those areas useful for housing the power plants. Now, based on soil use and type, the next areas were excluded: urban, industrial, leisure and commercial areas, dumping sites and wet, irrigated and protected lands. Finally, the PV plants were distributed as shown in Fig. 2 based on the next criteria: (i) the plants must be close to suitable feed-in points, (ii) they must be evenly distributed over the electric grid and, (iii) complementary to the windmills sites proposed in the next section.

3.3. Wind energy

In average, according to the simulation with the WRF model, the areas with the highest wind speed at 80 meters above surface are the southern and eastern mountainous systems. This result shows the existence of a certain complementarity with the PV solar energy, which is more suitable in flat lands without topographic shading. The yearly average wind speed over the mountains ranges from 6.5 to 7.5 ms^{-1}. In the flat areas around the river basin, the resource drops up to 4 ms^{-1}.

The amount of electricity that can be generated from this resource depends on the wind turbine which be used. We selected two commercially available standard windmills, the G80 and the G87, developed by Gamesa, with the turbine placed at 80 meters above surface. Both windmills give a maximum (nominal) power of 2 MW. By using Eq. (3) we calculated the energy produced by each turbine over the whole province and, then, the number of equivalent hours. Overall, the G87 model fitted better the local wind resources. Particularly, all mountains in the province have more than 1500 equivalent hours and, the eastern façade, more than 2000 hours.

Deployment of wind farms must accomplish a severe environmental normative. Actually, it is usual that several projects be rejected by the competent authority. Therefore, in this study, we based our proposal for the wind farms distribution on a previous work carried out by the provincial department of energy of Jaén [11] which describes a series of sites that already account with legal support for its suitability to house small wind farms. Overall, the installation of 50 windmills over 13 small wind farms is proposed (Fig. 2). All of them are placed along the south – south-eastern façades of the province, outside protected natural parks. The average number of equivalent hours is 1 702 and the estimated amount of electricity generated with these wind turbines is about 172 GWh.

4. Discussion and conclusions

Compared to Andalusia and the rest of Spain, the province of Jaén has a marked unbalance between its inner electricity production and consumption. Nevertheless, it has a promising potential to increase its production quota based solely on local renewable resources which, additionally, contribute to reduce pollutant emissions to the environment. On the one side, its industry is mainly based on the olive oil, being the major worldwide producer. This industry generates a huge amount of wastes that can be used as fuel in biomass power plants. On the other side, the province also counts with large solar and wind resources.

In this work, we have analyzed the potential for producing electricity from these three renewable sources. We have study a preliminary distribution of the production plants based on geographical and territory criteria. Hence, it is worth to note that this proposal does not aim to be the optimal energy mix in the region since we are not considering social and economic constraints, for instance. Overall, with this proposal, around 1 450 GWh could be produced every year. Consequently, the rate of produced to consumed electricity would increase from a 30% to a 77%. At the same time, the use of renewables instead of fossil-fuel-based technologies, would avoid the emission of almost one million tons of CO_2 to the atmosphere.

Currently, the project has other on-going tasks aiming a deeper knowledge of the current state of the electric distribution grid to identify the improvements required to support this intervention, as well as the environmental, social and economic implications of the plan. First results seem to recommend a smooth implantation of the facilities along a decade and should end with a first proposal of optimal energy mix.

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Different regional scenarios of renewable energies analyzed with the use of Analytic Network Process

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Abstract: In March 2007 Europe Union fixed strong environmental objectives for all its members, and for the 2020 it will be required a reduction of 20% of energy consumption, a 20% quota of energy consumption obtained by renewables and a 20% reduction of greenhouse gases. The Piedmont Region administration lunched a roadmap either for the industrial side that for the civil one, but our Region has several territory scenario strongly linked with the geomorphology and many technical solutions can't be used as a standard. With this work our aim is to make a comparison of the most used renewables technology in our territory like biomass, hydroelectric and photovoltaic with a multi-criteria analysis. The paper shows the application of Analytic Network Process (ANP), a multi-criteria technique, according to complex network, in order to select the most sustainable solution for the different scenario. The models enable all the elements of the decision process to be considered, namely technological factors, environmental aspects, economic costs and social impacts, and to compare them to find the best alternative. All the data used in the model are taken from public sources and the required elaboration were self-made.

Keywords: *Multi-criteria analysis, Renewable energy, Analytic Network Process.*

1. Introduction

In the last years the Piedmont Region started to considered the energies from renewable sources as a priority in the new government energy policies. As a result a deep study was conducted based on economics and technological models, to realize a strategic energy document useful for the sectorial demand and supply, forecasts of the trends of input-output items, and a list of actions, collecting several measures voted to fulfill the main aims of the energy plan [1]. This plan is addressed to reach the main goal of a 20 – 20 – 20 scenery (energy saving, production from renewable sources, reduction of greenhouse emissions), according to the many constraints and factors. To fully comply these needs could be useful the adoption of a multicriteria approaches in the selection of the most appropriate actions among all the available alternatives. The selection of the alternative options derives from the goal set identified by the decision – maker, with regard to the technical, economic and environmental spheres. Different multicriteria methods have been developed during the last 30 years for providing support to decision makers facing conflicting, or not so clear, decision situations. Recent literature surveys have shown that Multi-Criteria Decision Analysis has been used in energy planning [2,3], with some cases dealing with the comparative assessment of energy scenarios [4,5]. This paper presents a decision support approach, called Analytic Network Process [6], for energy planning application. The investigation takes place on a case study of different renewable energy technologies provision for local government in Italy, taking as its base the area of Piedmont, a region placed in the north-western part of the country.

2. Methodology

2.1. The ANP

The ANP model consists of control hierarchies, clusters and elements, as well as interrelations between elements [6,7]. The ANP allows interactions and counter-interactions between clusters to be studied and supplies a network structure that is able to connect clusters and elements in any manner in order to obtain priority scales from the distribution of the influence between the elements and clusters. The ANP requires a network structure to represent the problem, as well as a pairwise comparison to establish the relationships within the structure. The analytical tools provided by the ANP are very useful to support the decision making process; nevertheless, it is always important to supply a great deal of information or many experts to the model in order to arrive at a better solution. The literature in the ANP field is quite recent and some publications can be found in strategic policy planning [8], market and logistics [9], economics and finance [10] and in civil engineering [11], while research activity on territorial and environmental assessment is still poor [12,13,14,15]. From the methodological point of view, the model can be divided into several main stages as follow: Step I: Development of the structure of the decision-making process; Step II: Pairwise comparison; Step III: Supermatrix formation; Step IV: Final priorities.

2.2. Case study

2.2.1. Application of the Analitic Network Process to energy planning in Piedmont

This work presents an application of the ANP for the selection of the most suitable technologies in a RET (renewable energy technologies) diffusion plan for the Piedmont Region [1]. A group of technologies of energy conversion has been chosen in order to asses environment, energy and economic effects, which are associated with their actual and future (2020) diffusion in Piedmont. This set has been further restricted to macro technologies oriented to renewable resource use. Table 1 shows the selected alternatives/actions.

2.2.2. Definition of evaluation cluster

Aside the cluster filled with the alternatives a diffusion process of an innovative technology needs the following requirements: a) consistence with the local energy demand predictions, required to confirm or reject the expectations of lasting development for the considered improvement; b) affinity with the local economic and technical condition, which derives on the local capacity of managing the innovation both at financial and technical levels; c) compatibility with the political, legislative and administrative situation; d) compatibility with the actual environmental and ecological constraints. Agreeing with the above considerations, 13 criteria are identified and collected under 3 macro criteria as shown in Table 2.

2.3. Description of the criteria for the analysis

Regional scale objective of primary energy saving (A): It is an estimation of the amount of primary energy that a given action allows to save. This saving can be estimated by means of reduction of final energy consumptions, under the same operating conditions. This criteria is defined as the awaited annual saved energy in the potential scenario [1], which derives from fossil fuels, as ktep/year.
Technical reliability, maturity (B): It is fundamental based on the state of the art of the applied technology. The judgment is expressed by means of a score included within the range [1,5]. A level order is applied, with increasing preference from 1 to 5, as follows: 1. Laboratory level; 2. Pilot plants, where the demonstrative goals is correlated to the experimental one, referring to the operating and technical conditions; 3. Improvements are still possible; 4. Theoretical limits of efficiency are near to be reached; 5. A very efficient technology.

Table 1. List of the selected actions to be diffused

Number	Energy source	Technologies/actions	Macro technologies
1	Hydraulic energy	Hydro plants in derivation schemes Hydro plants in existing water distribution network	Hydro plants
2	Biomass energy	Electric power from solids biomass Electric power from liquids biomass Electric power from biogas Biofuels CHP plants fed by biogas CHP fed by solids biomass CHP fed by liquids biomass	Biomass
3	Solar energy	PV roofs: grid connected system generating electric energy	PV
4	Solar energy	Solar water heating for large demands at low levels of temperature Domestic solar water heaters	Solar water heaters
5	Geothermal energy at low enthalpy	GSHP, SGV, GWHP, plants that use lakes and drainage basin water to fed the circuit	Geothermal
6	Wind energy	Wind turbines (grid connected)	Wind turbines

Number of installation and maintenance requirements with local technical know-how (C): It is a qualitative comparison between the complexity degree of the considered technology, and the capacity of local actors of assure an appropriate support. The following qualitative scale is used: 1. Inadequate technical background for installation and maintenance; 2. Moderate technical background for installation and maintenance; 3. Good technical background for installation and maintenance.

Efficiency and predictability of performances (D): It is very important to know if exist a pattern of not continuous operational conditions. This situation is often strongly linked to the specific technology and does not indicate a factor of unreliability. Obviously when malfunctioning conveys toward condition of unpredictability, it could be a sign of weakness. The following scale of judgment is used for the evaluation: 1. Erratic and not constant operation; 2. Probable but not constant operation; 3. Probable and constant operation.

Impact on the local employment (E): The estimation of potential labor, due to employment of RET, was not possible using literature data, mostly due to a lack of information at Italian regional and national levels. This value was obtained for every technology [1,5] as the difference between the awaited installed power at the minimal energy scenario and the potential one [1]. Where 1 is the lowest grade and 5 the highest.

Regional economic incentives (F): Is the criteria that takes in consideration how much the generated electricity is paid with the economic incentives. It is a reference index expressed in €/MWh.

Affinity with political, legislative and administrative situation (G): The national normative promotes several innovative strategies of energy saving and conversion. The different strength of these national incentives represents a judgmental element among different alternative interventions. The examined criterion assesses the qualitative relevance of the above actors, and the policy of public information. The overall value judgment is expressed in the following way: 1. Lacking; 2. Middle; 3. High.

Market opportunity (H): This criterion evaluates the market availability and the status in the penetration process of a given technology, materials and services associated with the considered action. The adopted scale is the following: 1. Market availability of the technology for more than 10 years; 2. Market availability of the technology for less than 10 years; 3. Start of market availability; 4. Pilot plants; 5. Not present on the market at least in an experimental stage.

Scheduled lines of research (I): In the Regional energy plan every technology has several research fronts [1],this information is used to create a qualitative index [1-3] where 1 represent the lowest grade of active research channels and 3 the highest.

Sustainability reported to greenhouse pollutant emissions (L): The criteria is taken in consideration to measure the equivalent emission of CO_2, which will be avoided by the examined action in the potential scenario at 2020. Therefore it is a reference index expressed in kt of reduced CO_2.

Sustainability reported to greenhouse pollutant emissions (M): Pollutants taken in consideration are divided in the following categories: a) air emissions mainly due to combustion process; b) liquid wastes, which are associated mainly with secondary products; c) solid wastes, which are generated during the life cycle of actions. Category and volume of emissions, and costs associated with wastes treatment are considered. To obtain a synthetic index, the score is expressed through the following qualitative ranks: 1. Very high emissions, each category is relevant; 2. High emissions, at least two category are relevant; 3. Middle emissions, at least one category is relevant; low emissions, all the emissions category are insignificant or do not exist.

Estate requirement (N): This is probably one of the most critical factors for the intervention site, especially when the human activities are relevant factors of environmental pressure. Some technologies requires strong demand of and this could determinate an economic losses, which are proportional to the specific value of site and the possible attendant alternative needs. For the large scale of proposed actions it is difficult to perform specific evaluation and a mean index is assessed as m^2/kW of installed power. Local scale evaluations could describe better drawbacks or possible benefits, but this is not the scope of the present work.

Sustainability reported to other environmental impacts (O): In this criteria are evaluated all the relevant impacts like landscape, acoustic emissions, electro-magnetic interference, bad smells and microclimatic change. The synthetic judgment is expressed through the following rank: 1. Very high intensity; 2. High intensity impacts; 3. Middle intensity impacts; 4. Low intensity impacts; 5. Not existing impacts. All the scores, obtained from the application of the criteria to each action, are grouped in the table below (Table 3).

2.4. The network model

This model consists of elements grouped into cluster. The elements of a cluster can be related to elements of another cluster or to elements of the same cluster (feedback). The alternatives form an additional cluster.

Table 2. Groups of criteria

Technological criteria	Economic and social criteria	Environmental and energy criteria
Regional scale objective of primary energy saving	Impact on the local employment	Sustainability reported to greenhouse pollutant emissions
Technical reliability, Maturity	Regional economic incentives	Sustainability reported to other pollutant emissions
Number of installation and maintenance requirements with local technical know-how	Affinity with political, legislative and administrative situation	Estate requirement
Efficiency and predictability of performances	Market opportunity	Sustainability reported to other environmental impacts
	Scheduled lines of research	

Table 3. Synthesis of evaluation of alternatives, according to the fixed criteria.

Alternatives	A	B (1-5)	C (1-5)	D (1-3)	E (1-4)	F (€/MWh)	G (1-3)	H (1-5)	I (1-3)	L (kt)	M (1-4)	N (m2/KW)	O (1-5)
Hydro plants	272	5	5	2	2	220	3	1	1	844.7	4	-3.8	2
Biomass	-70.2	4	4	1	2	180-280	1	4	2	2089.8	2	-80.5	3
PV	26.6	2	2	1	1	251-402	2	4	2	82.7	4	0.0	4
Solar water heaters	67.2	4	4	1	1		1	2	3	196	4	0.0	4
Geothermal	30.5	3	3	2	4	200	1	5	1	53.6	4	0.0	5
Wind turbines	30.3	4	2	1	3	300	1	5	1	94.1	4	-10.0	3

2.4.1. Determination of the network.

In ANP, numerical data can be represented graphically and thus show the influence pattern of the network. This step is essential for the further development of the process because if all the complexity of the real-world case study is to be transferred to the model, it is fundamental to accurately identify the influences of some elements upon others based. The risk is that if one influence is not identified, the model will not take it into account and some valuable information will be lost. The decision model was built with the help of the Super Decisions v 2.0.8 software (www.superdecisions.com). Fig. 1 shows the relationships among the clusters.

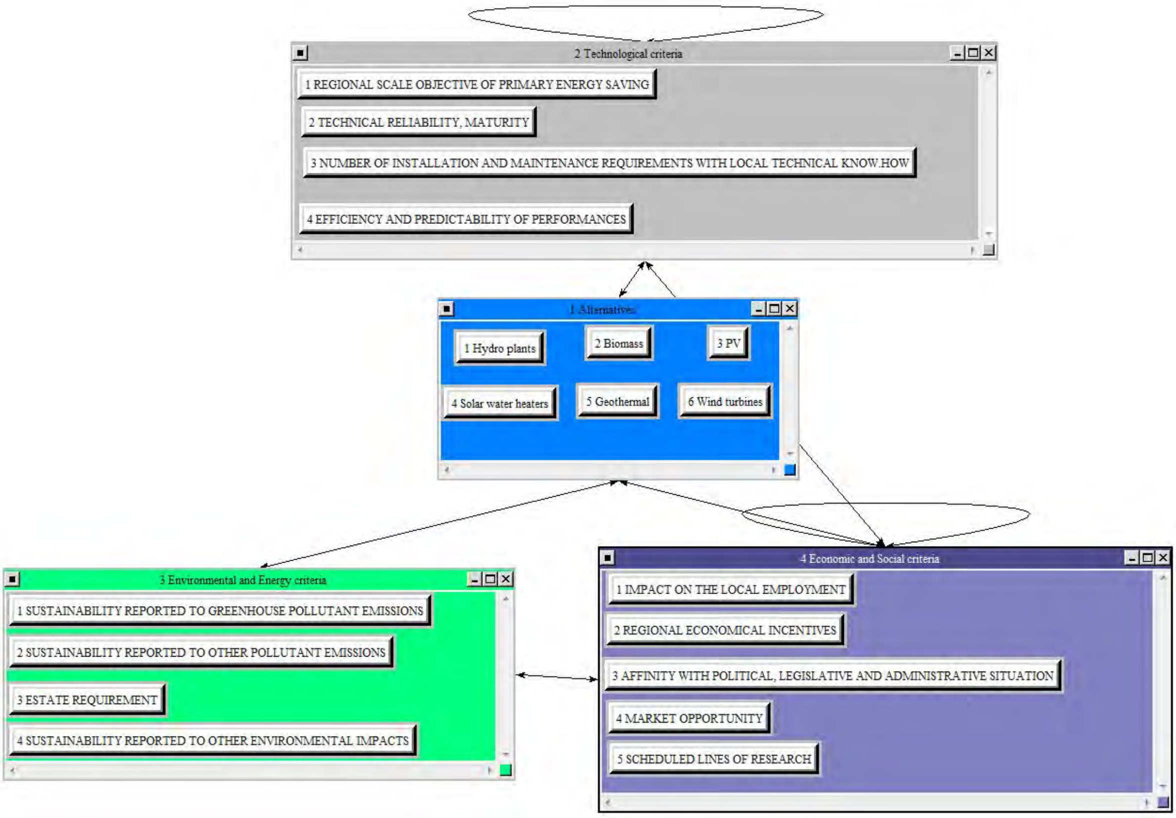

Fig. 1. ANP model scheme with inner and out dependencies.

2.4.2. Determination of element and cluster priorities

This stage includes all the steps of the ANP model. The first step consists of assigning priorities to related elements in order to build the unweighted supermatrix. For this end, each node is analyzed in terms of which other node have influence upon it; then the corresponding pairwise comparison matrices of each cluster are generated in order to obtain the corresponding eigenvectors. As in the case study different node from different clusters have influences on one cluster the unweighted matrix is nonstochastic by columns. All clusters that exert any kind of influence upon each group have to be prioritized using the corresponding cluster pairwise comparison matrices [16]. The value corresponding to the priority associated with a certain cluster weights the priorities of the elements of the cluster on which it acts (in the unweighted supermatrix), and thus the weighted supermatrix can be generated.

2.4.3. Calculation of the limit matrix and resulting prioritization.

By raising the weighted supermatrix to successive powers the limit matrix is obtained. The results of the model are shown in Fig.2.

Name	Graphic	Ideals	Normals	Raw
1 Hydro plants		1.000000	0.206519	0.06292
2 Biomass		0.946465	0.195463	0.05955
3 PV		0.680408	0.140517	0.04281
4 Solar water heaters		0.795539	0.164294	0.05005
5 Geothermal		0.709340	0.146492	0.04463
6 Wind turbines		0.710419	0.146715	0.04469

Fig. 2. Final results where the Raw *column gives the priorities from the limiting supermatrix, the* Normals *column shows the results normalized for each component and the* Ideals *column shows the results obtained by dividing the values in either the normalized or limiting columns by the largest value in the column.*

2.4.4. Phase of evaluation of results

Fig. 2 shows the results obtained with model of the study. The "best" alternative is the one with the "highest" score. The alternative selected by the model as the best options is the hydro plants technology, which is the action with the best behavior throughout the execution process, from project formulation to final score. The result shows the great complexity of the problem. In ANP the priorities are effected by the influences among clusters.

3. Discussion

It is clear that the results obtained from the model must be read in the correct way. Even if the model selected an action amongst the others it does not meaning that technology is always the preferred solution. Indeed the meteorology monitoring of the past few years has shown that precipitation in the Region are not so plentiful to allow a full energy production from the installed hydro plant. Nothing let us believe that this situation will change in the nearest future. So the second and the third actions could be very interesting in a planning situation, both biomass and solar water heaters are good potential technology. Biomass contains a big potential that could be express both in electricity and thermal power. At the same time solar water heating, even if a well know technology, could be implemented in more efficiency ways as the research in the optimization of thermal transformation proceeds.

4. Conclusions

An ANP model is applied in order to asses groups of actions focused on the implementation of several RET innovative technologies voted to use energy renewable resources. The introduction of a multicriteria approach makes a decisional process more flexible and transparent. In this case study 13 evaluation criteria grouped in 3 cluster have been defined, in order to increase the flexible approach to the decision-making. From the obtained results is clear as the RET represent in all forms a strong response to the limits imposed for the 2020 scenario.

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The Händelö area in Norrköping, Sweden Does it fit for Industrial Symbiosis development?

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Abstract: Today, sustainable cities/regions are playing an important role in sustainable development projects. The overall aim of the current paper is to demonstrate an Industrial Symbiosis development in the Händelö area of Norrköping city in the Östergötland county of Sweden. It is part of a research program called "Sustainable Norrköping" focusing on developing links between the industrial and the urban part of the city. As analysis of the current situation is important for understanding the future development, the paper tries to map the current industrial symbiosis links and symbiotic network to identify potentials exist. To achieve this, paper gives a general view of how this area has been developed, constructed, and grown. The next stage is devoted to an inventory of different actors, stakeholders, and companies, their processes and relationships in the form of energy, materials and by-products exchanges, flows and streams into and out of the Händelö area considering the Händelö/Norrköping as system boundaries. In addition, by describing different tools, elements and approaches of industrial symbiosis and considering and applying two main key tools as industrial inventories and input/output matching the paper also tries to show that whether the already industrial activities formed inside the Händelö fits for an industrial symbiosis development.

Keywords: *Sustainable Regions, Norrköping, Händelö Area, Industrial Symbiosis (IS)*

1. Introduction

Eco-industrial and sustainable regional/industrial developments are terms that now a days researchers, regional planners and business developers are encountered with. During the recent years, a substantial amount of research works has been conducted through emerging field of industrial ecology and one of its major applicable parts, industrial symbiosis. Almost both fields' aims are addressing sustainable development through systems at different levels and approaches. Hence, industrial symbiosis has been suggested as an efficient and applicable tool for sustainable regional/industrial development. Going back to historical view of industrial ecology, Erkman [1] proposed an analogy between industrial systems and natural ecosystems in which industrial systems and its processes are explained as mimicking the nature. The main elements of an industrial system are introduced as energy, materials, and information that flow inside the system. Chertow defined that industrial ecology preforms at three levels; "facility or firm", "inter-firm", and "regional/global" level. Moreover, as industrial symbiosis involves exchange cases amongst several firms, hence industrial symbiosis operates at "inter-firm" level. In a system perspective, by definitions, Chertow has defined key elements to IS as, "the keys to IS are collaboration and the synergistic possibilities offered by geographic proximity" and "Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products" [2]. Ristola & Mirata enhanced the sustainability of localized industrial systems using industrial symbiosis. Moreover, regional scale of industrial symbiosis is currently applied worldwide as a tool with the aim of developing more sustainable regions [3]. In a Swedish case study of the Landskrona industrial symbiosis project, the industrial symbiosis networks and its contribution to regional environmental innovation has been investigated by Mirata & Emtairah [4].

The present study is somehow intertwined with two current research projects at the division of environmental technology and management at Linköping University. From one side, it is part of a research program called "Sustainable Norrköping" which tries to study links between the industrial and urban part of the city. On the other side, it can be part of the Industrial Ecology Research Program (IERP), a research program developed in the framework of a 10-year funding agreement between TEKNISKA VERKEN (the energy corporation in Linköping) and Linköping University. IERP mainly focuses on regional Industrial Symbiosis development in Östergötland county of Sweden. It will show how and whether industrial symbiosis has the potential and capability to be an applicable tool towards regional sustainable development. Furthermore, it will practice how industrial symbiosis can contribute to a sustainable Östergötland development network. However, the Händelö area project is a real case as a sub-local development that can be expanded to a local (Norrköping city) and regional (Östergötland county) development. Hence, the current paper tries to find how industrial symbiosis fits in industrial activities of Händelö area at city of Norrköping. In the next phase, we analyze material exchange types at a spatial/organizational scale of Industrial Symbiosis by the application of a geographic information system (GIS) tool. Moreover, concepts like contribution to a CO_2-neutral eco-industrial park, moving toward maximize sharing of renewable energy resources will be also investigated in the next development stages of our research.

2. Methodology

The paper is being formulated based on the following approaches. First of all, a literature review with the subject of industrial ecology/industrial symbiosis projects and regional sustainable development has been performed, aiming at recognizing the main characteristics, challenges, and opportunities that other industrial symbiosis projects and regional development cases were encountered with. In the next stage, an inventory of the actors or an industrial inventory as one of the useful industrial symbiosis tools is introduced [2]. In this regard, an inventory of participating actors along with their processes is provided and analyzed. These types of information are mainly collected from interviews with key actors, field visits, and by setting up a technical meeting with responsible organizations involved in a regional project. Using a case study is another methodology used in this paper. As there are several actors in the city of Norrköping and the city consists of different parts and areas that have some technical, business and social relation with each other, the focus in this paper is mainly devoted to Händelö area and the energy cluster at Händelö as the nominated area for industrial symbiosis.

3. Results

3.1. Lessons learned from industrial symbiosis concepts and applications

Being deeper in most of recent and current industrial symbiosis or eco-industrial park projects worldwide, it is evident that there are some key items, concepts, approaches, tools and elements which have been used, discussed, and applied during those projects. Amongst several industrial symbiosis projects world wide, the Kalundborg in Denmark was pioneer in experiencing an industrial symbiosis model to create an eco-industrial park [2]. In this regard, it is shown that the Kalundborg's achievements not only energy, water, and waste exchanges, which have lead to better environmental and economic performances, but also social-human dimensions, equipment and information sharing were involved as well. On the basis of literature and projects experiencing in the field of industrial symbiosis [2,5], approaches, measures, key items, elements, applicable tools and definitions of different aspects of industrial symbiosis and industrial symbiosis projects have been found. With this knowledge in the first round of research can be identified whether an industrial area and the participants in the symbiosis can be matched with industrial symbiosis or not. Those elements and key items are summarized below.

3.1.1. Industrial Symbiosis tools

Regarding industrial symbiosis tools, Chertow [5] has defined several useful tools in industrial symbiosis analysis like industrial inventories, input/output matching, stakeholder processes, and material budgeting. It is suggested that, as soon as an industrial area is considered of interest for industrial symbiosis, the first step through an industrial symbiosis analysis can start with an inventory of local actors and relevant organizations. In the same literature, input/output matching has been introduced as “key to symbioses” for links of companies. Three methods: written surveys, interviews and utilizing simulation softwares, are mentioned for data gathering and analysis. Another industrial symbiosis tool is defined as materials budgeting, in which the aim is to map the energy and material flows through an industrial system. As the tool can help to map the route of flows and stocks, it could be fundamental to an industrial symbiosis analysis. Moreover, it is defined that, “The material budgeting can be a basic building block of an industrial symbiosis analysis” [5].

3.1.2. Elements of Industrial Symbiosis

Items such as embedded energy and materials, life cycle perspective, cascading, loop closing, and tracking material flows have been introduced by Chertow as elements of industrial symbiosis [5]. Embedded energy and materials is an industrial symbiosis element which shows that the sum of materials and energy consumed to generate a new product is equal to the amount of embedded in that product. Hence, “reusing by-products” in industrial symbiosis links, maintains the embedded materials and energy for a longer time within the industrial systems. Environmental impacts which appear at every stage of product life cycles, considered as life cycle perspective. According to industrial symbiosis, life cycle perspective is used to evaluating symbiotic opportunities. When energy or water recourses are consumed many times in several different relevancies, cascading is appeared. Cascading has been defined as a prevalent policy for industrial symbiosis; hence the environmental advantages of cascading are several. A special type of cascading is loop closing, where it is considered more ring-shaped. The environmental and economic advantages of loop closing are alike to those in cascading. Tracking of energy, water and material flows has been defined as another key to industrial symbiosis analysis. It is shown that applying material tracking at different levels has contributed to definite industrial ecology tools: substance flow analysis (SFA) and material flow analysis (MFA).

3.1.3. Material exchange types versus Spatial/organizational scale of industrial symbiosis

As different exchanges has different proximity and the distance amongst partners and organizations in industrial symbiosis plays an important role, hence another aspect of industrial symbiosis is devoted to the spatial scale of industrial symbiosis. The geographic proximity amongst firms refers directly to the spatial scale. In this regard Chertow proposed a methodology based on taxonomy of 5 different material exchange types to consider both components, spatial scale and materials exchange [2,5].

Type 1: through waste exchanges
Type 2: within a facility, firm, or organization
Type 3: among firms co-located in a defined Eco-Industrial Park
Type 4: among local firms that are not co-located
Type 5: among firms organized virtually across a broader region

In addition, Chertow argued a "3-2 heuristic" definition in which at least three different actors exchanging at least two distinct material/resources; differentiating industrial symbiosis from linear one-way exchanges [6]. More than that, it is discussed that types 3-5 "can readily be identified as industrial symbiosis" [2].

3.1.4. Exchange types and synergistic possibilities

The most common type of exchanges are considered as resource exchanges in which energy, raw material, waste handling, and by-products are cycling amongst different actors and firms based on a predefined collaboration. Considering several literature and researches [2,5], the concepts such as synergies and synergistic possibilities are argued. "Synergistic possibilities offered by geographic proximity" has been defined as key to industrial symbiosis. Synergistic possibilities may refer to both material exchanges and by-product exchanges. Chertow showed that by-product exchanges can be transported in a longer distances while the material exchanges (steam, hot water…), cannot be economically applied in longer distances and crossing the boundaries of symbiotic network [2]. In this regard, in the case of collaboration between different firms, industries and organizations, the synergistic possibilities may refer to business and economic synergies as well. A classification of different exchanges in the form of synergies amongst firms and industries has been defined by the Center of Excellence in Cleaner Production (CECP) [7]. They categorized the exchanges as supply, by-product, and utility synergies.

3.1.5. Industrial symbiosis project development

Chertow [2] discussed several examples of industrial symbiosis projects along with eco-industrial park projects in which different definitions regarding to project development, types of industrial symbiosis networks, and planning stages are being defined. In this regard, the symbioses can be developed based on a planned and structured process in contrast with continually spontaneously evolved projects in which several firms and partners in the symbiosis have developed and evolved simultaneously over time. Furthermore, the participants in industrial symbiosis can be defined as conscious or unconscious network regarding to the environmental characteristics of their exchanges. According to planning stages and development progress of industrial symbiosis projects, a sampling of twelve industrial symbiosis projects reviewed by Chertow [2], shows that most of the industrial symbiosis projects can be categorized in the phases: late planning, implementation phase, operational stages, and project completed. In addition, in the case of a planned project, different approaches are applicable. A project could be considered and performed as "Stream-Based" or "Business-Based". Similarly, an eco-Industrial park as a planned project would begin based on "New or Existing Operations". As an example it is implied that the case of the industrial district in Kalundborg Denmark, was a continually spontaneously developed project in which different partnerships in the symbiosis have evolved during the years. More than that, it is concluded that the spontaneous projects in contrast with planned and structured eco-industrial parks, "are proving to be more robust and resilient to market dynamics", [5].

3.2. History and background of the Händelö area

Händelö is a 600-hectare island in the Baltic Sea, just outside the city of Norrköping in the county of Östergötland in Sweden. The Händelö Island is surrounded by Motala River and Bråviken Bay. Historically, Händelö farm has registered on 1322, 60 years before Norrköping became a city. Vast areas of the former farm have been built by industries during the recent years. Now, over the years, the farm itself may be developed into a center of environmental technology, which owned green companies and clean technologies to generate sustainable economy. Due to the nature of Händelö, the area is also called as coexistence between conservation of nature and industrial sites both locates on an island with high business and economy potentials as well as high nature value, which makes the Händelö area being as a meeting point for nature and technology in a sustainable way. For around three decades, it is planned for large and new establishment of industries and infrastructure. Norrköping municipality owns Händelö area. Nowadays, the Händelö Island has vast and distinct facilities inside. Because of that it attracted the interests of business planners/developers, local authorities, and academia researchers. Facilities like the center of logistics companies, the renewable energy cluster and Natura 2000 conservation areas. More than that, the strategic position of the area such as access to the railway and vicinity to the harbor is another order of merits of the Händelö area.

3.3. An overview of an industrial ecosystem in Norrköping, Sweden

The current paper is a case study to examine industrial symbiosis in a sustainable development application at Händelö area in Norrköping. Nevertheless, for deeper understanding and further realization of relations between different parties inside and outside the border of Händelö, a brief description about the current situation of industrial ecosystem at Norrköping is given. Figure 1 shows a schematic relation and collaboration between different actors and organizations in Norrköping. The involved exchanges include mainly energy, materials/waste, and by-products. Municipal wastes from Norrköping city feed into E.ON, the combined heat and power plant that produces heat, electricity, and process steam. Heat is delivered to the district heating network, electricity to the grid, and steam to the nearby ethanol production plant (Agroetanol). Wheat from the agriculture sector feeds to the Agroetanol Company, which produces pure ethanol. The produced ethanol is used as vehicle fuel. Stillage, a by-product from the ethanol plant, is delivered to a biogas production plant, Svensk Biogas to produce vehicle biogas and bio-fertilizer for the agriculture sector.

Econova is an enterprise in the environmental technology sector and its main activities focus on products and services in the field of biomass, landfills, waste & by-products, and gardening. In this regard, Econova basically runs on two distinct business areas called Econova Energy and Econova Garden. The first one’s activities are utilizing and processing waste and by-products from municipalities and the forest industry. The second one‘s activities are based on producing and selling environmentally friendly garden products. Hence, the company’s main strategies are based on “eco-cycle” thinking and effective use of resources in an environmentally and economically efficient way. The business strategies of Econova facilitate that more and more customers organize their activities in local cycles. Furthermore, those strategies contribute to more efficient environment, better social relationships along with increasing resources economy. The main business partners of Econova are the agriculture sector, who receives bio-fertilizer, the forest sector which exchange biomass and bio ashes, the waste water treatment plant for sludge exchange, the municipalities for organic and household waste, and the CHP plant for exchanges of ashes and biomass [8].

Returpack and Cleanaway are neighbor companies with an unique strategy in closed eco-cycle system for depositing, handling, collecting, recycling of pet bottles and aluminum cans at Händelö in Norrköping. Returpack is the company in charge of the Swedish pet bottles and aluminum cans deposit system since 2003. They selected Norrköping for its vast facilities in logistics. Around 20,000 tonnes per year of pet bottles are delivered to Returpack. The daily processing is about 3.6 million Aluminum cans and pet (9). The transportation costs for sending this amount of pet bottles and Aluminum cans for recycling to other regions were too high so it was decided to follow the “Next door” strategy to build the Cleanaway Company close to Returpack to avoid logistic/transportation costs. Cleanaway, business partner of

Returpack is a company in charge of cleaning and recycling of pet bottles, and is constructed in 2006. Cleanaway delivered about 8 tonnes per day of pet bottles and around 27,000 of pet bottles per annual of which 20,000 tonnes brought in from Returpack and rest comes from Norway and Finland [9]. Around 75% of cleaned pet materials are used for producing new pet bottles, and the rest is used for producing other plastic products. The process waste is sent to the E.ON CHP plant at Händelö as combustible materials. The key successive items through collaboration between Cleanaway and Returpack is the "wall to wall" strategy which contribute to a set-up based on an agreement "among firms collocated in a defined eco-industrial perk".

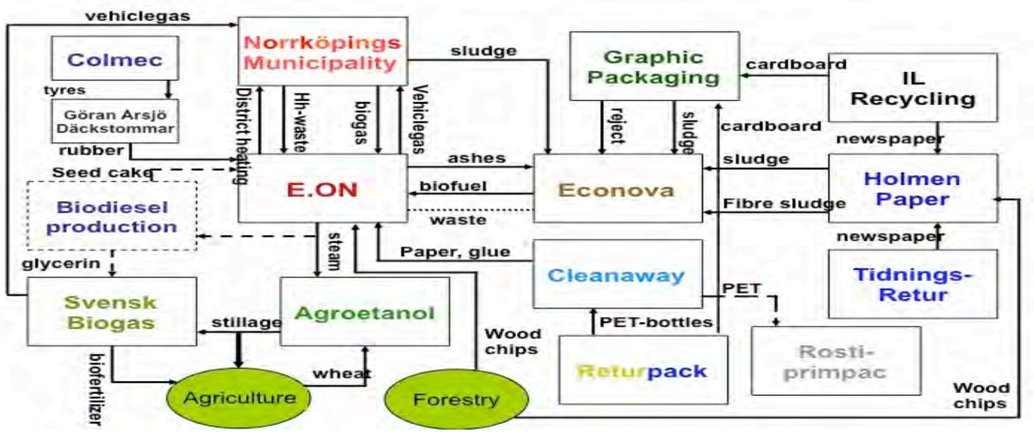

Fig. 1. Industrial eco-system at city of Norrköping (10)

3.4. Industrial symbiosis tools applicable at Händelö

As stated, an industrial inventory (inventory of the actors) is introduced as one of the useful industrial symbiosis tools. As soon as an industrial area is nominated as a possibility for industrial symbiosis, the first step through an industrial symbiosis analysis could be starting with an inventory of local actors and relevant organizations. Another industrial symbiosis tool is defined as materials budgeting, in which the aim is to map the energy and material flows through the nominated area. As the tool can help to map the route of flows and stocks, it could be fundamental to an industrial symbiosis analysis [5].

The energy services company, bio fuel (biogas, bioethanol) production companies, the agriculture sector, forestry, logistic companies, pet bottles, aluminum cans, and rubber tires recycling companies are major green partners through their links and the applications of clean technologies. Händelö became the center of industrial symbiosis and environmental technology to stimulate a sustainable economy in the area. As there are several actors and industrial companies in different sectors at Händelö that share some technical, business and social relationships with each other, the focus in this paper is mainly on the Händelö area and the energy cluster as the nominated area for industrial symbiosis. In this regard, an inventory of participating companies in the area and their processes containing energy, material, waste, and by-products exchanges along with mapping the energy and material flows through the area is provided and analyzed.

3.4.1. Industrial inventory at Händelö energy cluster

As discussed earlier, the energy cluster at Händelö area is part of the eco-industrial complex in Norrköping city. The primary partners at Händelö energy cluster are E.ON CHP plant, Lantmännen Agroetanol (ethanol production company), and Svensk Biogas (bio-gas production company) [9].

The E.ON combined heat and power plant as the engine, is a part of energy cluster at Händelö. E.ON produces heat and electricity that is delivered to the municipality of Norrköping. In addition E.ON produces process steam for the nearby ethanol production plant (Lantmännen Agroetanol). The municipality of Norrköping provides household waste to E.ON to use in their waste incineration plant. The main fuels to E.ON are wood/return chips, wood waste, rubber tires, and sorted household waste. The fuels contain 53% of biomass, 43%waste, 4%coal, and small amounts of oil during peak loads. The waste consumption of the incineration plant is about 20 tones per hour at full power. The overall heat capacity of the plant is around 1.1TWh including steam. The power production of the unit reaches to 300GWh. Of the total energy produced, 57% is processed into heat and is delivered to the district-heating network, 29% is processed into steam, which is delivered to the ethanol production plant, and 14% is processed into electricity that is delivered to the grid. Lantmännen Agroetanol is Sweden's only large-scale producer of grain-based fuel ethanol and has a large production plant at Händelö. Due to high demand for ethanol as a fuel in Sweden, it has expanded its production plant in Norrköping. The plant is also one of the Sweden's largest producers of protein-rich crops and feedstuff for animal feeding. At the Norrköping plant, wheat is the main raw material. The first batch of ethanol was delivered from the plant in 2001. In November 2008 the second production line started. This yields to an expansion in capacity to produce 210 million liters of bio-ethanol and 195 thousands tones of protein feed (DDGS) annually. The production is based on 550,000 tones of cereals. Lantmännen Agroetanol has several industrial, commercial, and social links with other companies in and outside the Norrköping region. E.ON, Svensk Biogas, oil companies, farmers, and animal feed factories are the main Lantmännen Agroetanol counterparts.

Svensk Biogas (Swedish Biogas) at Händelö has started in 2007. Biogas is produced from organic waste and residues. Sewage sludge, stillage, grains, crops, and plants from the agriculture sector are the most frequently used raw materials for biogas production plant at Händelö. Stillage is provided from the nearby ethanol production company and sewage sludge is a by-product of the wastewater treatment plant. Amongst different by-products of the biogas plant, the most important ones are bio-fertilizer and bio-manure which both return to the agriculture sector again. The produced biogas is refined and is fed into city gas filling stations for both private and public transportation. The biogas plant at Händelö produces around 2.6 million Nm^3 /year biogas.

4. Discussion and Conclusions

Having a look upon the business partners, actors and their processes at Händelö, it is evident that the most common type of material exchanges through the symbiotic network is a combination of both types tree and four, in which the exchanges are mainly, occurs "among firms co-located" in a symbiotic network. Stillage the by-product of the ethanol company is feed to both biogas plants at Händelö in its geographic proximity as well as to a more distant plant in Linköping, "over the fence". As the primary partners are linked together within a few-mile vicinity and have advantages of exchanging energy and materials, it can be classified as a type four exchange. As spatial/organizational scale of industrial symbiosis plays an important role in issues like material exchange types and geographic proximity amongst actors, the "Geographic Information System (GIS) tool" can be added as a new component to industrial symbiosis analysis. Considering two definitions of eco-industrial parks by USA/EPA and President's Council on Sustainable Developments (PCSD) [2], the Händelö area can be classified and evaluated as an eco-industrial park. Based on further steps in the research and its analysis, new definitions like CO_2-neutral eco-industrial parks through maximize sharing of renewables energy resources can be found.

Performing an industrial inventory as a starting point through an industrial symbiosis analysis shows how local actors depend on each other through the entire network. In this regard, Händelö is a clear sample of “cooperation between different industries by which the presence of each increases the viability of the others, and by which the demands of society for resource savings and environmental protection are considered” [2]. Having a look from an industrial symbiosis perspective at Händelö, it is easily seen that collaboration and synergistic possibilities within a geographic proximity are entirely embedded through the area. More than that, reusing by-products is a dominant process through the whole network where embedded energy and materials links as an industrial symbiosis tool is already performed. In addition the synergistic possibilities and exchanges are mainly devoted to by-product synergies and utility synergies. It is evident that the participants in the Händelö energy cluster have generated a conscious network with regard to the environmental characteristics of their exchanges. More than that it seems that the Händelö symbiotic network and the symbiosis is a type of continually spontaneously evolving projects in which several new firms and partners in the symbiosis have developed and evolved simultaneously over time. Rather than that, the Händelö energy cluster seems to be a sample of an “integrated bio-system” in which the involved processes mainly come from industry and agriculture [2]. Finally, an overview of industrial activities in both local (Norrköping city) and sub-local (Händelö area) level and specifically the energy cluster at Händelö shows social-human dimension of industrial symbiosis such as trust and communications are the most key factors in cooperation between the participants at the Händelö symbiotic network. In addition, amongst several current samples of industrial symbiosis projects and eco-industrial parks worldwide, the keyword industrial symbiosis, can be coined to green economies and clean technologies that have already formed at Händelö.

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Dynamics of Energy Consumption Patterns in Turkey: Its Drivers and Consequences

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Abstract: Turkey has a characteristics with very young population, high annual population growth rate, rapid urbanization and relatively high economic growth rate. Turkey's population has reached about 73 million in 2010 The country has faced with growing demand for energy during last two decades and primary energy demand is projected to reach 220 mtoe in 2020 which means 150 percent increase from current level. But primary energy supply met about 28 percent of energy demand in 2009. Increasing import dependency highlights the energy security problem for the country and also poses important burden on economy such as foreign current deficit. Total energy import increased nearly six folds for last 15 years with 12 percent annual average growth rate. The share of energy in total import has exceeded 20 percent in recent years. Increasing GHG emissions is another issue which has substantially increased during last two decade, particularly emitted from energy production. Therefore, energy dependency and GHG emission issues entails investment in renewable energy sources such as wind, biomass, hydro and solar to both reducing energy dependency and emission. In addition, ensuring greater energy efficiency will contribute energy security since current level of efficiency is rather low.

Keywords: *Turkey's energy consumption dynamics, drivers of energy demand, impacts of energy policies.*

1. Introduction

Turkey has been rapidly growing country for decades. The gross national product of country has grown at an average annual rate of 5 percent since 1983 . Turkey's energy demand has also risen rapidly as a result of economic growth and development. Turkey has an economy challenging by a growing demand for energy while its self sufficiency rate in primary energy sources are very low. Total primary energy production met about 28 percent of the total primary energy demand in 2009.

Turkey is heavily dependent on expensive energy imports which impose significant burden on the economy. As a result of increasing energy consumption, air pollution has been causing severe environmental issues in the country. Furthermore, to meet criteria of Kyoto Protocol, consumption pattern needs to be modified. As a candidate country, Turkey will have to adopt the bio-energy and bio-fuel directives of the EU in case of membership. In this regard, promoting renewable energy resources seem to be one of the effective energy policies in Turkey which also entails substantial investments.

The aim of this article is to analyze the dynamics of the energy consumption patterns in Turkey and evaluate the impacts of energy demand patterns change both on energy sector and whole economy. Furthermore, this paper aims to contribute the national energy sources management and policy decision by analyzing the energy demand patterns change and its macroeconomic consequences. The paper is organized as follows. In the second section, macroeconomic drivers of energy demand in the economic development process and national energy policy are presented. In the third section energy sector and energy consumption structure are analyzed. In the fourth section implications for energy consumption patterns change is evaluated. Final section concludes important results.

2. Energy Policies in Turkey and Macroeconomic Drivers for Energy Demand

Turkey is situated at the meeting point of the three continents (Asia, Europe and Africa) and is adjacent to regions which pose over 70 % of the world's proven oil and natural gas reserves. Moreover Turkey sits on major international waterways. Therefore Turkey is an important transit state for world energy resources [1]. Turkey's size 779,452 km^2 and Turkey's population was about 73 million in 2010. Moreover fast migration from rural regions to industrial and/or tourism regions has continued and fast growing urbanization is leading more energy consumption. Turkey is rapidly growing economy, and over the past decade it's Gross Domestic Product (GDP) has increased an exceptional rate compared to other OECD countries. Turkey is 17th largest economy expanded on average by 4.7 % a year [2].

Since 1980 (in liberal period), public investments including electricity investments has been gradually cut down to reduce the public share in the economy. Moreover, the Turkish government initiated some legal regulations to attract the private investors to the economy [3]. By the end of the 1990s, it was understood that quasi-privatization policies were not going on to be feasible given the rapidly deteriorating fiscal situation. Thus, Turkey adopted a radically different framework for the design of the energy markets. In 2003, Electricity Market Law (EML, No:4628) came into force [4]. The EML was designed to establish a competitive electricity market, to promote private participation and improve the efficiency in electricity supply [3]. In parallel with the electricity market reform, some other reforms were also initiated in other segments of market. In 2001, Natural Gas Market Law (NGML, No: 4646) also came into force to achieve similar goals in natural gas industry. The new regime established the Energy Market Regulatory Authority (EMRA). Also, Petroleum Market Law (PML, No:5015) and Liquefied Petroleum Gas Market Law (LPGM, No:5307) was enacted in 2003 and 2005 respectively. EMRA has responsibility for regulation of these markets as well [4].

Table 1: Population, Economy and Energy in Turkey, 1973-2020.

Year	Population (1000)*	Population Increase, (% o)	GDP per capita, ($**)	GDP, at current prices, (billon USD)	Total Energy Consumption, (Mtoe)
1973	38,073	20.7	2,369.00	90.2	20.04
1990	55,120	17.0	3,859.52	202.38	40.55
1995	59,756	15.4	6,693.43	223.74	63.21
2000	64,259	13.8	8,149.60	265.18	82.2
2005	67,903	13,0	11,005.80	482.78	92.5
2010	72,698	11.0	15,392.16	729.05	97.31
2020	80,257	8.8	19,748.55	1,344.29	220.0

* Mid-year population data; ** IMF, International USD PPP equivalent
Source: [5, 6, 7, 2, 8].

Turkey's GDP is expected to grow at a rate 5 % in 2012 and 5.5 % in 2013 [9]. Turkey is also expected to fastest medium-long term growth in energy demand among the IEA counties. The total energy consumption is expected to reach 220 Mtoe by the year 2020. But, Turkey's energy consumption per capita is still relatively low compared to developed countries [2]. As mentioned before, Turkey is a candidate country to EU. Therefore all candidate countries need to harmonize with the European Union energy policies. Moreover all candidate countries should have adequate legislation and well functioning institutions. In this regard, Turkey adopted a strategy which consists of a privatization and integration into European and global economy. EU energy policies essentially include the improvement of competiveness, security of energy supply and protection of environment [10]. In this context, some efforts for sustainable energy, energy efficiency and environmental issues have been observed in Turkey [11]. As a matter of fact, the Renewable Energy Law (REL, No:6094) was enacted by the Turkish Grand National Assembly in December 28, 2010.

3. Dynamics of Energy Patters

Energy consumption of Turkey has grown substantially since the beginning of the 1970s. The quantity of consumption almost quintuplicated between 1973 and 2010 from 20.4 to 97.31 millions tons of oil equivalent (Mtoe). Turkey's energy consumption is rapidly growing, but it's domestic primary energy sources (especially oil and natural gas) are relatively low. According to the Ministry of Foreign Affairs [7], primary energy demand is projected to reach 220 million toe in 2020, revealing 150 percent increase as compared to the current figure.

Table 2: Production, Supply and Consumption of Energy Sources in Turkey, thousand TEP,2008.

Energy	Domestic Production	Primary Energy Supply	Total Final Energy Consumption
Hard Coal	1204	14179	7010
Lignite	15205	15003	4138
Oil	2268	31784	28732
Natural Gas	931	33807	13957
Hydroelectric	2861	2861	0
Wood	3679	3679	3669
Biofuels	66	66	66
TOTAL	29257	106338	79559

Source: [13].

According to the MENR statistics (2008), petroleum products, natural gas and coal consist of the bulk of the primary energy consumption in Turkey. Although the consumption of oil has been increasing for the several decades, because of the natural gas, this rate was started to decrease. Roughly 90 percent of Turkey's oil supply is being imported. But oil is still the dominant energy source in Turkey. In the past four decades oil's shares were 42.3 %, 45.5 %, 41.1 % and 36.1 % for 1970, 1990, 2000 and 2008 respectively. Turkey oil consumption was 28,732 thousand TEP in 2008 [13]. Turkey's oil production in 2008 met only 7.9 of total in consumption [5]. The oil deficit between production and final consumption was met by imported oil from Saudi Arabia, Libya, Iran, Iraq, Russia, Syria and Algeria.

Turkey is a transforming country, so energy usage has shifted towards to manufacture sector and cycle and energy sector. While the manufacture sector share in total energy consumption was 24.5 % in 1970, this share nearly doubled in 2006. Moreover share of the cycle and energy sector increased more than two folds from 1970 to 2006. The shares of cycle and energy sector were 12 % and 28.6 % for 1970 and 2006 respectively. Shares in total energy demand for households, transportation, agriculture and out of energy were 30.7%, 19.3 %, 4.6 % and 5.4 % respectively. In the power sector it is expected that oil-fired power plants will continue to be replaced by other forms of power plant technologies [2].

Natural gas consumption has risen substantially in recent years in Turkey. The shares for natural gas in energy consumption for 1970, 1980, 1990 and 2008 were 0%, 5.9%, 17.5% and 31.6 % respectively. Natural gas has been particularly important in the power sector which has risen to tenfold from 1990 to 2008. Gas usage is expected to continue to increase rapidly in all sectors for medium and long term (61 bcm in 2020). Turkish natural gas is anticipated to increase rapidly over the next years with the most important consumers expected to be natural gas fired electric power plants and industrial users. Total natural gas production only met 6.7 % of gas consumption and the rest of the natural gas consumption (93.3 %) was imported. Natural gas has been imported mainly from Russia, Algeria, Iran and Nigeria. Turkey produces only a small amount of natural gas and therefore natural gas imports have increased rapidly [14]. Coal has been a major fuel source in energy consumption in Turkey after the oil and natural gas since 1970s. The share of coal (hard coal plus lignite) in consumption was 15.4 % in 1970 and declined to 14.4 % in 2008. Around 87 percent of domestic lignite is used for generating electricity in 2008. Power generation, industry (including coke ovens and blast furnaces) household usage accounted 46, 44 and 9 percent respectively in hard coal plus lignite consumption in 2007 [2].

There has been also rapid increase in electricity consumption. It has grown 9-10% per year except for recent economic crises. Electricity demand reached 194,079.1 Gwh[1] in 2009 and increased tenfold over the last 25 years [15]. Although significant increase realized in electricity consumption per capita in 2009 (2699 kwh/year), it is still under the EU average (6500 kwh/year) and developed countries average (8900 kwh/year) and just above the world average (2500 kwh/year) [16]. Electricity consumption increase is expected to continue over the next 15 years [17]. Besides natural gas, another fast growing source for electricity is coal. From 2000-2009, gas fired generation grew by 48 Twh, accounting for 72 % of total power generating. Coal fired grew by 17 Twh, accounting for 25 % of demand [2]. Demand projections up to 2018 indicate that annual average increase in demand will be 7 % and 6.3 % in high and low demand scenarios respectively [18].

4. Implications of Energy Consumption Pattern

As mentioned before, demand for energy has been rapidly increasing [19]. But Turkey's self sufficiency rate in primary energy source is very low. Total primary energy production met about 28 percent of total primary energy demand in 2009 and Turkey has no significant oil and natural gas reserves. So the first inevitable result of energy consumption in Turkey is energy security issue. Turkey is highly dependent on imported primary energy sources. Energy import by the sectoral break down is presented in Table (3).

Table 3: Energy Import by ISIC Rev 3 of Turkey, million $, 1996-2010

Energy/Year	1996	2000	2006	2007	2008	2009	2010
Hard Coal, cooking coal and briquette	623,5	676,3	2054,5	2666,5	3411,7	3113,4	2518,5
Petrol and petroleum based products	3998,3	5642,7	16608,3	19339,4	27034,4	15171,8	16921,2
Natural gas and manufactured gas	1280,4	3078,6	10177,7	11856,5	17819,3	11602,7	11185,2
Total energy import	5913,9	9529,3	28858,7	33882,8	48280,9	29905,1	30640,0
Energy import share in total import.	13,5	17,5	20,7	19,9	23,9	21,2	20,7

Source: [5].

[1] Gross demand is obtained by Gross Generation + import-export (15).

The highest dependency rate with 93.3 percent is in natural gas. Dependency rate for oil and hard coal are 92 % and 91 % respectively. It is projected that the production will decrease and meet the 23 % of total energy demand in 2020 which was 28 percent in 2009. This energy import dependency poses important burden on economy. The oil and natural gas import is expected to substantially increase over the next decade. The natural gas share in total import is expected to be 33 % in 2020 [2, 20]. Turkey's total energy import has increased nearly six folds for last 15 years and reached to 48281 million US Dollar in 2008 and 30640 million US Dollar in 2010. Energy import bill has nearly grown with annual average 12 percent except 2009. Economic crises in 2008 let to decrease in energy import in 2009 but this slowdown reversed again in 2010. The energy import share in total energy import also increased during last 15 years and constitutes about 20 % of the country total import. Because of the high import dependency rate, the government has developed an energy policy aimed at diversifying energy sources and suppliers and attracting private capital in Turkey [21]. Hence domestic energy sources of Turkey become strategically important. Although Turkey has no large oil and natural gas reserves, it has promising significant energy sources like coal (mainly in lignite), hydro and geothermal [10]. Turkey has also the great remaining potential for hydro. It is stated that Turkey's hydro electric potential can meet 33-46 % of electricity demand in 2020. Based on the electricity supply and demand projections, it has been targeted that the share of the nuclear power plants in electricity production will be 5% by the 2020. For this purpose, Construction and Operation of Nuclear Power Plants and Law on Sale of Energy (No:5710) came into force in 2007. An intergovernmental agreement was signed between Turkey and Russia for the construction a nuclear power plant in Mersin-Akkuyu [12]. In the context of the energy diversification issue in Turkey, alternative energy sources such as biofuels became an important focus in recent years. Furthermore, as a candidate country, Turkey will have to adopt the bio-energy and bio-fuels directives of EU in case of membership. Turkey has potential for ethanol based biofuels [22]. European Commission introduced a legislative framework to promote the achievement of 20% target for renewable energy in 2020 [23]. According to the [12], the renewable energy share in electricity energy is planned to be 30 % in 2023 in Turkey.

Table 4: GHG by Sectors in Turkey, 1990-2008, million tones CO_2 equivalent

Sectors	1990	1995	2000	2005	2008
Energy	132.13	160.79	212.55	241.75	277.71
Industrial Process	15.44	24.21	24.37	28.75	29.83
Agricultural activities	29.78	28.68	27.37	25.84	25.04
Waste	9.68	23.83	32.72	33.52	33.92
Increase to 1990 (%)	-	26.99	58.80	76.37	95.96

Source: [5].

In Turkey, the highest growth of CO_2 emission between 1990 and 2008 was observed in energy industries with 114% in 2008. It is followed by manufacturing industries with 79%. Approximately 91% of total CO_2 emission has been emitted from energy sector and the rest portion, which is %9, was originated from industrial processes in 2008. However, 59% of CH_4 emission is originated from waste disposal and 31% from agricultural activities while 72% of N_2O emission is from agricultural activities. In terms of fuel combustion, 36% of total CO_2 emissions is originated from energy industries while 19% from manufacturing industries, 16% from transport and 21% from other sectors in 2008. Energy related CO_2 emissions have more than doubled since 1990 and it will most likely to continue to increase fast over the medium and long term because of the increasing energy demand [5].

Turkey is a Party to United Nations Framework Convention on Climate Change (UNFCCC) and a Party to Kyoto Protocol in 2009. However, as developing economy with low emission per capita, Turkey has preferred not to determine quantitative overall target to limit emissions. Although Turkey has no legal compulsory commitment, she has been working on further developing it's post 2012 approach and determining it's commitment. For example it has set a unilateral quantitative target for $C0_2$ emissions from energy sector (- 7 % from scenario level in 2020) as determined in it's 2009 National Climate Change Strategy report [2]. Both biofuels targets and greenhouse emission commitments will bring important implications in agriculture, industry and household sector. There has been increasing effort in energy production from biomass, but, unfortunately official statistics are not available to evaluate its contribution to energy supply and GHG emission reduction.

5. Conclusion

Turkey has no large oil and natural gas reserves and it's domestic energy supply is low relative to total demand. Hence Turkey is dependent on imported energy sources that constitutes big burden on the economy. Turkey has potential for further growth in energy demand as a result of social and economic development. Growing energy consumption combined with the insufficient primary energy sources negatively effects not only the foreign trade balance and greenhouse emissions but also energy security. Moreover growing demand makes additional investments inevitable in energy sector. These issues constitute dilemma for energy policy in Turkey.

If the precautions cannot be taken in time, Turkey will be at the risk of energy deprivation and volatility of energy prices. Electricity energy demand also has been growing so it has pressure on other primary energy resources and also investment needs. Investments in electricity generation capacity have to be enhanced. Improvement in electricity market in terms of competition would have positive impact on increasing the domestic and foreign private funds in the sector. Much more exploiting hydro and other renewable resource such as wind, biomass, solar for electricity generation would contribute both in generating capacity and also energy security. Increasing the renewable energy usage and supporting the R&D studies in renewable energy technologies would improve the energy independency and economic development. Geothermal energy is a promising energy source for the future. Turkey has to develop the usage of solar and wind energies because the potential for these energies is good. Ensuring the sufficient energy supply for economic development should be the government's main target. According to the recent research [24], Turkey has potential about 25% for the efficient energy usage. In this context, government should stimulate the efficient energy using in the country and prepare additional regulations for the Renewable Energy Strategies. Environmental concern has risen because of the high value GHG especially emitted from energy sector. Although there is a development in energy efficiency in Turkey, the efficiency of energy is not as important as in Europe. Although Turkey has no official target for CO_2 emissions, eventually she will have to prepare its plan. In this context, emission targets will bring important commitments on households and industries.

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Optimization of a renewable energy supply system on a remote area: Berlenga Island case study

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Abstract: HOMER software was used to technical and economically assess two renewable energy supply (RES) system configurations – PV-only (80 kW) and PV (34 kW)/WT (36 kW), both with a three day storage capacity and requiring 11kW of electric power – proposed by a partnership project responsible for the implementation of sustainable measures on a Portuguese small island. HOMER calculation showed insufficient storage capacity for both RES system proposed, so extra storage capacity should be added. Economically, life cycle cost (NPC) of the cheaper configuration (PV/WT) resulting from HOMER calculation was significantly lower (20%) than the one advanced by the project. On a second stage, HOMER was used to compute an optimal RES system configuration to attend water desalination and street lighting electric additional loads. The optimal configuration – PV (25 kW)/WT (18kW) – costs 18% less than the equivalent PV/WT system proposed by the project when the same additional load is considered. Sensitivity analysis on the electric load showed the cost difference between project's and HOMER's proposals fading as the load increased. Variation on wind speed average demonstrated the significance of data accuracy: using NASA's average wind speed data the NPC increased on 15% compared to using wind speed values revealed on a monitoring campaign on the island.

Keywords: *Remote off-grid energy systems, Optimization software, Sensitivity analysis*

1. Introduction

Decentralized energy generation systems have become a recent trend on the development of energy systems. Concerns related to energy security and climate change have been fostering the implementation of projects that allow the production of power and heat closer to the point of use [1], as the current and dominant approach of centralized energy production, based on fossil fuels, lead to inequities, external debts and significant environmental degradation [2]. Sustainability of energy systems is based on the energy hierarchy principles: top priority is energy conservation, next the adoption of renewable resources for energy production, and last the use of fossil resources [3].

Planning energy systems represents a major issue on the development process of our society. Available computational energy models can support energy planners to decide the best configuration for an energy supply system, as they allow simulating different solutions and working conditions, and checking their technical and economical feasibility in an early stage of the decision process. Optimization models, namely linear programming mathematical models, are usually used to solve cost minimization problems subject to specific technological, political and demand satisfaction constraints given by energy models [4]. This is the case of HOMER®, a software developed by the US National Renewable Energy Laboratory to address the need for a hybrid system design tool accurate enough to predict energy system performance. It has been used on several situations all over the world: a feasibility study for the implementation of a zero home energy in a Canada's city [5]; study of wind penetration into an existing diesel plant of an Saudi Arabia village [6]; analysis of the technical and financial viability of grid-only, renewable energy supply (RES)-only and grid/RES hybrid power supply configurations for a large-scale grid-connected Australian hotel [7].

2. Methodology

2.1. HOMER Software

HOMER is primarily an optimisation software package which simulates different RES system configurations and scales them on the basis of net present cost (NPC), which is the total cost of installing and operating the system over its lifetime. Depending on the input data and constrains imposed by the user, HOMER firstly assesses the technical feasibility of the RES system (i.e. whether the system can adequately serve the electrical and thermal loads and any other constraints imposed by the user), and then estimates the system's NPC [7]. Besides the electric load to attend, the user has to specify the "search space", i.e., the sizes and/or quantities of the different components of the RES system (wind generators (WT), photovoltaic array (PV), batteries, inverters, electrolyser, generator…) that will be used to calculate the optimal system design. It also performs sensitivity analysis to evaluate the impact of a change in one or more of the input parameters.

HOMER was used on this paper with three purposes: first, to assess the technical and economical performance of two predetermined RES system configurations; second, to optimise a RES system based on wind and solar resources on the Berlenga Island; and third, to assess the impact of the variation on electric load and the average wind speed has on the optimal RES system configuration.

2.2. Case Study: Berlenga Island

The Berlengas Archipelago is located 6 miles away from the Carvoeiro cape on Western Portugal, and has approximately 100 ha. Its island is called Berlenga Island. There is no resident population on this small group of islands, which contributed for the preservation of singular species of flora and fauna. Despite the absence of resident population, there is some human activity on Berlenga Island all year long: lighthouse workers are present on the island 24H/7day during all year. They work on rotation teams and spend several days in a row all year long; some Peniche's municipality workers spend some periods of time on the island form March to November; from May to October nearly 30 fisherman and restaurant workers stay full time on the island. Besides these "permanent" residents, there is a legal limitation of 350 islands visitors [8].

Before 2007, when a partnership program called "Berlenga – Sustainability Lab" (from now on called Berlenga Project) started, electricity generation was based on diesel generators (130 kW), producing 30 MWh/year and consuming nearly 15000 L/year (roughly 40 ton CO_2 emissions/year) [9]. This system had several drawbacks: high O&M diesel costs due to the aggressive environment on the island; limited energy supply schedule; island development compromised due to electrical limitations (water treatment systems) [9-10]. As so, Berlenga Project intended to develop a zero CO_2 emission electric system to supply the Berlenga Island. Two possible configurations were proposed: Configuration A – PV/WT system; Configuration B – PV-only system. Accordingly to Berlenga Project, Configuration A is less expensive than Configuration B (600 k€ and 750 k€, respectively), however it has an higher environmental impact (mainly because of WT's visual impact and sound pollution) [10].

2.2.1. Berlenga Project Electric Load

In an early stage of Berlenga Project, island's electric monthly load profile was monitored – Fig. 1. Island's electric load profile shows irregular electricity consumption due to the "tourist invasion" during summer months. This domestic electric load profile refers to electricity use on households only. From December to February the only residents on the island are the lighthouse workers. The lighthouse already had a PV array installed and that justifies the absence of electric load on those months. To perform a HOMER simulation, a monthly load profile is not accurate enough. It is required an hourly electric load profile. For that purpose it was used a typical household hourly load profile – Fig. 2 – in order to calculate an hourly load for an average day of each month of the year. The maximum electric power considered was 11 kW and the electric load is subject to 5% standard deviation on daily averages and 10% deviation between the difference of hourly data and the average daily profile.

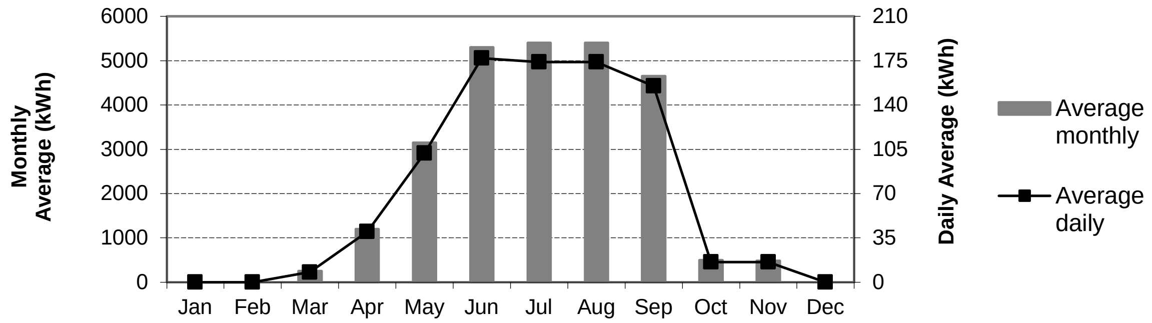

Figure 1. Monthly and daily average domestic electric load profile – adapted from [9].

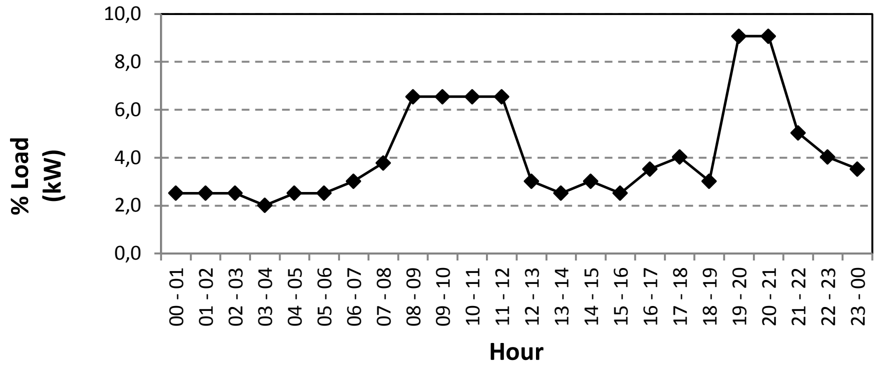

Figure 2. Hourly load percentage distribution during a typical day – adapted from [11].

2.2.2. Additional Electric Loads

Installation of street lighting on the island was assessed on this study. The street lighting system should include 10 street lamps with 125W each working on average 10h/day (3650 hours/year). During winter (Oct-Mar) street lightning works 12 hours/day (from 19:00 to 07:00) and on summer period (Apr-Sep) only 8 hour/day (from 22:00 to 06:00).

The island doesn't have fresh water reserve aquifers. Fresh water is supplied to the island through an 8 m^3 container, by the ship that takes the visitors to the island [12]. According to the last report on this matter [12], fresh water consumption on the island during high season (July and August) was 3 m^3/day and 2 m^3/day on 2007 and 2008 respectively. The fresh water load and electric load required to produce it using a reverse osmosis equipment, are shown on Fig. 3. This electric load was considered as a *deferrable load*, i.e. electrical load that must be met within some period of time, but the exact timing is not important.

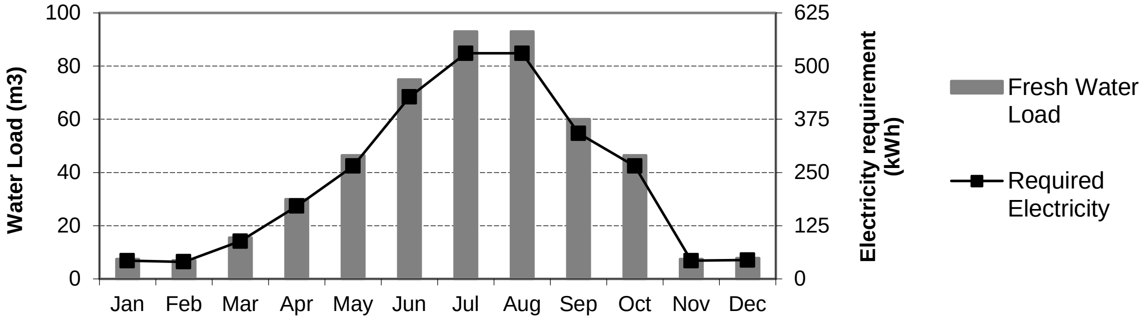

Figure 3. Fresh water consumption and required electricity to produce it.

2.3. Renewable Resources – Wind and Sun

Two sources of information were available on wind average speed. Through NASA's website on data information on surface meteorology and solar energy [13] it's possible to get a monthly profile according to the geographic coordinates of a certain location. To the location of Berlenga Island the database indicate a baseline annual average of 5,16 m/s. In addition to this information, wind potential on the island was evaluated through a monitoring campaign from December 2006 to September 2007 [14]. The campaign's reported an average wind speed of 6,74 m/s, significantly higher than NASA's baseline annual average. As so, it was used 6,74 m/s as a scaled annual average value on the simulation. The scaled data retains the shape and statistical characteristics of the baseline data, but may differ in magnitude.

Solar data information provided by HOMER database was used, according to the geographic coordinates of the island – 4,092 kWh/m2/day and 0,518 Clearness Index.

2.4. Equipments

To perform HOMER simulations, RES system equipments shown on Table 1 were considered.

Table 1. Capital and operation and maintenance costs of a RES system's equipment.

Equipment	Capital Cost	O&M Cost
6 kW Wind Turbine	29445 €/unit [15]	600 €/year [16]
15 kW Wind Turbine	76700 €/unit[15]	850 €/year [16]
Photovoltaic Array	5500 €/kW [17]	10 €/kW [18]
Battery 6CS – 7,6 kWh	850 €/unit [19]	10 €/year [19]
Battery 4KS – 6,94 kWh	770 €/unit [19]	10 €/year [19]
Inverter/Converter	550 €/kW [19]	-

3. HOMER simulation results

Solar and wind data, electric loads and equipments required to build a RES system were described on the previous sections. The project lifetime is 25 years.

3.1. Berlenga Project Configurations

The Berlenga Project originally proposed two alternative configurations for the required RES system: Configuration A – PV (34 kW)/Wind Turbine (36 kW); Configuration B – PV (80 kW). In order to meet Berlenga Project constrains, both configurations should attend the required domestic electric load and include batteries with capacity to bear three days of average consumption, i.e., 230 kWh [9-10]. After running the simulation with this storage capacity, the only feasible configuration resulted on a PV (80 kW)/WT (36 kW) system, mainly due to high electric demand on summer days. As so, it was necessary to extend the storage capacity to enable the simulation of both Configurations A and B – Table 2.

3.2. Additional electric load scenario

Configuration A and B were simulated to attend the domestic electric load monitored on the scope of the project as shown on Fig. 1. It was simulated a RES system configuration to attend additional street lighting and water desalination electric loads – Current Load Scenario – resulting on Configurations C and D, as shown on Table 2. Adding these two additional loads resulted in higher Initial Capital Cost (IC) and NPC, basically due to the requirement of extra storage capacity and respective O&M costs, however the cost of energy (COE) dropped. HOMER defines COE as the average cost per kWh of useful electrical energy produced by the system. The lower COE shows more efficient use of the electricity produced, as the same amount of electricity is produced and more energy is effectively used.

Table 2. RES systems configurations proposed by Berlenga Project.

RES Config	PV (kW)	WT 6kW (unit)	6CS (unit)	4KS (unit)	Conv (kW)	IC (k€)	O&M ($/yr)	NPC (k€)	COE ($/kWh)
3 day storage	80	6		30	21	642	8789	764	1,415
A	34	6	35		19	390	5744	506	0,937
B	80			65	21	495	4168	579	1,073
C	34	6		40	19	398	6101	520	0,757
D	80			80	21	508	4874	606	0,882

3.3. Optimal configuration by HOMER

As an alternative solution to the originally proposed configurations, above referred as A and B, HOMER was used to shape an optimal RES system based on PV panels, wind turbines and a battery bank to store electricity in order to attend the same domestic electric load shown on Fig 1. It was included a 15 kW wind turbine on this simulation in addition to the 6kW wind turbine. The optimization results are shown on Table 3. Three different configurations result to be possible for the implementation of a RES system on the Berlenga Island: Configuration 1 – PV (25kW) + WT (3x6kW); Configuration 2 – PV (65 kW); Configuration 3 – WT (9x6kW). Configuration 1 represents the HOMER optimal configuration – lowest NPC. The RES system based on PV-only (Configuration 2) is significantly more expensive than mixing PV and WT. A third option (Configuration 3) is available using wind turbines only. This one has a lower IC than configuration 2, but the higher O&M costs results on a higher NPC.

Table 3. HOMER optimal configuration when attending the domestic, water desalination and street lighting loads.

RES Config	PV (kW)	WT 6kW (unit)	WT 15kW (unit)	4KS (unit)	Conv (kW)	IC (k€)	O&M ($/yr)	NPC (k€)	COE ($/kWh)
1	25	3		85	22	298	6374	426	0,620
2	65			95	21	438	5430	548	0,796
3		9		100	19	350	10387	559	0,813

Comparing Berlenga Project's original configurations C (PV/WT) and D (PV-only) with configurations 1 (PV/WT) and 2 (PV-only) resulting from HOMER optimization, it is clear that the last ones present better financial indicators, especially the PV/WT configuration.

3.4. Sensitivity Analysis by HOMER

3.4.1. Electric Load

The effect of higher electricity requirement on HOMER optimal configuration was assessed through a sensitivity analysis, by creating two additional electric load scenarios: 10% Increase Scenario – 10 % increase on domestic and water desalination electric load; 20% Increase Scenario – 20 % increase on domestic and water desalination electric load. Street lighting remained unchanged on both scenarios. A PV/WT system resulted to be the optimal configuration for both scenarios. The NPC increases linearly with the electric load – Fig. 3. Comparing configuration C (34 kW PV/36 kW WT) with HOMER optimal configuration for each electric load scenario, it can be stated that the greater the electric load the closer is the economic performance of both configurations even though the optimal configuration proposed by HOMER is always cheaper – Fig. 4.

With 10% load increase scenario the three possible configurations for the RES system showed on Table 3 are feasible. As the electric load increase 20%, PV-only solution becomes unfeasible.

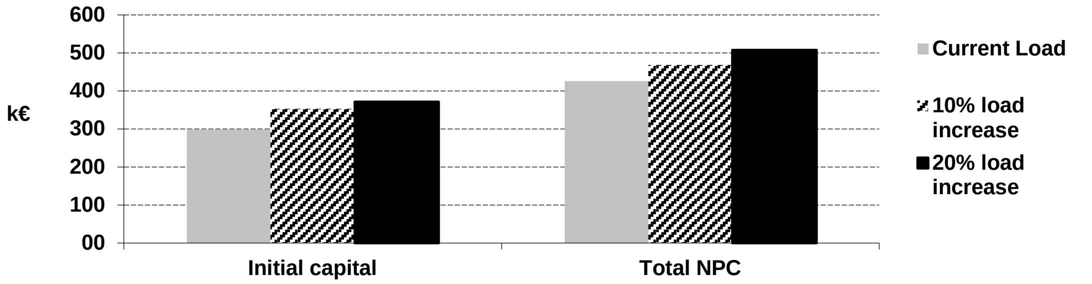

Figure 4. Effect of increasing electric load on RES system costs.

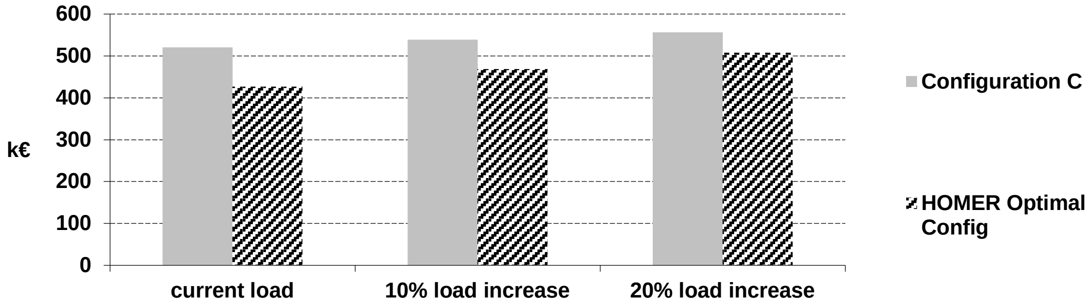

Figure 5. NPC comparison between Configuration C and Configuration 1.

3.4.2. Wind speed

As occurred with the electric load sensitivity analysis, a PV/WT system resulted to be the HOMER optimal configuration when assessing wind speed influence. The economic impact of the average wind speed on the optimal RES system can be assessed on Fig. 5. Using NASA's database value for annual average wind speed, NPC increased around 11% on all three electric load scenarios.

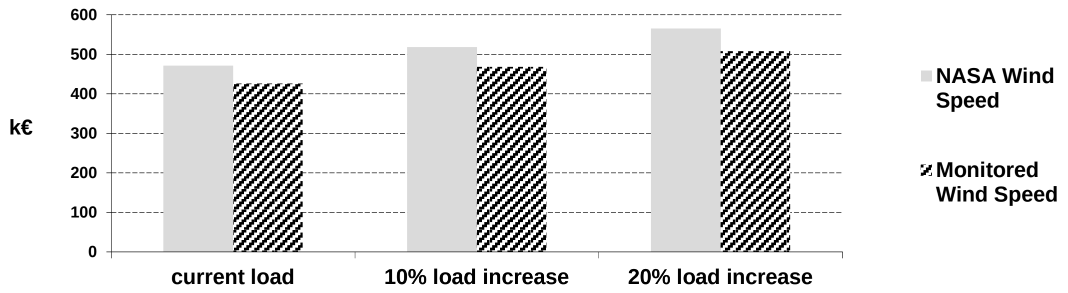

Figure 6. Effect of the average wind speed on system's NPC for each of the electric load increase.

For the current load scenario, the feasibility of the three possible configuration systems is not affected despite the WT-only system results to be almost 80% more expensive than the PV/WT optimal configuration. As the load increase 10% the WT configuration becomes no longer feasible and with 20% electric load increase PV/WT is the only feasible configuration.

4. Conclusions

One of the assumptions made by Berlenga Project's authors was to use a three day storage capacity (230 kWh). HOMER's system simulation showed that this storage capacity not enough for the proposed RES system configurations (A and B) mainly because of the high demand on summer months.

Information on system's cost issued by the Berlenga Project is not completely obvious. A cost of 600 k€ for configuration A (PV/WT) and 750 k€ for configuration B (PV-only system) was assumed, but it is not clear if those are IC or NPC [9]. Assuming those values as NPC and that the aim is to attend the domestic electric load monitored under the Berlenga Project, the costs resulting from HOMER simulation for both system configurations are lower than those proposed by the Berlenga Project: 506 k€ for configuration A and 579 k€ for configuration B. When attending additional street lighting and the water desalination loads (configurations C and D) the costs rose, due to higher storage capacity needed, but they still were far from the costs advanced by the Berlenga Project. This cost gap can be explained, at some extent, by the fact that the costs advanced by the Berlenga Project were from 2007, three years ago. When performing the "free" optimization to attend domestic, water desalination and street lighting loads (Current Load Scenario), the optimal configuration (configuration 1) includes 25 kW photovoltaic panels and three 6 kW wind turbines. Both PV/WT and PV-only optimized configurations resulted to be cheaper than the ones proposed by the Berlenga Project.

Two sensitivity analyses were performed to assess the impact of electric load deviation and average wind speed on the RES system cost and configuration attending domestic, street lighting and water desalination loads. As the electric load rises, the closer is the economic performance of both Berlenga Project (configuration C) and HOMER optimal configurations, even though the latter is always cheaper. This means that the configuration proposed by the Berlenga Project was oversized for the present electric load requirement. This may be an assumed choice, having in mind the future load growth, when new electric loads were included in the grid, the only equipments to add on the RES system should be batteries to store electricity. Despite using NASA's data to profile the average monthly wind speed, a scaled value for the wind speed based on the monitoring campaign made on the Berlenga Island was used to compute the simulation, for a better representation of local conditions. Higher average wind speed means more available wind resource and less costs to generate the same amount of electricity. The higher wind speed value results on a 10% lower NPC for the optimal PV/WT configuration. This is true both for current load and for load increase scenarios. This analysis stresses the importance of use valid reliable data, namely renewable resources availability data, when performing a technical and/or economical assessment of a RES system.

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Pathway to a fully sustainable global energy system by 2050

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Abstract: We present a possible pathway to a global, sustainable energy system by 2050. This new energy scenario follows a comprehensive examination to all aspects of energy use across the entire world and the possible means of supplying this energy from the sustainable sources we have available to us. It does so, from the perspective of actual, physical activities that require energy: our industrial processes, our cars, our buildings.

For each of these activities, the scenario asks the questions:
- What is the minimum amount of energy required to deliver these functions?
- How can we supply this energy in a sustainable way?

The key aspects of this new Energy Scenario are:
- It is an ambitious, but feasible pathway for all sectors; we *can* build an energy system by 2050 which sources 95% of its energy from sustainable sources.
- This energy system will use only a small fraction of each of the sustainable energy sources, making this a robust scenario.
- We can progress towards a world that still sustains comfortable lifestyles, despite consumption patterns, demonstrating a more efficient use of energy and other resources, particularly in developed countries.
- Energy efficiency is the key requisite to meeting our future energy needs from sustainable sources. Total energy demand in 2050 is lower than in 2000, despite the growth of population and energy services.
- Electricity is the energy carrier most readily available from sustainable energy sources and therefore, electrification is key.
- All bioenergy required, (primarily for residual fuel and heat demands) can be sourced sustainably, provided the appropriate management practices and policies are in place.
- The scenario's energy system will have large cost advantages over a business-as-usual system because the initial investments will be more than offset by savings made on energy costs, in later years.

The scenario is based on a comprehensive energy model, developed by Ecofys, to establish a scenario for future energy demand and supply worldwide. Unlike many world models, it is based on physical activity indicators and takes a comprehensive look at all aspects of energy demand and supply across all sectors.

The work pays particular attention to the implementation speed of sustainable energy technologies and assesses energy at the detailed carrier and sub-sector level.
It also contains a comprehensive assessment of biomass as a sustainable energy source, with a multitude of different source options and conversion technologies, subject to stringent sustainability criteria.

Keywords: *Sustainability, Renewable energy, Energy efficiency, Scenario, Global*

1. Introduction

The last 200 years have witnessed a substantial increase in energy use by societies worldwide. In recent decades, it has become clear that the way this energy is supplied is unsustainable and now both, short- and long-term energy security, are at the top of the political and societal agenda.

Evidence suggests that we should be able to meet our energy demand from renewable sources, given their abundance: Worldwide energy use, in units of final energy (after conversion from primary fuels), was ~310 EJ in 2007 (~500 EJ in primary energy terms) [1] whereas technical potentials range from 100s to 1000s of EJ/a (see Fig. 3).

In an attempt to reconcile these figures, the energy scenario provides a comprehensive view of the energy system. It incorporates and examines all energy uses; all quantities, locations, carrier forms (e.g. electricity or fuel) and all purposes (heat in buildings or heat in industry)

This level of detail is (partially) captured in the various energy scenario models that are currently used to predict the most likely energy future for the world and the possible alternative scenarios. However, because cost-optimisation is often the driving algorithm, not many of the models have been used to push the share of renewable sources in the energy system to the highest technically possible levels. One of the few studies which has prioritised renewable sources, is the Energy [R]evolution published by Greenpeace. [2] Even this scenario however, falls short of reaching a fully sustainable energy system by mid-century.

The fundamental question that guided this study was:

"Is a fully sustainable global energy system possible by 2050?"

We find that an (almost) fully sustainable energy supply is technically and economically feasible, given ambitious, yet realistic growth rates of sustainable energy sources. The path to achieving this system deviates significantly from 'business as usual' and the difficult choices that must be made on the way are discussed in this article.

This article is a summary of three full-length publications. The reader is referred to the full publications.[3]–[5]

2. Methodology

Energy demand is the product of:

- the volume of the activity requiring the energy (e.g. travel or industrial production), and
- the energy intensity per unit of activity (e.g. energy used per volume of travel).

This energy scenario forecasts future global demand and supply by inherently following the paradigm of Trias Energetica:

1. Reducing energy demand to the minimum required to provide energy services
2. Providing energy by renewable, where possible, local, sources first
3. Providing remaining energy from 'traditional' energy sources as sustainably as possible.

The Trias Energetica approach was translated into this calculation logic:

1. Future energy demand scenario
    a. Future demand side activity was based on existing studies or projected from population and GDP growth.
    b. Future demand side energy intensity was forecasted assuming fastest possible roll-out of most efficient technologies.
    c. The resulting energy demand was aggregated by carrier (electricity, fuel, heat).
2. Future supply scenario
    a. The potential for supply of energy was estimated by energy carrier

b. Demand and supply were balanced in each time period according to the following prioritisation:
    i. Renewables from sources other than biomass (electricity and local heat)
    ii. Biomass up to the sustainable potential
    iii. Traditional sources, such as fossil and nuclear which were used as 'last resort'.

Energy flows have been characterised by carrier type and differentiated into electricity, heat and fuels, consistent with the energy carriers reported in the IEA energy balances, to which this work is calibrated, with 2005 as the base year. [6]
Unless stated otherwise, all energy in this publication is final energy.

2.1. Sector definitions

There are many different ways of analysing energy demand. We have chosen to distinguish between energy demand in industry, buildings and transport. (These sectors are congruent with the sectors for which the International Energy Agency (IEA) reports energy statistics, which form the basis of this work.) These three sectors, which cover ~85% of total energy use, were studied in detail. The remaining sectors, (including agriculture, fishing, mining etc.) are included in this study, but were not examined separately. Non-energy use of energy carriers was excluded from this analysis.

In the Industry sector, we distinguish between 'A' sectors, for which actual activity measures are available (Iron & steel, non-ferrous metals, non-metallic minerals, paper & pulp) and 'B' sectors, for which activity has to be based on proxy indicators, such as value added (Chemical & petrochemical, food & tobacco, all others).

3. Results – Part 1: Demand

For each of the sectors, we established an activity and energy intensity forecast, to arrive at a final demand projection for the period to 2050.

3.1. Activity

Activity forecasts were made as follows:

- Industry: Population and GDP forecasts were coupled with assumptions on the evolution of per capita production of industrial products.
- Buildings: Population and GDP forecasts were coupled with assumptions on the evolution of per capita residential and commercial building areas.
- Transport: Modal shifts, (from road and air to rail transport) are incorporated into an existing BAU transport scenario [7].

The overall evolution of activity is given in Fig. 1.

3.2. Intensity

The most significant means of reducing energy demand is the efficient use of energy, i.e. the reduction of energy intensity to a minimum.
We describe our approach to each sector's energy intensity below.

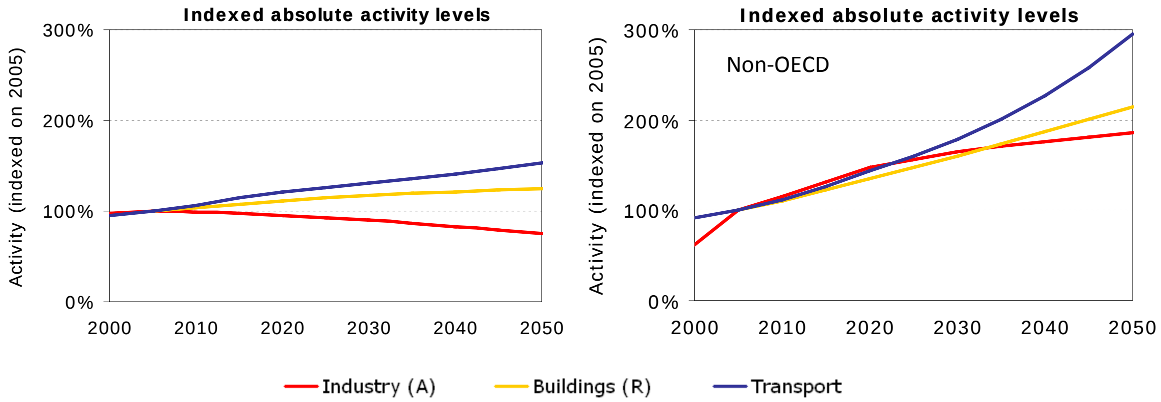

Fig. 1 Activity levels indexed on 2005 in absolute terms. Shown industrial production volumes in the 'A' sectors (Industry), residential floor space (Buildings), and passenger kilometers (Transport).

3.2.1. Industry

Future energy intensity is projected based on key marker processes. We adopt a decrease in energy intensity, measured in energy per tonne produced for 'A' sectors [8]–[11], and in energy per economic value for 'B' sectors.

'A' sectors

The energy intensity evolution was examined in detail for the four 'A' sectors, yielding, on average, a ~50% reduction in energy used, per tonne of material produced in 2050 against the 2000 figures. Although the individual technologies vary by sector, all sectors follow these common assumptions:

- Increased use of recovered input materials or alternative routes
    - i.e. recycling of steel, paper and aluminium and alternative input materials into the clinker process in cement production
- Ambitious refurbishment of existing plants to meet performance benchmarks
- Stringent requirements for using best available technology (BAT) in all new plants.
- Continuing improvements of BAT over time

'B' sectors

For the 'B' sectors, an annual efficiency improvement of 2% was adopted, which may be obtained through improved process optimisation, more efficient energy supply, improved efficiency in motor driven systems and lighting and sector-specific measures.

3.2.2. Buildings

The following steps are followed to project the future evolution of energy intensity, i.e. the possible future heat and electricity demand per square metre of living or commercial floor space.

Existing buildings stock

1. All existing buildings will have to be retrofitted by 2050 to ambitious energy efficiency standards. This requires retrofit rates of up to 2.5% of floor area per year, which is high (compared to current practice), yet feasible.
2. For any given retrofit it is assumed that, on average, 60% of the heating requirements are abated by insulating walls, roofs and ground floors, replacing old windows with

highly energy efficient windows and by installing ventilation systems with heat recovery mechanisms.
3. A quarter of the remaining heating and hot water need is met by local solar thermal systems and the rest, by heat pumps.
4. Cooling is provided by local, renewable solutions, where possible.
5. Increased electricity needs per floor area due to increased cooling demand, increased use of appliances (per area) and heat pump powering have been partially offset by increasing efficiency.

New building stock

1. Increasingly, new buildings will be built to a 'near zero energy use' standard, reaching a penetration of 100% of new buildings by 2030.
2. The residual heat demand is met by passive solar (radiation through windows) and internal gains (people, appliances), renewable energy systems in the form of solar thermal installations and heat pumps.
3. This building type only requires electric energy.
4. The near zero-energy concept is applied to warm/hot climates, often returning to traditional building approaches.
5. There is a residual cooling demand in warm/hot climates. Increased electricity needs from increased cooling and appliances, as well as the use of heat pumps, have been estimated and included in this scenario.

3.2.3. Transport

The following steps ensure that the scenario employs the most efficient transport modes that have the greatest possible share of renewable energy in the energy supply:

1. Moving to efficient technologies and modes of employment, e.g. trucks with reduced drag, improved air traffic management or reduced fuel needs in hybrid buses.
2. Electrifying the mode as far as possible, e.g. electric cars in urban environments and electric rail systems.
3. Finally, providing the fuel from sustainable biomass, where possible (see next section).

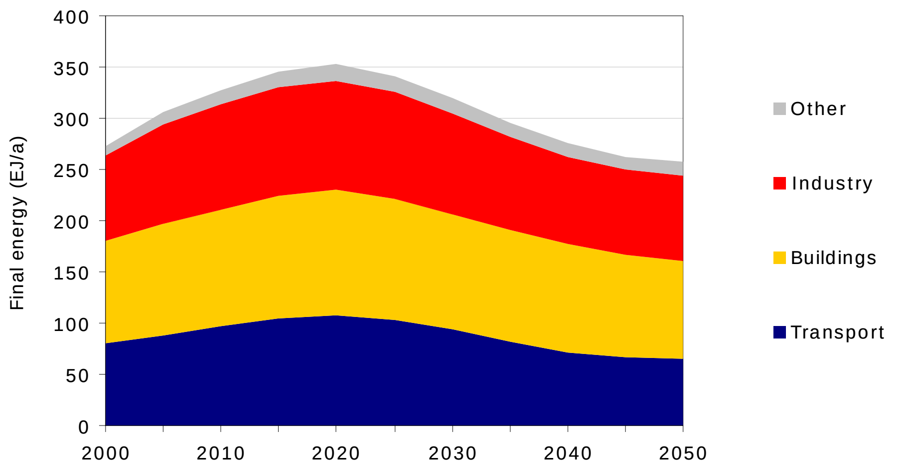

Fig. 2 Global energy demand across all sectors, from 2000 to 2050.

Noteworthy assumptions are:

- A complete shift to plug-in hybrids and/or electric vehicles as the primary technology choice for light-duty vehicles.

- Long-distance trucks undergoing significant efficiency improvements due to improved material choice, engine technology and aerodynamics, rather than a complete electrification of freight road transport (due to the prohibitive size and weight of batteries required with current technology). Delivery vans covering 'the last mile' are electrified, leading to an electric share estimate of 30% for trucks.
- A (small) share of shipping fuel gradually being replaced by hydrogen, won from renewable electricity. This has been deemed a feasible option because of the centralised refuelling of ships.

3.3. Summary

The activity and intensity assumption detailed above lead to the following overall evolution of energy demand (Fig. 2)

4. Results – Part 2: Supply

4.1. Renewable sources excluding bioenergy

Once total demand has been established, demand must be matched with energy supply.

This scenario is based on the deployment potential shown in Fig. 3. This is the potential which can be captured at any time, considering technical barriers and ambitious, yet feasible market growth developments. The deployment potential does not necessarily represent the most cost-effective development, i.e. it does not account for market barriers or competition with other sources.

The realisable potential (R.P.) is the fully achievable potential of the resource with a long-term development horizon.

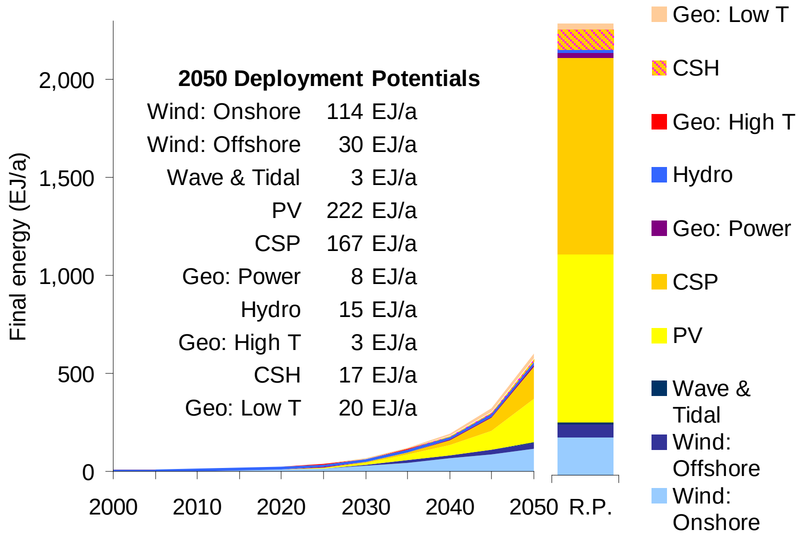

Fig. 3 Global renewable energy potentials (excl. bioenergy), from 2000 to 2050. [5], [12]–[29]

4.2. Bioenergy

The scenario incorporates a significant share of sustainable bioenergy supply to meet the remaining demand once other renewable energy options have been employed. The scenario only includes bioenergy supply that is sustainable and leads to high greenhouse gas emission savings in comparison to fossil references. The complete approach the scenario takes to bioenergy is discussed in a separate publication. [4]

4.3. Results of balancing demand and supply

Following the strict prioritisation of options described in the Methodology section, the overall evolution of energy supply is determined, as shown in Fig. 4.

Stabilising energy demand, driven by strong energy efficiency, coincides with fast renewable energy supply growth in later years, resulting in an energy system that is 95% sustainably sourced.

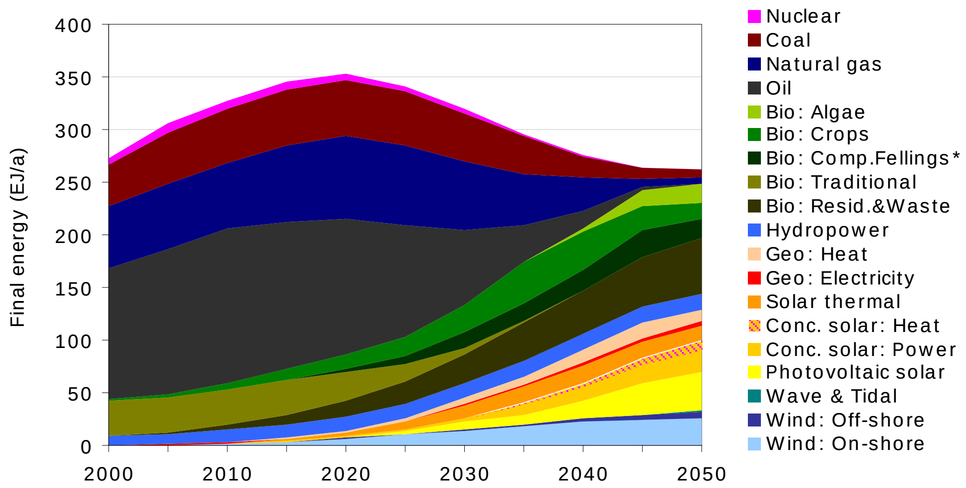

*Fig. 4 Global energy supply in the Scenario, split by source. (*Complementary fellings include the sustainable share of traditional biomass use.)*

5. Discussion

The energy scenario we have presented combines the most ambitious efficiency drive with a high-growth of renewable source options to reach a fully sustainable global energy system by 2050. Both sides of the equation are important: the transition to a renewable energy system cannot be achieved on the supply side alone.

This energy scenario examines the feasibility of a fully renewable energy future by taking a bottom-up, physical approach to the energy system. It does not necessarily present the most cost-efficient way of achieving this goal. It is however, insightful to estimate the associated investment and savings of this energy system in comparison to a BAU energy system.

This cost study is presented in a separate publication. [5] The key findings are, that upfront investments are estimated at less than 2% of global GDP and the energy system proposed in this scenario would be significantly cheaper to operate than BAU by 2050.

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