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 (SCEC[3])* 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.

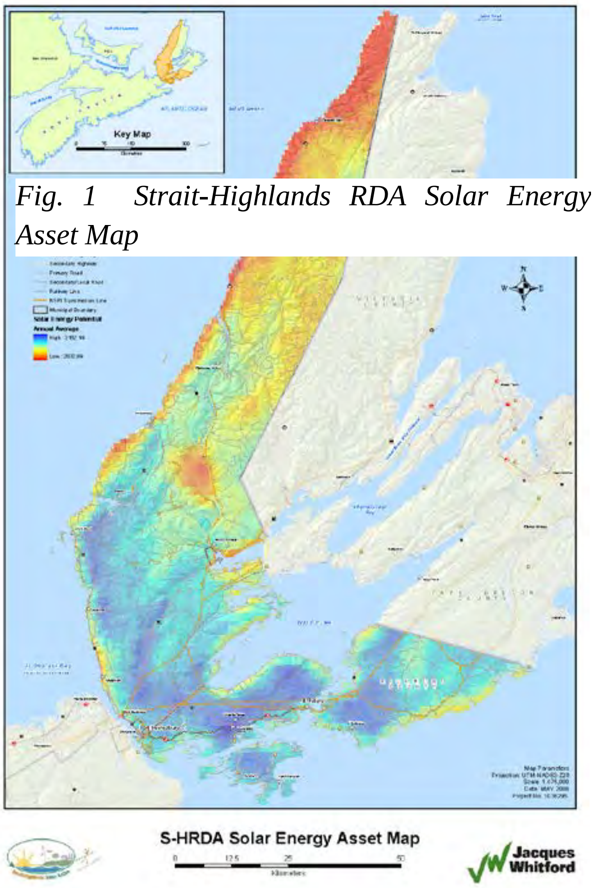

Fig. 1 Strait-Highlands RDA Solar Energy Asset Map

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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