Proposal of a framework for the selection of renewable energy technology systems in Africa

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Abstract: Energy is essential for economic development in Africa. The current electrification figures show that countries in sub-Saharan Africa are facing major challenges in reaching positive economic growth and supplying basic energy services to rural communities. Prior to this study a comprehensive framework of factors to select renewable energy technologies did not exist. The purpose of this research was to develop such a framework and to validate it by means of empirical analyses. A triangulation of methodologies including a literature analysis, focus group, Delphi study and case study was used to determine the framework of factors. This paper presents the final framework that includes both the thirteen criteria and measures to be used for the selection of renewable energy technologies in Africa. The paper further recommends the critical documentation that must be created for each competing technology.

Keywords: *Renewable energy technology selection, Developing countries, Sustainable energy, Selection criteria, Framework of factors*

1. Introduction

Energy is essential for economic development in Africa [1]. The current electrification figures show that countries in sub-Saharan Africa are facing major challenges in reaching positive economic growth and supplying basic energy services to rural communities [2]. Sustainable energy technologies are available and can be used to great effect in Africa to alleviate this problem [3]. Sustainable energy technologies can also contribute to job creation [4]. The implementation of renewable energy technologies in sub-Saharan Africa to date, however, has not always been successful due to both technical and non-technical factors [4-9]. Prior to this study a comprehensive framework of factors to select renewable energy technologies did not exist. The purpose of this research was to develop such a framework and to validate it by means of empirical analyses.

2. Methodology

A triangulation of methodologies was used to determine the framework of factors [10]. The analysis of the literature investigated renewable energy technologies and their application, the challenges in renewable energy technologies for implementation in Africa, and the selection methods in the fields of project, portfolio, programme and technology management. This was followed by a focus group [11, 12] with three experts,[13] in which thirty eight factors that need to be taken into account during the selection of renewable energy technologies in Africa were identified [13]. The factors identified by the focus group were confirmed and the eleven most applicable factors were selected through a two-round Delphi study [14-16]. Finally, case studies on the implementation of renewable energy technologies were undertaken in three countries [17, 18]. These case studies confirmed the eleven factors identified during the Delphi study and identified a further two factors that were added to the framework [19].

3. Results

The final list of factors, factors identified during the focus group, the Delphi study definition of each factor as well as the important issues for each factor identified in the case studies, is shown in Table 1.

Table 1. Framework of thirteen final factors to consider for sustainable, renewable energy technology selection in Africa

Factor description	Focus group identification	Delphi study definition	Important issues for each factor from case studies
Technology factors			
Ease of maintenance and support over the life cycle of the technology	Maintenance/ support	Security of supply is enhanced. It also implies that spares are affordable and can be easily acquired.	Quality of the installations, the maintenance plans, the training of technicians, maintenance training for users, keeping maintenance simple and adapting the technology to the specific environment
Ease of transfer of knowledge and skills to relevant people in Africa	Transfer of knowledge and skills	Transfer of knowledge and skills to the community involved. Dedicated personnel to run the facility are required.	Identification of stakeholders to train; methods of skills transfer applicable to the environment; quality of training; and formalization of skills transfer.
Site selection factors			
Local champion to continue after implementation	Local hero – champion to continue after implementation	Facilitators of the technology exist which will ensure that the facility will continue after implementation.	Local champions must be identified during technology selection, their responsibilities must be clearly defined and they must be aware of the long term implications of their role
Adoption by community	Passion/ ownership/ buy-in/ adoption by community, responsibility	Community adopting the technology, accepting ownership, demonstrating buy-in and taking responsibility	A determination must be done of the capacity of the population to adopt the new technology, the benefits of the new technology must be determined and communicated to the community and that measures must be in place to ensure client satisfaction
Suitable sites ready for pilot studies	Pilot study site selection issues	Pilot studies are necessary to demonstrate technology to decision makers	Selection of pilot sites is very important and valuable; pilot sites must be selected in such a way that they will be accessible for demonstration purposes to the community
Access to suitable sites can be secured	Not applicable	Access for implementers to sites where the technology can be implemented must be secured up front	Determine priorities of population; set implementation targets; identify site criteria; and identify site
Economic/ financial factors			
Economic development	Economic development (community eventually able to pay), economic	Economic development translates into (a) the community being able to pay for services and (b) economic sustainability	Income generation, cost and time saving and national income and savings all contribute to economic development

Factor description	Focus group identification	Delphi study definition	Important issues for each factor from case studies
	sustainability		
Availability of finance	Available budget – the finances to support a project	The determination of the required budget and the availability of finance for this budget are addressed here. The type of finance whether debt, equity or grant must also be taken into account.	Finance can be facilitated by implementing payment methods which are applicable for the households, as for example, bartering and that finance methods must be in place before the technology can be implemented on a large scale
Achievability by performing organization			
Business management	Proper project management	The performing organization having the business management capacity and procedures in place to ensure that the implementation of technology can be done successfully	Which business management skills should be transferred, how the skills are to be transferred and what to do in the short term when the skills of the organization are lacking
Financial capacity	Financial capacity	Both the administrative capacity to manage finances and the ability to deliver, given the payment conditions.	Financial capacity for performing organizations can be problematic at the outset but that various methods can be used to alleviate the financial capacity required by the performing organization.
Technological capacity	Capacity	The performing organization has the correct technology necessary for implementation of the project at their disposal.	Technological capacity is directly related to quality. Quality assurance must be enforced; regulation of performing organizations and the dictating of standards also contribute to quality installations.
Other factors			
Government support	Regulatory financial incentive, tax regimes must be supportive" and does it fit under national priorities	Governmental support has been obtained for the technology	In the first place, the government must be aware of the new technology and support its implementation. If the government is also prepared to assist in the implementation, success of implementation is further enhanced.
Environmental benefits	Environmental impact assessment	The implementation of the technology will have a positive impact on the environment	Environmental benefits may include: decrease in the release of greenhouse gasses; protection of fragile ecosystems; halting soil erosion; halting desertification; prevention of fresh water pollution.

The focus group used the nominal group technique to identify 38 factors that need to be taken into account for the selection of renewable energy technologies in Africa and classified these factors into six categories.

The Delphi study was conducted over two rounds with the purpose of confirming and prioritising the factors identified during the focus group. The Delphi questionnaires were sent to experts (both academics and practitioners) in the field of renewable energy, with the emphasis on Africa.

In the first round, respondents were presented with the factors identified during the focus group and then asked to: comment on the classification of factors; comment on the description of factors; provide additional factors that were overlooked during the focus group; and provide a preliminary rating of the factors identified during the focus group in terms of feasibility, desirability and importance of considering these factors during the selection of renewable energy technologies in Africa. At the end of the first round Delphi the factors were regrouped into four categories.

In the second round of the Delphi study, the respondents were presented with a summary of the comments and ratings supplied in the first round and were then asked to supply new ratings in terms of feasibility, desirability and importance. The results were analysed. Eleven of the factors were rated by the experts to be feasible, highly desirable and highly important when selecting renewable energy technologies in Africa.

The eleven factors identified in the Delphi study were then used to generate the framework for the eight case studies which were conducted in the following three African countries: Rwanda; Tanzania and Malawi. The sources of evidence used included interviews, documentation and observation. The case studies confirmed that the eleven factors identified during the Delphi study are important for the selection of renewable energy technologies in Africa. Two additional factors were also found to be important and the wording of one of the factors was changed.

In conclusion, the thirteen most important factors that need to be considered for the selection of renewable energy technologies in Africa have been collated into a framework.

4. Discussion and/or Conclusions

The critical documentation that must be generated before renewable energy technologies are selected in Africa is shown in Table 2. The issues that have been identified in this study that must be addressed for each of the factors are also shown.

Table 2. Critical documentation for selection of renewable energy technologies in Africa

Description	Quality plan	Maintenance plan	Technology plan	Human resource plan	Financing plan
Technology factors					
Ease of maintenance and support over the life cycle of the technology	Standards, monitoring, evaluation, corrective action, responsibility, warranty	Operator maintenance, technical maintenance, spares	Adaption of technology	Responsibility for maintenance	Maintenance funding model
Ease of transfer of knowledge and skills to relevant people in Africa				Local skills levels, operator training and manuals, technical training and manuals, responsibility, quality, stakeholders, skills transfer	Skills transfer funding model
Site selection factors					
Local champion to continue after implementation				Identification of local champions	
Adoption by community			Capacity determination, benefits determination, information distribution, adoption probability		
Suitable sites ready for pilot studies			Selection of pilot sites		Pilot site funding model
Access to suitable sites can be secured			Priorities of population, implementation targets, site criteria identification		
Economic/ financial factors					
Economic development					Income generation, domestic cost and time

Description	Quality plan	Maintenance plan	Technology plan	Human resource plan	Financing plan
					savings, national income saving
Availability of finance					Initial investment donor funding, loan availability and rates, government support
Achievability by performing organization					
Business management				Capabilities of current organizations, business skills training, interim measures	
Financial capacity				Administrative capacity of performing organizations	Capital outlay requirements, capital outlay funding
Technological capacity	Quality assurance responsibility; technical guarantees	After sales service	Technological capacity of performing organization, regulation of standards for technology	Manufacturing training, installation training, maintenance training, refresher courses, quality training, technical backstopping	Financial incentive for quality
Other factors					
Government support			Government acceptance and support; energy policies, legislation and standards		Relief on taxes or duties; funding or subsidies; licensing
Environmental benefits			Environmental benefits of technology		

The critical documentation can be used at various levels and by various organizations to select the most appropriate renewable energy technologies for implementation in Africa. The critical documentation must be completed for each competing technology. The technology that performs the best in terms of addressing all the issues for all of the factors can then be selected. By using the framework proposed in this study, selection of renewable energy technologies can be done with the assurance that the most important factors for the successful implementation of these technologies have been taken into account.

The successful implementation of renewable energy technologies in Africa will lead to the improvement of the lives of the population in Africa, will increase their productivity and quality of life, and will contribute towards the alleviation of poverty and the empowerment of women and children. African children who have sustainable access to energy will be better educated and thus be better future leaders.

Further work is required to implement the factors into a selection method for example the analytical hierarchy process or analytical network process.

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