Multi criteria selection of RETs sites using Simple Additive Weighting (SAW)

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Abstract
One of the critical steps in developing a Renewable Energy Technologies (RETs) project is to find a suitable site and assess its feasibility for development.
This paper uses the Simple Additive Weighting (SAW) scoring method to determine various renewable energy sites for development under the Millennium Science Initiative (MSI) project for rural electrification, sponsored by Uganda National Council for Science and Technology (UNCST). SAW is one of the most linear multi criteria decision analysis techniques that uses regular arithmetical operations. In this research, a desk study of possible sites was done as a first step and 20 sites were visited for primary data collection using designed questionnaires for group meetings and target persons in the second step. The SAW technique adequately checks site suitability for different RETs and in this research, the tool successfully ranked the top six sites which were consequently developed. The results present the scores for all the sites based on attributes including demand, fuel or source of energy, technology, application of electricity and the human factors. The RETs installed include a solar PV energy kiosk, a solar PV mini grid, a pico-hydro mini grid, and three gasification plants.

Keywords: Site selection, SAW, Mini grids, Rural electrification, MSI.

Introduction

The Ugandan energy sector is dominated by biomass, accounting for 92% of the energy use, followed by petroleum (6%) and electricity (2%). The national access to electricity is currently at just 14% while rural access is about 7%. Energy generation in Uganda is very centralized: large hydropower plants near Jinja town and thermal power plants around Kampala. This, together with the dispersed housing patterns of Ugandan rural households, results in high distribution costs and explains the low electrification rates in rural areas (Mackay, 2009).

The Government of Uganda places highest preference and priority on extension of the existing electricity grid. However, it is also clear that grid extension is not possible everywhere and thus small-scale, independent grid systems are promoted by the government as the next step in rural electrification through the Rural Electrification Strategy and Plan (RESP) for the period 2013 to 2022 (MEMD, 2012). Where these so-called mini and micro-grid systems are not feasible, stand-alone systems such as solar PV home systems or even the smallest solutions, pico-solar PV, in the form of lanterns or kits are the last steps towards providing electricity in rural areas.
However, one of the biggest challenges of the projects is the question:where to place them?”. There has to be scientific means to choose a location based on relevant factors. Some examples of these factors can include but are not limited to: Distance to the nearest point of the national grid. The farther the better; Number of potential consumers. A critical mass of customers is needed for any business model. This parameter can also be calculated by obtaining potential and actual demand for the area; Interest from the local community. The business model and uptake of services rely heavily on the acceptance of the local community (Rasmus, 2014).
These factors are not necessarily of the same importance weight in all projects, as they depend on the overall success criteria. They have to be analysed by conducting baseline studies and using multi criteria decision methods in order to select the most appropriate sites at a given time.

Background

Different multi-criteria methods have been applied to energy and environmental problems. The main approaches can classified based on the type of decision model they apply to. In many situations, the alternatives to be considered are very many. The use of multi-objective programming methods to tackle these cases is well known (Pokharel, Chandrashekar, 1998; Ramanathan, Ganesh, 1995). Nevertheless, these approaches face a considerable drawback as they sometimes end up with an infeasible alternative. It is for this reason that we recommend discrete multi criteria decision aid (MCDA) techniques for tackling energy planning issues. A concise overview of discrete multi-criteria analysis methods is described in the next paragraphs.The main families of methodologies include: the Elimination Et Coix Traduisant la Realite (ELECTRE) family (Vincke, 1992), the Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) I and II methods and Regime Method Analysis (Nijkamp, Rietvelt, Voogd, 1990). In ELECTRE IV an option of no weighting is provided while in PROMETHEE weights can be seen more as trade-offs between criteria and not as coefficients of importance (Munda, 2004).
The value or utility function-based methods, include the Multi-Attribute Utility Theory (MAUT), the Simple Multi

Attribute Rated Technique (SMART), the Analytic Hierarchy Process (AHP) and the most elementary multicriteria technique, the Simple Additive Weighting (SAW); other methods include the Novel Approach to Imprecise Assessment and Decision Environment (NAIADE) (Munda, 1995), Flag Model and the Stochastic Multi-objective Acceptability Analysis (SMAA).

The SAW method is also known as a weighted linear combination or scoring method. It is simple and the most often used MCDA. In this method, an evaluation score can be calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by the decision makers or experts, followed by summing of the products for all attributes. The advantage of the SAW method is that it is a proportional linear transformation of the raw data. This means the relative order of magnitude of the standardized scores remains equal.
SAW is the basis of most MCDA techniques such as AHP and PROMETHEE that benefit from the additive property for calculating the final score of alternatives.

Research Objectives

1. Selection of an appropriate MCDA method
2. Pre-selection of sites to be visited by desk work using referenced data, renewable energy country resource maps and national zones
3. Field visits to preselected sites for primary data collection
4. Selection of the appropriate sites by ranking using the chosen MCDA method and the data collected

Methods

We used the SAW technique and the final score of each alternative is obtained as follows;

1) A set of decision makers or experts are selected depending on the technology considered ;
2) A set of possible alternatives,
$$A = (A_1, A_2, \ldots, A_m) \ ;$$
3) A set of attributes to measure the performance of the alternatives,
$$C = (C_1, C_2, \ldots, C_j) \ ;$$
4) The performance rating of alternative, A_i, with respect to attribute, C_j , provided by the experts is denoted by, r_{ij} ,
$$j = 1, 2, \ldots, n \quad i = 1, \ldots, k \ ;$$
5) The importance weight of attributes, C_j , provided by the experts is denoted by, w_j ,
6) The score for each alternative , V_i , is obtained by summing the product of the importance weight of each attribute, w_j, and the performance rating, r_{ij}, of each alternative site as stated in the equation below;

$$V_i = \sum_{j=1}^{n} w_j r_{ij} \qquad (1)$$

20 potential sites were pre-selected from the desk study using referenced data and resource maps. 5 sites for each of the technologies scoped for the study including, gasification, solar PV, Pico-hydro and biogas. Survey questions were designed to collect actual quantifiable data from each site on demand for electricity, fuel or energy source available for conversion to electricity, adaptable technology options, the existing applications and the human factors. The attributes listed were selected by a team of experts with diverse experience in planning, training and implementation of renewable energy systems. The experts included persons from engineering, computer and information technology, social sciences, business, private sector, civil society, financiers and target beneficiaries. The attributes are presented in figure 1 below.

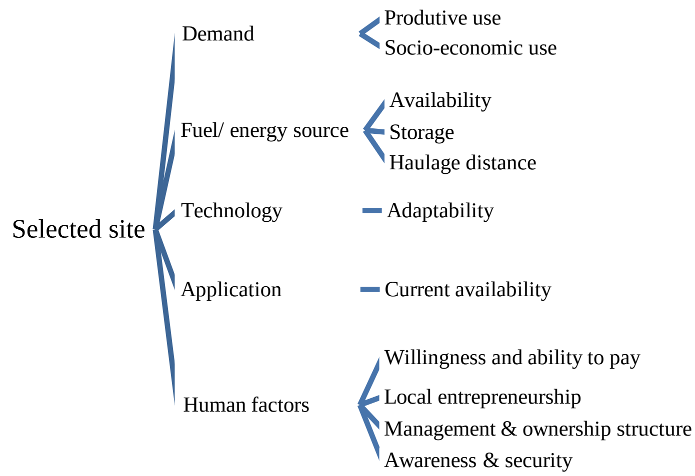

Figure 1: Attributes

Results

The importance weights, $\boldsymbol{w_j}$, are assigned to each attribute by a group of experts based on their experience with RETs implementation and perspective on local context. The average weights obtained from experts are as detailed in figure 2 below:

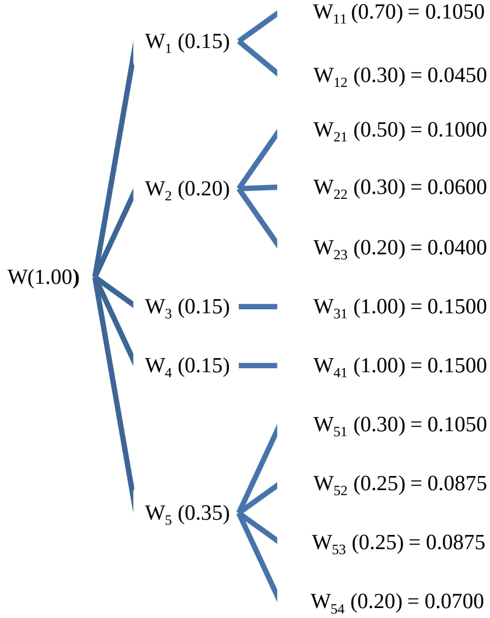

Figure 2: Importance weights of attributes

From the data collected, the performance ratings of each of the 20 potential sites visited with respect to each attribute were presented as ratios.

Table 1: Data for evaluation of gasification sites

Attribute	Weight	G1	G2	G3	G4	G5
1.0 Demand						
1.1 Productive use	0.0105	0.72	1.00	0.83	0.74	0.80
1.2 Socio-econ use	0.0450	1.00	1.00	1.00	0.80	0.75
2.0 Fuel/Source						
2.1 Availability	0.1000	0.74	1.00	0.91	0.72	0.85
2.2 Storage	0.0600	0.10	1.00	0.50	0.10	0.40
2.3 Haulage distance	0.0400	1.00	1.00	0.17	0.20	0.30
3.0 Technology						
3.1 Adaptability	0.1500	1.0	0.80	0.90	1.00	0.70
4.0 Application						
4.1 Availability	0.1500	0.06	1.00	0.90	0.07	0.08
5.0 Human factors						
5.1 Ability to pay	0.1050	0.48	1.00	0.45	0.52	0.60
5.2 Local entr.	0.0875	0.61	1.00	0.32	0.66	0.70
5.3 Mgt& ownership	0.0875	0.66	0.91	1.00	0.62	0.77
5.4 Awareness& sec.	**0.0700**	**0.57**	**0.71**	**1.00**	**0.57**	**0.69**

Using the ratings, r_{ij} , for the five alternative gasification sites, G1, G2, G3, G4 & G5 and the importance weights, w_j , from table 1, the scores for each site are computed using equation 1 above. The results of the scores are presented in table 2 below. Tables 3, 4, and 5 present the scores of the other 15 sites.

Table 2: Scores for gasification sites

Site location	Alternative	Score
Muduma-Mpigi	G1	0.53
Opit-Gulu	G2	0.85
Sekanyonyi - Mityana	G3	0.68
Bussunju - Wakiso	G4	0.50
Doctina - Jinja	G5	0.52

Table 3: Scores for solar PV sites

Site location	Alternative	Score
Kabanga - Mukono	S1	0.65
Mayuge-Iganga DSS1	S2	0.28
Mayuge-Iganga DSS1	S3	0.37
Mayuge-Iganga DSS1	S4	0.32
Nakasengere - Kiboga	S5	0.76

Table 4: Scores for Pico hydro sites

Site location	Alternative	Score
Haven-Jinja	H1	0.78
RMS-Kasese	H2	0.89
Arlington - Mbale	H3	0.60
Wild waters - Jinja	H4	0.82
KSB site 3 - Jinja	H5	0.75

Table 5: Scores for biogas sites

Site location	Alternative	Score
Flora poultry-Mukono	B1	0.65
Softpower-Jinja	B2	0.73

Jesa - Mityana	B3	0.91
Meat packers - Kampala	B4	0.70
Arlington - Mbale	B5	0.76

From the rankings, the top six sites were selected for actual installations with overall consideration on the available funds and project objectives. The details are in table 6 below.

Table 6: Installed sites

Site	Alternative	Technology	kW	Funds
Opit	G2	Gasification	10	MSI
Sekanyonyi	G3	Gasification	10	MSI
Muduma	G1	Gasification	32	Norgesvel
Kabanga	S1	Solar PV kiosk	01	MSI
Nakasengere	S5	Solar PV grid	01	MSI
RMS-Kasese	H2	Pico hydro	05	WB

Discussion

The study shows that the SAW scoring method is simple but effective in guiding decision makers and experts during site selection for renewable energy systems. It was observed that other financiers and investors besides MSI were attracted much more easily. It should be noted that this method was used at the preliminary stage of the project for site selection but in the next step, the study will consider other MCDAs operationalized in fuzzy environments to reduce on the subjectivity of the decision makers, the complexity with the weighting process and the possible limitations in computational reliability and applications of the SAW method.

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