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Selection of renewable energy project using Multicriteria Method

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ABSTRACT*: Nowadays, many investors are interesting on implementing new renewable energy project around the world. The success of the decision making process regarding the selection of this projects, depends a lot on the effectiveness of the feasibility stage. During last decades, it is observed that many researches had used the Multicriteria Decision Making Methods to assist decision makers. Therefore, this paper proposes a comparative study of a three decision making process, applied in different countries. This study compares the related process in different levels. A new process is also proposed to validate a local renewable energy project.*

Keywords: *Renewable Energy Projects, Multicriteria Method, AHP Method, PROMETHEE Method, VIKOR Method, ELECTRE Method.*

I. INTRODUCTION

The selection of Renewable Energy (RE) project is a multi-dimensional process, since it has to consider technological, financial, environmental, and social factors. Multi-criteria Decision Analysis (MCDA) appears to be the most appropriate approach to understand the different perspectives and to support the evaluation of RE project. During this last decade, the MCDA methods have attracted the attention of decision makers due to its ability of providing solutions to increasing complex energy management problems. These methods are based on one of the three approaches:

- The top-down approach, seeks to aggregate the "n" criteria into a single criterion, it supposed that the judgment are transitive (ex: a>b b>c so a>c). It includes the AHP and ANP Method.
- The Bottom-up approach, tries to compare potential alternatives to each other and set up relationships between themes. It includes the ELECTRE and the PROMETHEE Method.
- The local aggregation which tries to find an ideal solution in the first step, then, proceeds to an iterative search to find a better solution. It includes the VIKOR and the TOPSIS Method.

This article first present the results of the comparative analyze. Second explain the new proposed multicriteria process. Finally an experiment simulation is conducted to demonstrate its effectiveness and feasibility of the real cases.

II. THE PROPOSED COMPARATIVE STUDY

This section includes three international and published studies that deal with the problem of selection of an optimal renewable energy project in various countries.

First Study was published on 2009 [2] and it covers the selection of a suitable wind farm in southern China. The proposed process is using the analytic hierarchy process (AHP) associated with benefits, opportunities, costs and risks (BOCR). The example treated in their paper was based on a set of 5 power plant namely A–E. To model the selection process, they have considered a set of 29 criteria based on technical, economic, financial and political risks. The scheme proposes the installation of 500 wind turbines, each with a generating capacity of 2.5MW, a hub height of 80 m and a blade diameter of 120 m (total height 140 m). **Second Study** was published on 2011 [3] and it considers the selecting of the best electrical generation technology based on the renewable energy sources in Spain. This study had used the VIKOR method to resolve the problem of selection. The decision making matrix process includes 7 criteria and a set of 13 evaluated projects. The designed systems will be evaluated according to the considered criteria: Power (P), Investment Ratio (IR), Implementation Period (IP), Operating Hours (OH), Useful Life (UL), Operation and Maintenance

Costs (O&M) and tons of emissions of CO2 avoided per year (tCO2/y).

Third Study was published on 2011 [4] and it considers the selecting of the best photovoltaic plant projects in Corsica Island of France. This study had used the ELECTRE IS method to resolve the problem of selection. The decision making matrix process includes 8 criteria and a set of 16 evaluated projects. The designed systems will be evaluated according to the considered criteria: Net production in (Gwh/yr), Rent area unoccupied by the installation (RA-EA/RA in ha), the potential of ecological degradation, the observer–plant minimum distance in (meter), Use conflicts risks , Economic activity and financial benefits to inhabitants from RES facilities, Financial income at the communal level (£/yr/inhab).

Table 1: The Criteria comparative list

Criteria Type	First Study criteria	Second Study Criteria	Third Study Criteria
Technical	– Energy availability: power, speed or irradiation, density. – Site advantage: height of installation... – Connection to Grid – Foundation: Peripheral construction... – Technical risk	– Pr owe (P) – Operating Hours (OH) – Implementation Period (IP)	– Net production – Rent area unoccupied by the installation
Technological	– Technical functions: power, capacity, technical availability... – Advanced technologies – Material design and manufacturing	– Useful Life (UL)	
Financial	– Financial scheme: switchable tariff, discount...	– Operation and Maintenance Costs (O&M) – Investment Ratio (IR),	– Economic activity and financial benefits to inhabitants – Financial income at the communal level
Environmental & Social	– Distance to specific area. – Policy support – Concept conflict: policy, makers... – Uncertainty of land	– tons of emissions of CO2 avoided per year (tCO2/y)	– the observer–plant minimum distance – the potential of ecological degradation – Use conflicts risks

According to the above comparative table, all used criteria could be split into four categories: Technical, Technological, Financial, Environmental and social. It also observed that all criteria have selectability or rejectability effect on the decision process. The improvement of an exhaustive and detail criterion, that could be used in the evaluation of various projects (wind, solar, geothermal or hydraulic resources) and in different locations would be very useful. These criteria could have the same impact on the process, for example the energy availability might include wind speed, solar irradiation or both in the case of hybrid resources Wind-Solar as [7].

III. THE PROPOSED NEW MULTICRITERIA APPROACH

According to previous review, the success on the building of any new renewable energy project is due to the follow of this ten steps: addressing site, obtaining zoning, obtaining environmental expertise, analyzing of the existing transmission lines, studying the securing access to land, measuring the renewable resource, establishing scenario to access to capitals, identifying reliable power purchaser or market, understanding the green energy's policy and support. In fact the integrating of the life cycle concept allows a better understanding of the impact of the each criterion on the project. The figure1 proposes key steps needed in the design of a useful criterion, while figure 2 detailed a new criteria and sub criteria suitable for various renewable energy cases studies.

Figure 1: Proposed Renewable energy Life Cycle Project Analysis

According to the proposed new decision making process, once the studied projects are listed, the managing boards are asked to evaluate them according to the criteria & sub-criteria; these criteria are split into benefit/cost for the quantitative criterion and opportunity/risks for the qualitative criterion (see Figure 2).

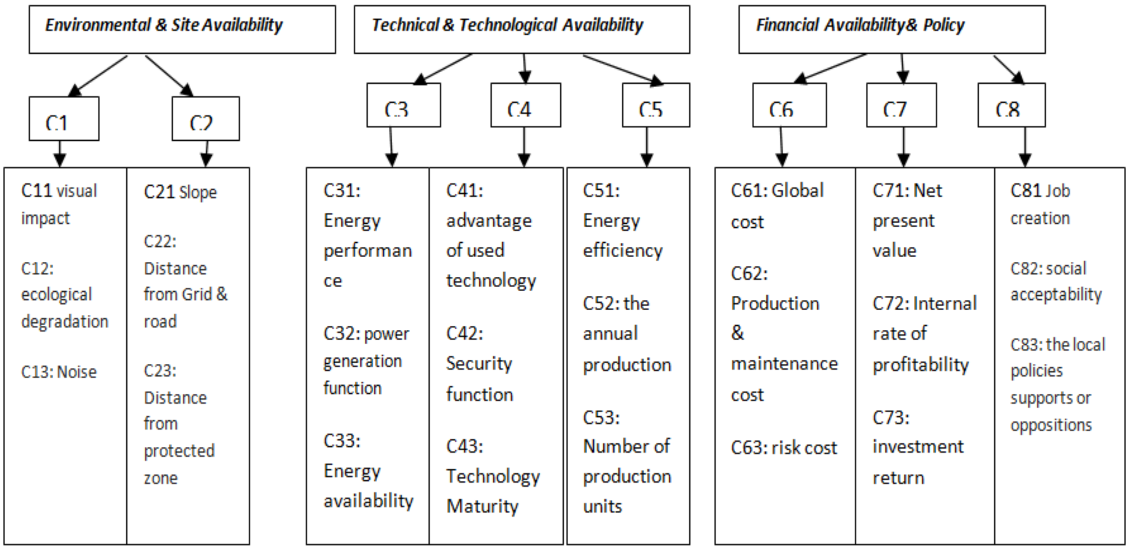

Figure 2: Proposed Global criteria and sub criteria

Finally this process proposes an aggregation of the well-known PROMETHEE II and the AHP method. This phase includes four steps (from the constitution of the decision matrix to the final ranking of alternatives).

- **Step1:** Listing the criteria according to which the decision problem will be evaluated **C= {c_1....c_m}** and splitting these Criteria into two categories: Select-ability criterions (Criterions to Maximize) and Reject-ability ones (Criterions to Minimize).
- **Step 2:** Establish a Normalized version of the initial decision matrix. The structure of the initial matrix can be expressed as follows listing of the alternatives A= {a_1.....a_n} evaluations for each criterion element.

$$Z = (z_{ij})_{nxm} = \begin{matrix} A_1 \\ A_2 \\ \cdot \\ \cdot \\ A_3 \end{matrix} \begin{bmatrix} z_{11} & z_{12} & \cdot & \cdot & z_{1m} \\ z_{21} & z_{22} & . & . & z_{2m} \\ \cdot & & & & \\ \cdot & & \cdot & & \cdot \\ z_{n1} & & z_{n2} & & z_{nm} \end{bmatrix} \quad (1)$$

The selectability criterion Ω_b: $z_{ij} = \frac{a_{ij} - a_j^{min}}{a_j^{max} - a_j^{min}}$ (2)

The Rejectability criterion Ω_c: $z_{ij} = \frac{a_j^{max} - a_{ij}}{a_j^{max} - a_j^{min}}$ (3)

Step 3: The "m" criteria in the same level are compared using 1-to-9 scale proposed in the AHP method, then the consistency ratio CR is calculated.

$\sum w_j = 1 \; for \; j = 1 \dots m \quad CR = CI/RI$ where CI=$(\lambda_{max} - n)/(n-1)$ (4)

- **Step 4:** The final ranking of alternative is calculated by applying the PROMETHEE II, this method use the net outranking flow to order alternatives:

$\Phi(z) = \Phi^+(z) - \Phi^-(z)$ (5)

While $\pi(a,b) = \sum_{j=1}^{k} P_j(a,b) w_j$ (6)

And $\Phi^+(z) = \frac{1}{n-1} \sum_{x \in A} \pi(z,x)$, $\Phi^-(z) = \frac{1}{n-1} \sum_{x \in A} \pi(x,z)$ (7)

IV. THE NUMERICAL SIMULATION

Solar power plants have known considerable technological and industrial progress in recent years. These power plants use the sun's radiation to produce electricity. Finding optimal scenario for future Concentrating Solar Power (CSP) plants is a crucial task in the early stage of project development. Therefore, this section is presenting a concentrated solar power (CSP) plant comparative study.

Table 2: The evaluated decision matrix

CRITERIA	E	F	A	B	C	D
C33: Energy availability	8	4	1	3	8	1
C32: The power generation function	4	3	4	9	1	9
C81: Job creation	1	9	8	1	1	6
C42: Security function	10	5	25	100	20	6
C83: the local policies supports or oppositions	100	120	18	30	40	50
C71 Net present value	1	9	8	4	3	6
C61: Global cost	1	3	6	8	9	1
C12 : ecological degradation	3	9	6	8	4	3
C82: social acceptability	1	3	4	9	1	9
C63: risk cost	3	9	6	8	4	3

In order to demonstrate the usefulness and efficiency of the use of the MCDM process in the real comparative studies, it was chosen to apply this study to the local construction of 6 solar complexes, A, B, C, D, E and F. The projects are evaluated according to ten sub criteria chosen from the proposed global criteria.

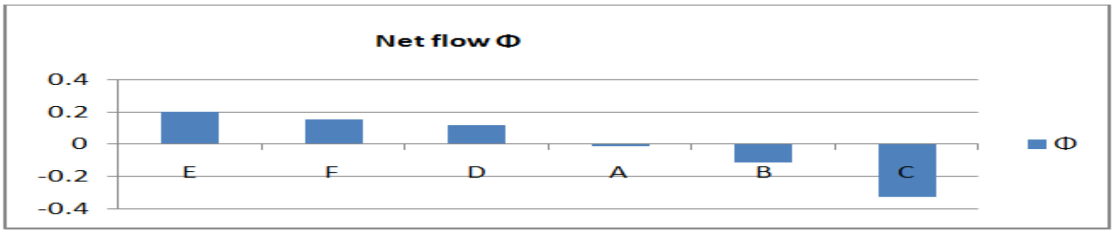

Figure 3: Project's net flows ranking.

According to the above results it can be concluded that the E project is the best one followed by F and D, while projects A, B and C are the worst ones. These results match the local CSP strategy, effectively, the first CSP projects were costly with a small power capacity, but during last years, and due to the maturity in technology and its widely use, the implanted CSP projects had became easier, cheaper and efficient. That exactly explains the better ranking of the (D, E & F) projects, which are considered by many experts as one of the most successful project around the world.

V. CONCLUSION

This paper had tried to present innovative approach to assist stakeholders in their decision making process, thought demonstration the usefulness of the MCDM theory. It had also presented a comparative study of a three decision making process, applied in different countries and applying each new MCDM method. The originality of this work is due to the proposed criteria/sub criteria and the process. One of the future works will be focused on the improvement of a new decision support system based on innovative MCDM approach, this tool will be a Web-DSS.

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