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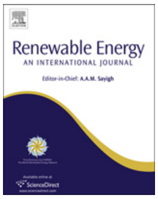

Multi-criteria decision-making in the selection of a renewable energy project in spain: The Vikor method

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ABSTRACT

One of the characteristics of the Spanish energy system is its high degree of dependence on imports. In 2005, the Spanish government approved the new Renewable Energy Plan in the following sectors: Windpower, Hydroelectric, Solar Thermal, Solar Thermo-electric, Photovoltaic, Biomass, Biogas and Biofuels. The aim of the Plan is to make it possible to reach the target of 12% of primary energy being met from renewable sources by 2010. When selecting one from various Renewable Energy investment projects different groups of decision-makers become involved in the process. Decision-making has to take into consideration several conflicting objectives because of the increasingly complex social, economic, technological, and environmental factors that are present. Traditional single-criterion decision-making is no longer able to handle these problems. The Compromise Ranking method, also known as the VIKOR method, introduces the Multi-criteria ranking index based on the particular measure of "closeness" to the "ideal" solution. In this paper, we apply the method in the selection of a Renewable Energy project corresponding to the Renewable Energy Plan launched by the Spanish Government. The method is combined with the Analytical Hierarchy Process method for weighting the importance of the different criteria, which allows decision-makers to assign these values based on their preferences. The results show that the Biomass plant option (Co-combustion in a conventional power plant) is the best choice, followed by the Wind power and Solar Thermo-electric alternatives.

1. Introduction

The exploitation of Renewable Energy (RE) sources has gained enormous interest during recent years. A rising awareness of environmental issues, due to the increase in negative effects of fossil fuels on the environment, the precarious nature of dependency on fossil fuel imports, and the advent of RE alternatives, has forced many countries, especially the developed ones, to use RE sources. These are environment-friendly and capable of replacing conventional sources in a variety of applications at competitive prices (Aras et al. [1]; Haralambopoulos and Polatidis [2]).

The selection of various energy investment projects is a laborious task. Multiple factors that affect the success of an RE project must be analyzed and taken into account. Decision-making has to take into consideration several conflicting objectives because of the increasingly complex social, economic, technological, and environmental factors that are present. Different groups of decision-makers become involved in the process, each group bringing along different criteria and points of view, which must be resolved within a framework of understanding and mutual compromise (concessions) (Haralambopoulos and Polatidis [2]).

Traditional single-criterion decision-making is no longer able to handle these problems. The policy formulation for fossil fuels energy substitution by RE must be addressed in a multi-criteria context. The complexity of energy planning and energy projects makes Multi-criteria analysis a valuable tool in the decision-making process. The Compromise Ranking Method, also known as the VIKOR method, is an effective tool in Multi-Criteria Decision-Making. This method introduces the Multi-criteria ranking index based on the particular measure of "closeness" to the "ideal" solution. In this paper, we show how the method can be used in the selection of an RE investment project. In order to do this, the method is applied to the Renewable Energy Plan launched by the Spanish Government in 2005 (Plan de Energias Renovables [3]). The paper is organised as follows. In the next section, we review the use of Multi-Criteria Decision-Making techniques in RE project investment. Then, the VIKOR method is applied to the selection of RE projects and, finally, there appears a concluding section with the main results of the paper.

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2. MCDM techniques and energy projects

Multi-Criteria analysis, often called Multi-Criteria Decision-Making (MCDM) or Multi-Criteria Decision Aid methods (MCDA), is a branch of a general class of Operations Research models which deal with the process of making decisions in the presence of multiple objectives. These methods, which can handle both quantitative and qualitative criteria, share the common characteristics of conflict among criteria, incommensurable units, and difficulties in design/selection of alternatives (Pohekar and Ramachandran [4]). Many specifications and categorisations exist. Following Guitoni and Martel [5], these methods can be assigned to one of the four following categories: (i) elementary methods; (ii) the single synthesizing criterion approach; (iii) the outranking synthesizing approach; and (iv) the mixed methods. Table 1 shows the main methods belonging to each of these categories.

In general, MCDM methods are divided into Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM). The main distinction between the two groups of methods is based on the determination of alternatives. In MODM, also known as multi objective programming or a vector optimization/maximization/minimization problem, the alternatives are not predetermined but instead a set of objective functions is optimized subject to a set of constraints. In MADM, where alternatives are predetermined, a small number of alternatives are to be evaluated against a set of attributes. The best alternative is usually selected by making comparisons between alternatives with respect to each attribute (Pohekar and Ramachandran [4]). MCDM methods have been widely used in RE projects in areas such as wind farm projects, geothermal projects, hydro-site selection, etc. MODM, Decision Support Systems, MADM (Analytical Hierarchy Process, PROMETHEE, ELECTRE, Multi-attribute utility theory), and Fuzzy programming have been the main MCDM methods applied to RE projects. Table 2 shows the application areas of these methods (Pohekar and Ramachandran [4]).

MODM methods have been used in deciding the optimum mix of RE technologies in various sectors (Iniyan and Sumanthy [6], Suganthi and Williams [7], Sinha and Kandpal [8], Cormico et al. [9]) and RE energy-economy planning showing the interactions between the energy system and the economy (Borges and Antunes [10]).

In AHP, a multiple criteria problem is structured hierarchically by breaking down a problem into smaller and smaller consistent parts. The goal (objective) is at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, respectively, and decision alternatives at the bottom of the hierarchy. The best alternative is usually selected by making comparisons between alternatives with respect to each attribute. This type of method has been used in RE planning (Mohsen and Akash [11], Wang and Feng [12], Ramanathan and Ganesh [13]), and Windfarm projects (Aras et al. [14], Lee et al. [15]). The PROMETHEE method uses the outranking principle to rank the alternatives, combined with ease of use and lessened complexity. It performs a pair-wise comparison of alternatives in order to rank them with respect to a number of criteria. The method has been used in geothermal projects (Goumas et al. [16], Goumas and Lygerou [17], Haralambopoulos and Polatidis [2]), hydro-site selection (Mladineo et al. [18]) and for promoting parabolic solar cookers in India (Pohekar and Ramachandran [19]). The ELECTRE method is capable of handling discrete criteria of both quantitative and qualitative in nature, providing complete ordering of the alternatives. The method chooses alternatives that are preferred over most of the criteria and that do not cause an unacceptable level of discontent for any of the criteria. Based on a concordance, discordance indices and threshold values, graphs for strong and weak relationships are developed. These graphs are used in an iterative procedure to obtain the ranking of alternatives. Applications of this method in RE projects can be seen in Beccali et al. [20]; Georgopoulou et al. [21]. MAUT is concerned with the theory developed to help decision-makers assign utility values, taking into consideration the decision-maker's preferences, to outcomes by evaluating these in terms of multiple attributes and combining these individual assignments to obtain overall utility measures (Keeney and Raiffa [22]). Selecting portfolios for solar energy projects (Golabi et al. [23]) and RE planning (Jones et al. [24]) are the main applications of this method in RE projects.

Table 2
Application areas of multi-criteria methods.

Method	Application area
Multi-objective decision making	RE planning [6–9] and RE economic planning [10]
Decision support systems	RE planning [28]
Analytical Hierarchy Process	RE planning [11–13] and wind farm projects [14,15]
PROMETHEE	Geothermal projects [2,16,17], hydro-site selection [18] and parabolic solar cooker [19]
ELECTRE	RE planning [20,21]
Multi-attribute utility theory	Solar energy projects [23] and RE planning [24]
Fuzzy programming	Wind site selection [25] and Solar system [26,27]

Other decision-making tools used in RE investment projects are Fuzzy programming to evaluate solar system and wind site selection (Skikos and Machias [25], Mamlook et al. [26], Mamlook et al. [27]), Decision Support Systems for RE project planning (Georgeopoulos et al. [28]), and Geo-spatial multi-criteria analysis methodology used to deploy a wave energy farm (Nobre et al. [29]).

Both the VIKOR method and TOPSIS method, which was developed by Huang and Yong [30] as an alternative to ELECTRE, are based on an aggregating function representing "closeness to the ideal" which originates in the compromise programming method. These two methods introduce different forms of aggregating function for ranking and different kinds of normalization to eliminate the units of criterion function (Opricovic and Tzeng [31]). Whereas the VIKOR method uses linear normalization and the normalized values do not depend on the evaluation unit of a criterion, the TOPSIS method uses vector normalization, and the normalized value could be different for a different evaluation unit of a particular criterion. As regards the aggregating function, the VIKOR method introduces an aggregating function representing the distance from the ideal solution, considering the relative importance of all criteria, and a balance between total and individual satisfaction. On the other hand, the TOPSIS

Table 1
List of some multi-criteria decision making methods (Guitoni and Martel [5]).

Category	Methods
Elementary methods	Weighted sum, Lexicographic method, Conjunctive methods, Disjunctive method, Maximin method
Single synthesizing criterion	TOPSIS, MAVT (multi-attribute value theory), (UTA) utility theory additive, SMART (simple multiu-attribute rating technique, MAUT (multi-attribute utility theory), AHP (analytical hierarchy process), EVAMIX, Fuzzy weighted sum, Fuzzy maximin.
Outranking methods	ELECTRE, PROMETHEE, MELCHIOR; ORESTE; REGIME.
Mixed methods	QUALIFLEX, Fuzzy conjunctive/disjunctive method, Martel and Zaras method.

method introduces an aggregating function including the distances from the ideal point and from the negative-ideal point without considering their relative importance. However, the reference point could be a major concern in decision-making, and to be as close as possible to the ideal is the rationale of human choice (Opricovic and Tzeng [31]).

In this paper we show the use of the Compromise Ranking Method, also known as the VIKOR method, in the selection of a Renewable Energy project. The method is improved by introducing the Analytical Hierarchy Process for assigning the weights of relative importance of attributes. Similar approaches can be found in Rao [32], who applies the method for material selection for a given engineering application, or in Lihong et al. [33], who applies the VIKOR algorithm based on AHP and Shannon entropy in the selection of Thermal Power Enterprisés Coal suppliers in China. As the authors suggest, this combination allows the decision-maker to systematically assign the values of relative importance to the attributes based on their preferences.

3. Application

One of the characteristics of the Spanish energy system is its high degree of dependence on imports. Eighty percent of energy consumption has to be met from imported sources. Spain imports approximately 64% of the coal, 99.5% of the oil and 99.1% of the gas it uses. Moreover, oil accounts for around 50% of primary energy consumption (Renewable Energy World [34]). On August 26, 2005 the Spanish government approved the new Renewable Energy Plan, which supersedes the Renewable Energy Promotion Plan dating back to 1999, for the following areas: Windpower, Hydroelectric, Solar, Biomass, Biogas and Biofuels.

With the overall aim of making it possible to reach the target of 12% of primary energy being met from renewable sources, in 2010 electricity generation in Spain from renewable sources will account for 30.3% of gross consumption and liquid biofuels will account for 5.8% of petrol and diesel consumption for transport purposes. To do so, it has set more ambitious goals in those areas that have been developing successfully and has established new measures to support technologies that have not yet managed to take off. Of the different areas covered by the overall RE Project, we have selected as example for multi-criteria decision-making, only the alternatives for electric generation. These are shown in Table 3.

The designed systems will be evaluated according to the criteria shown in Table 4. The attributes considered are: 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 CO_2 avoided per year (tCO_2/y). These emissions are estimated by the Spanish Government according to the increase in RE projects [3]. The data considering the 13 alternative RE projects and 7 selection attributes are shown in Table 5.

Table 3
Alternatives for electric generation.

	Alternative
A_1	Wind power $P \le 5$ MW
A_2	Wind power $5 \le P \le 10$ MW
A_3	Wind power $10 \le P \le 50$ MW
A_4	Hydroelectric $P \le 10$ MW
A_5	Hydroelectric $10 \le P \le 25$ MW
A_6	Hydroelectric $25 \le P \le 50$ MW
A_7	Solar Thermo-electric $P \ge 10$ MW
A_8	Biomass (energetic cultivations) $P \le 5$ MW
A_9	Biomass (forest and agricultural wastes) $P \le 5$ MW
A_{10}	Biomass (farming industrial wastes) $P \le 5$ MW
A_{11}	Biomass (forest industrial wastes) $P \le 5$ MW
A_{12}	Biomass (co-combustion in conventional central) $P \ge 50$ MW
A_{13}	Bio fuels $P \le 2$ MW

Table 4
Criteria used to evaluate the alternatives.

	Name	Unit
f_1	Power (*P*)	KW
f_2	Investment Ratio (IR)	€/KW
f_3	Implementation Period (IP)	Years
f_4	Operating Hours (OH)	Hours/year
f_5	Useful Life (UL)	Years
f_6	Operation and Maintenance Costs (O&M)	$€ * 10^{-3}$/KWh
f_7	Tons of CO_2 avoided (tCO_2/y)	tCO_2/y

Assuming that each alternative is evaluated according to each criterion function, the compromise ranking could be performed by comparing the measure of “closeness” to the “ideal” solution, F^*. The compromise solution F^c is a feasible solution that is the “closest” to the ideal solution and a compromise means an agreement established by mutual concessions (Opricovic and Tzeng [31]). The multi-criteria measure for compromise ranking is developed from the L_p-metric used as an aggregating function in a compromise programming method (Yu [35], Zeleny [36]):

$$L_{p,j} = \left\{ \sum_{i=1}^{n} \left[w_i \left(f_i^* - f_{ij} \right) \Big/ \left(f_i^* - f_i^- \right) \right]^p \right\}^{1/p}$$

$$1 \le p \le \infty, \; j = 1, 2, \ldots, J \qquad (1)$$

where $L_{1,j}$ (as S_j in Eq. (2)) and $L_{\infty,j}$ (as R_j in Eq. (3)) are used to formulate ranking measure.

Within the VIKOR method, the various *J* alternatives are denoted as $a_1, a_2, \ldots, a_j$. For alternative a_j the rating of the *i*th aspect is denoted by f_{ij}, i.e., f_{ij} is the value of the *i*th criterion function for the alternative a_j; and *n* is the number of criteria. The compromise ranking algorithm VIKOR has the following four steps (Opricovic and Tzeng [31]).

Step I: Determine the best f_i^* and the worst f_i^- values of all criterion functions, $i = 1, 2, \ldots, n$. If the *i*th function represents a benefit then $f_i^* = \max_j f_{ij}$ and $f_i^- = \min_j f_{ij}$, while if the *i*th function represents a cost $f_i^* = \min_j f_{ij}$ and $f_i^- = \max_j f_{ij}$. Of the attributes considered, Power, Operating Hours, Useful Life and Tons of emissions avoided are beneficial attributes and so higher values are desirable. Investment Ratio, Implementation Period, and Operating and Maintenance Costs are non-beneficial attributes and so lower values are desirable. *Step II*. Compute the values S_j and R_j, $j = 1, 2, \ldots J$ by the relations

$$S_j = \sum_{i=1}^{n} w_i \left(f_i^* - f_{ij} \right) \Big/ \left(f_i^* - f_i^- \right) \qquad (2)$$

Table 5
Alternatives and attributes for RE project selection.

Alternatives	Attributes						
	P	IR	IP	OH	UL	O&M	tCO_2/y
A_1	5000	937	1	2350	20	1.470	1,929,936
A_2	10,000	937	1	2350	20	1.470	3,216,560
A_3	25,000	937	1	2350	20	1.510	9,649,680
A_4	5000	1.500	1.5	3100	25	1.450	472,812
A_5	20,000	700	2	2000	25	0.700	255,490
A_6	35,000	601	2.5	2000	25	0.600	255,490
A_7	50,000	5.000	2	2596	25	4.200	482,856
A_8	5000	1.803	1	7500	15	7.106	2,524,643
A_9	5000	1.803	1	7500	15	5.425	2,524,643
A_{10}	5000	1.803	1	7500	15	5.425	2,524,643
A_{11}	5000	1.803	1	7500	15	2.813	2,524,643
A_{12}	56,000	856	1	7500	20	4.560	4,839,548
A_{13}	2000	1.503	1.5	7000	20	2.512	5,905,270

	P	IR	IP	OH	UL	O&M	tCO_2/y
	Max	Min	Min	Max	Max	Min	Max
f_i^*	56,000	601	1	7500	25	7.106	9,649,680
f_i^-	2000	5000	2.5	2000	15	0.600	255,490

$$R_j = \max_i \left[w_i \left(f_i^* - f_{ij} \right) \Big/ \left(f_i^* - f_i \right) \right] \tag{3}$$

where w_i are the weights of criteria, expressing the decision-maker's preference as the relative importance of the criteria. In the RE Plan launched by the Spanish government three stakeholders are involved: the government who subsidizes the projects, the banks that contribute with private funds and the development companies. It is these stakeholders who act as the decision-makers that must choose the most suitable RE project and who must, therefore, determine their preferences for weighting the importance of the different criteria. The weights of relative importance of the attributes may be assigned using AHP (Saaty [37]). The steps are explained below as follows (Rao [32]).

1. Find out the relative importance of different attributes with respect to the objective. To do so, one has to construct a pair-wise comparison matrix using a scale of relative importance. The judgments are entered using the fundamental scale of the AHP. An attribute compared with itself is always assigned the value 1 so the main diagonal entries of the pair-wise comparison matrix are all 1. The numbers 3, 5, 7, and 9 correspond to the verbal judgments "moderate importance", "strong importance", "very strong importance", and "absolute importance" (with 2, 4, 6, and 8 for compromise between the previous values). Assuming n attributes, the pair-wise comparison of attribute i with attribute j yields a square matrix $A_{n \times n}$ where a_{ij} denotes the comparative importance of attribute i with respect to attribute j. In the matrix, $a_{ij} = 1$ when $i = j$ and $a_{ji} = 1/a_{ij}$.

$$\begin{bmatrix} 1 & 5 & 9 & 3 & 5 & 7 & 1 \\ 1/5 & 1 & 5 & 1/3 & 1/3 & 5 & 1/3 \\ 1/9 & 1/5 & 1 & 1/5 & 1/7 & 1/3 & 1/5 \\ 1/3 & 3 & 5 & 1 & 1 & 3 & 1/5 \\ 1/5 & 3 & 7 & 1 & 1 & 5 & 1/3 \\ 1/7 & 1/5 & 3 & 1/3 & 1/5 & 1 & 1/5 \\ 1 & 3 & 5 & 5 & 3 & 5 & 1 \end{bmatrix}$$

2. We need to know the vector $W = [W_1, W_2, \ldots, W_N]$ which indicates the weight that each criteria is given in pair-wise comparison matrix A. To recover the vector W from A we outline a method in a two-step procedure:
   - For each of the A's column divide each entry in column i of A by the sum of the entries in column i. This yields a new matrix, called A_{norm} (for normalized) in which the sum of the entries in each column is 1.
   - Estimate W_i as the average of the entries in row i of A_{norm}. The weights calculated are $W_P = 0.32$; $W_{\text{IR}} = 0.09$; $W_{\text{IP}} = 0.03$; $W_{\text{OH}} = 0.12$; $W_{\text{UL}} = 0.13$; $W_{\text{O\&M}} = 0.04$; $W_{tCO_2/y} = 0.27$.

Once we have the pair-wise comparison matrix it is necessary to check it for consistency. Slight inconsistencies are common and do not cause serious difficulties. We can use the following four-step procedure to check for the consistency in the decision-maker's comparisons. From now on, W denotes our estimate of the decision-maker's weight.

- Compute AW^T.
- Find out the maximum Eigen value

$$\lambda_{\max} = 1/n \sum_{i=1}^{n} \text{i}^{\text{th}} \text{ entry in AW}^T / \text{i}^{\text{th}} \text{ entry in W}^T$$

.

- Compute the Consistency Index (CI) as follows: $\text{CI} = (\lambda_{\max}) - n/n - 1$. The smaller the CI, the smaller the deviation from the consistency is. If CI is sufficiently small, the decision-maker's comparisons are probably consistent enough to give useful estimates of the weights for their objective. For a perfectly consistent decision-maker, the ith entry in $AW^T = n$ (ith entry of W^T). This implies that a perfectly consistent decision-maker has $\text{CI} = 0$.
- Compare the Consistency Index to the Random Index (RI) for the appropriate value of n, used in decision-making (Saaty, [37]). If $(\text{CI/RI}) < 0.10$, the degree of consistency is satisfactory, but if $(\text{CI/RI}) > 0.10$, serious inconsistencies may exist, and the AHP may not yield meaningful results

The Eigen value, $\lambda_{\max}$, obtained is 7.73 and the Consistence Ratio is 0.093, which is less than the allowed value of 0.1. Thus, there is a good consistency in the judgments made. The values of S_j and R_j, obtained using Eqs. (2) and (3), are, respectively.

Step III: compute the values Q_j , by the relation

$$Q_j = v \left(S_j - S^* \right) \Big/ \left(S^- - S^* \right) + (1 - v) \left(R_j - R^* \right) \Big/ \left(R^- - R^* \right) \tag{4}$$

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	i_{13}
S_j	0.713	0.646	0.371	0.693	0.621	0.539	0.536	0.709	0.698	0.698	0.681	0.238	0.545
R_j	0.301	0.272	0.183	0.301	0.273	0.273	0.266	0.301	0.301	0.301	0.301	0.140	0.319

Table 6
Values of Q_j for different values of v.

v	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	A_{11}	A_{12}	A_{13}
0	0.901	0.736	0.242	0.901	0.742	0.742	0.706	0.901	0.901	0.901	0.901	0	1
0.2	0.923	0.763	0.251	0.914	0.757	0.722	0.691	0.921	0.916	0.916	0.909	0	0.930
0.4	0.944	0.789	0.259	0.927	0.771	0.701	0.676	0.941	0.931	0.931	0.917	0	0.861
0.5	0.955	0.802	0.263	0.934	0.778	0.691	0.669	0.951	0.939	0.939	0.921	0	0.826
0.6	1.326	1.110	0.364	1.300	1.082	0.977	0.944	1.321	1.307	1.307	1.286	0	1.191
0.8	0.897	0.767	0.251	0.863	0.725	0.585	0.576	0.890	0.872	0.872	0.843	0	0.621
1	1.009	0.867	0.284	0.966	0.814	0.639	0.632	1	0.977	0.977	0.941	0	0.652

where $S^* = \min_j S_j$; $S^- = \max_j S_j$; $R^* = \min_j R_j$; $R^- = \max_j R_j$ and v is introduced as a weight for the strategy of maximum group utility, whereas $(1-v)$is the weight of the individual regret. The solution obtained by $\min_j S_j$ is with a maximum group utility ("majority" rule), and the solution obtained by $\min_j R_j$ is with a minimum individual regret of the "opponent". Normally, the value of v is taken as 0.5. However, v can take any value from 0 to 1. Table 6 shows the values of Q_j (Eq. (4)) for different values of v.

Step IV: rank the alternatives, sorting by the values S, R, and Q in decreasing order. The results are three ranking lists. Propose as a compromise solution the alternative $A^{(1)}$, which is the best ranked by the measure Q(minimum), if the following two conditions are satisfied:

a. Acceptable advantage. $Q(A^{(2)}) - Q(A^{(1)}) \geq DQ$, where $DQ = 1/(J-1)$ and $A^{(2)}$ is the alternative with second position on the ranking list by Q;
b. Acceptable stability in decision-making. The alternative $A^{(1)}$ must also be the best ranked by S or/and R. This compromise solution is stable within a decision-making process, which could be the strategy of maximum group utility (when $v > 0.5$ is needed), or "by consensus" ($v \approx 0.5$), or with veto ($v < 0.5$).

If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of:

c. Alternative $A^{(1)}$ and $A^{(2)}$ if only condition b is not satisfied, or
d. Alternatives $A^{(1)}, A^{(2)}, \ldots, A^{(M)}$ if condition a is not satisfied. $A^{(M)}$ is determined by the relation $Q(A^{(M)}) - Q(A^{(1)}) < DQ$ for maximum n (the positions of these alternatives are "in closeness").

Ranking the alternatives by the VIKOR method gives us, as a compromise solution and for all the values of v considered, the alternative A_{12}. This alternative, a Biomass plant (Co-combustion in a conventional power plant) of $P \geq 50$ MW is the best ranked by Q. In addition, conditions IV-a and IV-b are satisfied as this alternative is also the best ranked by S and R, and $Q(A^{(3)}) - Q(A^{(12)}) \geq DQ$.

4. Conclusions

Selecting the best from various Renewable Energy investment projects requires that different groups of decision-makers become involved in the process. The fact that social, economic, technological and environmental factors need to be taken into consideration in decision-making, make the process more complex. Traditional single-criterion decision-making is no longer able to handle these problems properly. The policy formulation for fossil fuels energy substitution by Renewable Energies must be addressed in a multi-criteria context. In this paper, we have shown how the VIKOR method, which introduces the multi-criteria ranking index based on the particular measure of "closeness" to the "ideal" solution, can be used in the selection of a Renewable Energy project. Combining the VIKOR method with AHP for weighting the importance of the different criteria, allows the decision-maker to systematically assign the values of relative importance to the attributes based on their preferences.

The results show that the Biomass plant alternative (co-combustion in a conventional power plant) is the best choice, followed by the Windpower $10 \leq P \leq 50$ MW and Solar Thermo-electric alternatives. The greater weight that the decision-makers have given to the criteria of Power (KW) and amount of tCO_2/y avoided, together with the highest values of these two criteria corresponding to the Biomass plant and Wind power alternatives against the highest Investment Ratio corresponding to the Solar Thermo-electric installation, has meant that the Biomass plant is the best choice.

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