An Integrated Multi-Criteria System to Assess Sustainable Energy Options: An Application of the Promethee Method

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Summary

The planning and appraisal of sustainable energy projects involve rather complex tasks. This is due to the fact that the decision making process is the closing link in the process of analysing and handling different types of information: environmental, technical economic and social. Such information can play a strategic role in steering the decision maker towards one choice instead of another. Some of these variables (technical and economic) can be handled fairly easily by numerical models whilst others, particularly ones relating to environmental impacts, may only be adjudicated qualitatively (subjective or not). In many cases therefore, traditional evaluation methods such as cost-benefit analysis and the main economic and financial indicators (NPV, ROI, IRR etc.) are unable to deal with all the components involved in an environmentally valid energy project. Multi-criteria methods provide a flexible tool that is able to handle and bring together a wide range of variables appraised in different ways and thus offer valid assistance to the decision maker in mapping out the problem. This paper sets out the application of a multi-criteria method (PROMETHEE developed by J.P. Brans et al. 1986) to a real life case that is in tune with the objectives of sustainable development.

Keywords: Renewable energy, Multicriteria, Sustainable devolopment

JEL Classification: Q42, Q48, C63

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1.Introduction

The energy sector plays a key role in achieving sustainable development and in the future the energy production system must take the lead in meeting environmental goals. The challenge lies in getting environmental and energy objectives to converge and the overall success of future energy policy will be to demonstrate that economic growth, an assured energy supply and environmental protection are compatible goals.

The contribution of renewable energy sources (RES) to the European energy balance still remains modest in comparison to the potential that is technically available. RES are not uniformly exploited in the EU and their contribution is decidedly undersized; this despite the fact that many forms of RES are already available and their effective economic potential is reasonably acceptable (Cavallaro F. –Clasadonte M.T., 2000).

Although some technologies exploiting renewable energy sources have reached a certain maturity, there are numerous hurdles to their market penetration. It is fundamental to kick-start the launch of RES in order to accelerate and increase their market share. This strategy would favour the creation of economies of scale and consequently reduce costs. To achieve the target of doubling the share of renewable energy (to 12%) in the EU by 2010, there is an EC campaign involving member states cooperating closely over a period spanning several years. This initiative clearly signals the need to resort increasingly to renewable energy sources and to promote large-scale projects involving the various types of RES (SEC (99) 504, 14/04/99, *Campaign for take-off* - CTO).

This intense attention directed towards the environment has prioritised those RES that would have a minimal impact not only on the environment, but also on health and the quality of life. Therefore, this growing awareness of the environmental problem has partially modified the traditional decision making structure in the energy field. Indeed, the need to insert strictly environmentally related considerations into energy planning has resulted in the adoption of multi-criteria decision models.

The use of decision making tools, referred to in the literature as Decision Support Systems (DSS), for resolving environmental problems is wide-ranging. DSS based on multi-criteria algorithms do not replace decision makers, rather they assist them in all the phases of the decision making process by supplying useful information to reach decisions that are transparent with a clearly documented trail. Various studies have been developed to illustrate the potential applications of this approach: for the evaluation of energy options when compared to a set of criteria and in order to make the choices clearer (Siskos J. – Hubert Ph. 1983; Roy B. – Bouyoussou D. 1986; Georgopoulou E., *et al.* 1998; Beccali M. *et. al.* 2003; for the assessment of geothermal energy projects (Goumas M., *et. al.*, 1999); for the siting of power plants (Barda O.H, *et al.* 1990); and for the evaluation of energy strategies for small islands (Cavallaro F., 1999; Cavallaro F. – Ciraolo L., 2005).

2. Multi-criteria assessment aids to environmental and energy decisions

Cost-benefit analysis (CBA) is one of the most well known methods used for effecting choices between a number of different projects. This method is widely used to justify investments in economic terms rather than as a tool to aid planning. Under CBA everything is accounted for that can be translated into monetary terms. Such an operation inevitably leads to some approximations and may be somewhat arbitrary as not all of the benefits considered in the analysis can be readily assigned a monetary value. Considerable difficulties can be met when environmental impacts, such as different forms of pollution or the social impacts on the geographical area affected by the project, are to be incorporated in the analysis. The financial values of these impacts are generally not easy to ascertain and in some cases indeed it is not ethically acceptable to put a price on certain values such as biodiversity, people's health, the quality of life and social factors. Another critical element lies in setting the discount rate to apply, as the higher this is then the lower the discounted value of projected future benefits will be.

At the core of traditional decision making tools lies the idea that there is only one solution to a given problem – the *optimum* – which has to be sought. In contrast, the nature of environmental management activity is such that it requires subjective judgements of a technical, socio-economic, and environmental nature; thus it is very difficult to arrive at a clear and unanimous solution in the environmental planning process.

The multi-criteria approach differs substantially from CBA in that the merit of the project is evaluated by considering it from differing viewpoints or applying heterogeneous criteria. The impacts produced by the proposals under review are estimated in respect of each criteria and, unlike CBA, these need not necessarily be expressed in monetary terms but may be either quantitative or qualitative values measured using a range of different scales. The choice is made by assessing the contributions made by the various project options and comparing them with the overall objective considered from diverse, and often conflicting, standpoints.

From this arises the need to develop a planning and management tool that can assist the decision maker in assessing a set of alternatives, from different viewpoints, and to choose the option of "compromise" namely the one held to be most acceptable by all criteria considered altogether. The activity linked to the search for a 'best compromise' solution requires a suitable assessment method and the various multi-criteria methods seem best suited to such a purpose.

The final solution according to Roy is a *creation* rather than a *discovery* (Roy B., 1985, 1990). Thus the main objective of a *Multiple Criteria Decision Aid* (MCDA) is to build or create a support tool for decision makers that conforms to their objectives and priorities (a constructive or creative approach) (Roy B, 1990). The "ideal" solution, the option that performs best for *all* the criteria selected, is difficult to achieve. Therefore it is necessary instead to find a compromise from among the different hypothetical solutions. It is for this reason that a choice resulting from MCDA is "justified" and not "optimum".

The points in favour of a decision making model built on a multi-criteria algorithm are summarised below:

- it can handle the large amounts of, often conflicting, information, data, relations and objectives that are generally encountered when facing a specific decision problem;
- it does not reveal the solution to the decision maker as a *revealed truth*, instead it sustains the entire decision making process providing the means to deal with the information to hand;
- the approach is based on systematic observation and on the verification of factors influencing the decision, thus it is not a "black box" type of decision model but a *transparent* tool**;**
- it provides the instruments to *construct* the problems clearly in order to make them more understandable;
- it enables the decision making process to be *monitored* and *checked* as it evolves;

3. The PROMETHEE method I and II

The methodology adopted for the purpose of this case study is based on the method of outranking called PROMETHEE (Preference Ranking Organization Method of Enrichment Evaluation) devised by Brans J.P.et al. (1985, 1986, 1994, 1998). This technique, besides possessing all the advantages of B. Roy's outranking methods, is also easy to use and its level of complexity is low. It is based on ranking and is well-suited to problems in which there are a finite number of actions to be assessed on the basis of a range of conflicting criteria. The following procedure is recommended to implement the method:

Identification of alternatives

The outcome of any decision making model depends on the information at its disposal and the type of this information may vary according to the context in which one is operating, therefore it is useful for decision making models to consider all the information as a whole. The availability of information is intrinsically bound up with the phase in which the problem is defined, therefore, the very first step in dealing with any decision problem is to construct it correctly.

As stated earlier, in MCDA the decision procedure is normally carried out by choosing between different elements that the decision maker has to examine and to assess using a set of criteria. These elements are called actions and they make up part of a global set labelled *actions or alternatives*.

Defining a set of criteria.

The criteria represent the tools which enable alternatives to be compared from a specific point of view. It must be remembered that the selection of criteria is of prime importance in the resolution of a given problem, meaning that it is vital to identify a coherent family of criteria and not just any set of criteria willy nilly. The alternatives are compared pairwise under each criterion and the decision maker, faced with the two actions *a* and *b*, can express: an outright preference (*a*P*b*); a weak preference, if it is less marked, (*a*Q*b*); indifference (*a*I*b*); or incomparability (*a*R*b*) if none of the former apply. Methods based on this approach were initially developed by Roy B. in the late 1960s.

Evaluation matrix

Once the set of criteria and the alternatives have been selected then the payoff matrix is built. This matrix tabulates, for each criterion–alternative pair, the quantitative and qualitative measures of the effect produced by that alternative with respect to that criterion. The matrix may contain data measured on a cardinal or an ordinal scale.

Determining the multi-criteria preference index

The preference is expressed by a number between 0 and 1 (from 0 indicating no preference or indifference up to 1 for an outright preference). When the pairs of alternatives *a* and *b* are compared the outcome of the comparison must be expressed in terms of preference in the following way (Brans et al., 1986):

- $P(a,b) = 0$ means there is indifference between *a* and *b* or no preference;
- $P(a,b) \cong 0$ expresses a weak preference for *a* over *b*;
- $P(a,b) \cong 1$ strong preference for *a* over *b*;
- $P(a,b) = 1$ outright preference for *a* over *b*.

In practice this *preference function* $P(a,b)$ represent the difference between the evaluation of the two alternatives so that it can be expressed as follows (Brans J.P-Mareschal B.,1998):

$P_i(a,b) = P_i[d_i(a,b)]$
$d_i(a,b) = f(a) - f(b)$
Thus $0 < P_i(a,b) < 1$

Once the decision maker has described a preference function P_i (i= 1,2,3,….n represent the criteria) then the weights of each criterion must be determined. The weights π represent the relative importance of the criteria used for the assessment, if all criteria are equally important then the value assigned to each of them will be identical. A variety of techniques exist to determine weights, the simplest but also the most arbitrary is direct assignment where weights are set by the decision maker, other techniques require that the decision maker and analyst work together to obtain a vector of weights that conforms as closely as possible to the decision maker's preferences. In addition to weighting, the method involves setting thresholds that delineate the decision maker's preferences for each criterion and the critical thresholds are thus: the indifference threshold q_i and the preference threshold p_i.

The index of preference Π is calculated for each pair of actions *a* and *b* as the weighted average of preferences calculated for each criterion. The index Π is therefore defined as follows (Brans J.P. et al., 1986):

$$\prod(a,b) = \frac{\sum \pi_i P_i}{\sum_i \pi_i}$$

Π (a,b) represents the strength of the decision maker's preference for action *a* over action *b* considering all criteria simultaneously and Π (b,a) how much *b* is preferred above *a*. Its value falls between 0 and 1 whereby:

Π $(a,b) \cong 0$ indicates a weak preference for a over b for all criteria;

Π $(a,b) \cong 1$ indicates a strong preference for a over b for all criteria.

Ranking the alternatives

The traditionally non-compensatory and methodologically important models include ones in which preferences are aggregated by means of outranking relations. Outranking is a binary relation **S** defined in A such that *a*S*b* if, given the information relating to the decision maker's preferences there are enough arguments to decide that "*a is at least as good as b*" while there is no reason to refute this statement, i.e. *a*Sj*b* implies *b*Sj*a*. The ranking of alternatives under PROMETHEE uses the following:

$$\Phi^{+}(a)=\sum_{b\in K}\Pi(a,b)/(n-1)$$

This indicates the preference for action a above all others and show how 'good' action *a* is.

$$\Phi^{-}(a)=\sum_{b\in K}\Pi(b,a)/(n-1)$$

This indicates the preference for all the other actions compared with *a* and shows how weak action *a* is.

According to PROMETHEE I *a* is superior to *b* if the leaving flow of *a* is greater than the leaving flow of *b* and the entering flow of *a* is smaller than the entering flow of *b.* The PROMETHEE I partial preorder (P^I, $I^{I,}$ R^I) is obtained by considering the intersection of these two preorders (Brans J.P. et al., 1986):

$$\begin{cases} aP^{I}b \quad \text{(a outrank b)} \qquad \text{if} \qquad \begin{Bmatrix} \Phi^{+}(a)>\Phi^{+}(b) \text{ and } \Phi^{-}(a)<\Phi^{-}(b) \\ \Phi^{+}(a)=\Phi^{+}(b) \text{ and } \Phi^{-}(a)<\Phi^{-}(b) \\ \Phi^{+}(a)>\Phi^{+}(b) \text{ and } \Phi^{-}(a)=\Phi^{-}(b) \end{Bmatrix} \\ aI^{I}b \quad \text{(a is indifferent to b)} \quad \text{if} \qquad \Phi^{+}(a)=\Phi^{+}(b) \text{ and } \Phi^{-}(a)=\Phi^{-}(b) \\ aR^{I}b \quad \text{(a and b are incomparable) otherwise} \end{cases}$$

Where P^I, $I^{I,}$ and R^I stand for preference, indifference and incomparability. Finally *a* outranks *b* if:

$$\Phi^{+}(a)\geq\Phi^{+}(b) \text{ and } \Phi^{-}(a)\leq\Phi^{-}(b)$$

Equality in Φ^+ and Φ^- indicates indifference between the two compared alternatives. Under the Promethee I method some actions remain incomparable, in the case that a complete preorder is required that eliminates any incomparable items, then Promethee II can give a complete ranking as follows (Brans J.P. – Mareschal B., 1994):

$$\begin{Bmatrix} aP^{II}b \text{ iff } \phi\, a>\phi\, b \\ aI^{II}b \text{ iff } \phi\, a=\phi\, b \end{Bmatrix}$$

All alternatives are now comparable and equal positions are possible.

4. Evaluation of alternative energy projects using PROMETHEE

4.1 The proposed energy options

The case study proposes a number of alternative renewable energy installations operating in the area of Messina in Sicily (Italy). The following options are hypothesised :

1. *Photovoltaic (PV - A..1)*: installation of 200 PV units each with a power of 3 kW, linked to the grid and suitable for household use;
2. *Wind power (Wind – A..2)*: installation of 4 wind turbines of 600 kW each, in sites with annual average windspeed of around 4.7 m/s;
3. *Biomass (Biomass – A..3)*: 5MW steam boiler fuelled by energy crops especially "Mischantus Sinensis*"*. The adoption of a fluidized bed combustion system was favoured over a traditional combustion furnace because, in spite of its higher cost, it does ensure superior performance in environmental terms;
4. *Tidal currents (Kobold – A..4)*: this considers the possibility of using a *Kobold*[1] turbine, namely a vertical axis Hydro-turbine, to convert the kinetic energy contained in marine currents (tidal streams) into mechanical energy. A prototype for demonstrative purposes is already installed in the Strait of Messina, although it is not yet in production. This case study hypothesised the introduction of 5 new turbines producing 150MWh each per annum.

4.2 Sets of criteria: identification and selection

The criteria are the tools that enable alternatives to be compared from a specific viewpoint. Undoubtedly, selecting criteria is the most delicate part in formulating the problem before the decision maker, and thus it is requires the utmost care and attention. The number of criteria is heavily dependent on the availability of both quantitative and qualitative information and data. Here 11 criteria were selected; 7 of these technical-economic and 4 socio-environmental. Quantitative measures apply to 6 of the criteria while the remaining 5, being qualitative in nature, were scored by applying impact scales from either 1-4 or 1-5.

Economic and technical criteria

These criteria refer to the costs that must be borne in order to realize the various projects included in each strategy and to guarantee the supply of energy. These factors are of special interest to State authorities.

[1] The prototype KOBOLD turbine was designed and built by the research group headed by Prof. D. Coiro of the Dip. di Progettazione Aeronautica dell'Università di Napoli Federico II°, while the patent is owned by the company "Ponte di Archimede S.p.A.". Our thanks to Prof. Coiro for data and suggestions provided regarding the prototype.

- ***Investment costs***. This includes all costs relating to the purchase of mechanical equipment, technological installations, to construction of roads and connections to the national grid, to engineering services, drilling and other incidental construction work. This criterion is measured in Euros;
- ***Operating and maintenance costs.*** This includes all the costs relating to plants, employees' wages, materials and installations, transport and hire charges, and any ground rentals payable. This criterion is measured in Euros;
- ***Primary energy saving.*** This refers to the amount of fossil fuel currently used by power plants to produce electricity that could be saved. It is measured in Kg/per annum;
- ***Cost of generating electricity (growth).*** This refers to the potential risk of an increased cost to industry of generating energy. This risk is linked to the fact that for some, not fully mature, technologies there is no certainty regarding the effective yield of the system, consequently an energy production deficit could mean increased unit cost of production. This criterion is measured as a percentage;
- ***Maturity of technology***. Measures the degree of reliability of the technology adopted as well as how widespread the technology is at both national and European level. This is appraised using a qualitative judgment transformed into the following four-point scale (Beccali M. et al., 2003):
  - Technologies tested in laboratory= 1
  - " only performed in pilot plants=2
  - " requiring further improvements to increase their efficiency levels=3;
  - Commercial mature technologies with a solid market position=4;
- ***Continuity of power supply:*** This criterion indicates whether the energy supply is subject to interruptions (e.g. PV does not work at night, wind generators cannot function when there is no wind, etc.) and thereby affects the stability of the electricity grid. This case is also evaluated qualitatively and expressed via the following four-point scale:
  - Highly discontinuous activity =1
  - Moderately discontinuous activity =2
  - Slightly discontinuous activity =3;
  - Stable and continued activity (except when the plant undergoes maintenance)=4;
- ***Realization time.*** This measures the time to realize and put into operation the plants designed. It is expressed in number of months.

Environmental and social criteria

These criteria refer to protection of the environment and to the principle of *sustainability*:

- ***Sustainability of Climate Change:*** This refers to the amount of CO_2 emissions avoided as a result of the production of the proposed plants. It is measured in Kg/per annum.
- ***Sustainability of other impacts:*** This criterion takes into account other impacts: the visual nuisance that may be created by the development of a project in a specific area or any noise disturbance and odours arising from productive activity of plants, the potential risk to eco-systems caused by the production operations of the various projects included in the strategies. This is also measured qualitatively and translated into the following five-point scale(Beccali M. et al., 2003):
  - Extremely high impact=1
  - High impact=2
  - Moderate impact=3
  - Slight impact=4
  - No impact =5.
- ***Social acceptability***. Expresses the index of acceptance by the local population regarding the hypothesized realization of the projects under review. The following four-point qualitative scale was applied:
  - The majority of inhabitants are against the installation of any plant whatsoever regardless of where it is =1
  - The opinion of the population regarding the installations is split =2
  - The majority accepts the installations provided they are located far from residential areas =3
  - The majority of inhabitants are favourably disposed towards the installations =4
- ***Contribution to local development***. This criterion estimates the global social and economic effects that may be felt in the areas affected by the initiatives. The potential effects are: the creation of new jobs, new supply chain businesses, emerging energy sector businesses, industrial districts etc. The following rating scale was applied:
  - Impact on local economy rated weak =1
  - Impact on local economy rated moderate (some permanent jobs)=2
  - Impact on local economy rated medium-high (jobs + supply chain businesses)=3
  - Impact on local economy rated high (strong impetus to local development, creation of small industrial districts)=4

4.3 The evaluation matrix

Table 1 shows the matrix containing the alternative actions and how they perform with respect to the evaluation criteria selected.

Tab. 1 Evaluation matrix

Criteria			**Weights %** α	β	γ	**Sustainable options** *A..1 (PV)*	*A..2 (Wind)*	*A..3(Biomass)*	*A..4 (T. Kobold)*
Investment costs	Euros	a	1	13	5	4,648,112	3,098,741	9,683,567	750,000
O. & M. costs	“	b	1	9	5	46,481	92,962	645,571	15,000
Primary energy saving	kg/year	c	1	10	12	467,925	1,814,470	9,292,500	375,000
Increased cost of elec. gen.	%	d	1	8	6	8%	2%	4%	3%
Maturity of technology	qual. 1-4	e	1	10	6	3	4	4	2
Continuity of power supply	“ 1-4	f	1	9	9	2	3	4	3
Realization time	no. months	g	1	10	7	12	18	24	12
Sustainability of climate change (CO_2 avoided)	kg/year	h	1	5	14	814,190	3,157,178	16,168,950	652,000
Sustainability of other impacts	qual. 1-5	i	1	5	13	4	3	3	5
Contribution to local devt.	“ 1-4	l	1	14	13	1	2	3	1
Social acceptability	“ 1-4	m	1	7	10	4	3	2	4

α= equal weights; β= economic-oriented scenario; γ= environmental-oriented scenario

4.4 Results

The data in the evaluation matrix are used in calculations to determine the indices of preference Π (see pag. 4) presented in the table 2. It is immediately apparent that the best performers are Wind A..2 and Kobold A..4. The table 2 shows the preference index that is calculated for each pair of actions *a* and *b* as weighted average of preferences calculated for each criterion. The index represents the strength of the decision maker's preference for action *a* over action *b* considering all criteria simultaneously. Its value fall between 0 and 1.

Tab. 2 Preference indices of the four alternatives

Actions	*A..1*	*A..2*	*A..3*	*A..4*
A..1: PV	0.00	0.27	0.45	0.27
A..2: Wind	0.64	0	0.55	0.45
A..3:Biomass	0.55	0.36	0	0.45
A..4:Kobold	0.45	0.45	0.45	0

Tab. 3 Preference flows

Actions	leaving Φ^+	rank	entering Φ^-	rank	net flow $\Phi(a)=\Phi^+(a)-\Phi^-(a)$	rank
A..1: PV	0.33333	4	0.57576	4	-0.24242	4
A..2: Wind	0.54545	1	0.36364	1	0.18182	1
A..3:Biomass	0.45455	3	0.48485	3	-0.3030	3
A..4:Kobold	0.48485	2	0.39394	2	0.09091	2

Tab 4. Complete ranking

PROMETHEE II° Complete ranking		
Rank	**Actions**	**Net flow**
1	A..2: Wind	0.18182
2	A..4: Kobold	0.12091
3	A..3:Biomass	-0.03030
4	A..1:PV	-0.24242

Fig. 1 Complete Ranking “base case”

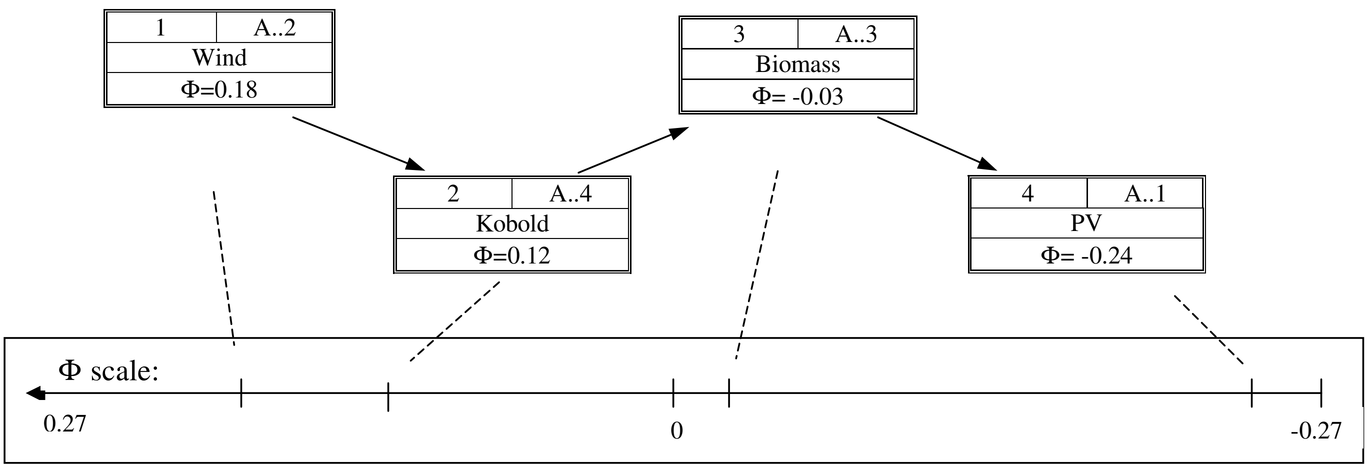


Table 3 presents the results regarding preferences (leaving and entering flows) of the various alternatives expressed numerically while table 4 gives the figures following the order of the final ranking. Fig. 1 graphically illustrates the positions of each alternative in the final ranking. It is clear that option A..2 Wind (Φ= 0.18) outranks all the others, however option A..4 Kobold (Φ= 0.12) also performs well and does not lag not far behind, next comes A..3 Biomass (Φ= -0.03) and at the bottom of the ranking lies option A..4 PV (Φ= -0.24). The rather negative performance of the latter is due to it being heavily penalized by the high cost of investment compared to the efficiency of energy production.

The resultant scenario arises from equal weights (1%) being assigned to each criterion. The results of multi-criteria analysis hinge on the weightings allocated and thresholds set. As stated earlier, the weights express the importance of each criterion and obviously may deeply influence the final outcome of the entire calculation procedure. For some authors, the problem of how to determine the weights to assign is still unresolved since the different outranking methods do not lay down any standard procedure or guidelines for determining them. Here, three scenarios with three different weight vectors were formulated to circumvent this problem. The first scenario, representing the *base-case,* was calculated attributing equal importance to all the criteria, both technical and economic and socio-environmental. A further two scenarios were then developed: 1) *economic-oriented* in which higher weights were assigned to economic and technical criteria; 2) *environment-oriented* where greater importance was attributed to social and environmental criteria.

The calculations relating to the economic-oriented scenario compared to the base case conferred a fair degree of stability in the results. Indeed, although the figures vary slightly, the order of the final ranking is unchanged (see tables 5 and 6).

Tab. 5 Preference indices (economic-oriented case)

Actions	*A..1*	*A..2*	*A..3*	*A..4*
A..1: PV	0.00	0.27	0.45	0.29
A..2: Wind	0.58	0	0,50	0.47
A..3:Biomass	0.55	0.36	0	0.50
A..4:Kobold	0.44	0.53	0.45	0

Table 6 (economic-oriented case)

PROMETHEE II° Complete ranking		
Rank	Actions	Net flow
1	A..2: Wind	0.13294
2	A..4: Kobold	0.9067
3	A..3:Biomass	0.0109
4	A..1:PV	-0.18471

As far as the environment-oriented scenario is concerned, the results show a change in the ranking order. Although option A..2 still comes out top, the second position is here taken by option A..3 (i.e. the project regarding a biomass combustion plant) followed by A..4 and lastly by A..1 (see fig. 2 and tables 7 and 8). Under this scenario, option A..3 does better than the other options because its energy production levels are higher and therefore so too are the fossil fuel savings and avoided CO_2 emissions. By attributing higher weightings to these criteria this option has moved up one position in the ranking. Apart from this change in position, the overall outcome still lead to the conclusion that the analysis performed and results obtained under all three scenarios are highly stable. Option A..2 (Wind) dominates all the others in all three scenarios, closely followed by A..4 (Kobold) which performs very well under two of the scenarios revealing an excellent opportunity for development in the renewable energy field thanks to its extraordinarily innovative nature.

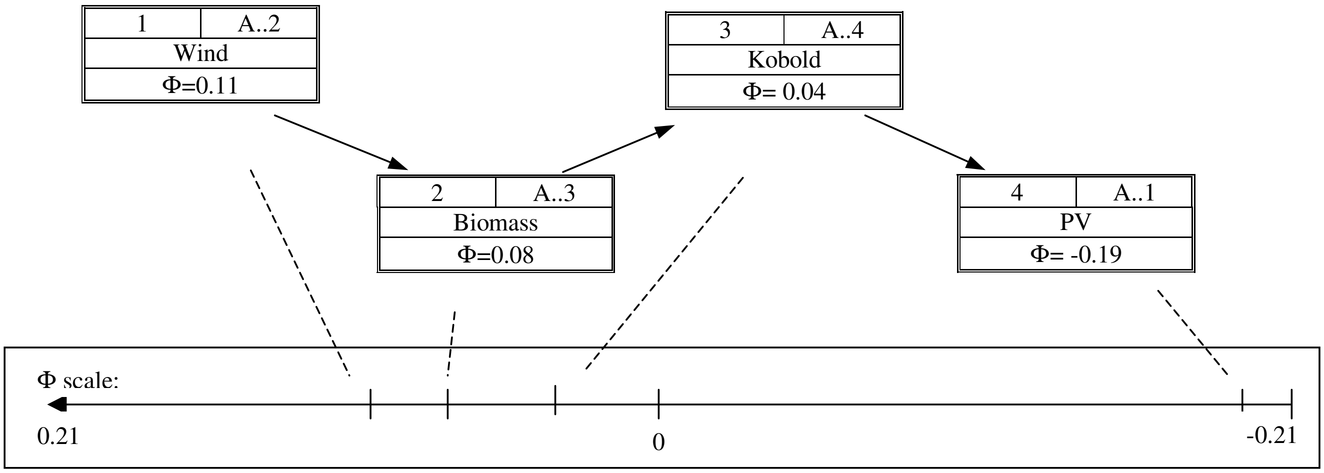
Tab. 7 Preference indices (environment-oriented case)

Actions	*A..1*	*A..2*	*A..3*	*A..4*
A..1: PV	0.00	0.28	0.42	0.31
A..2: Wind	0.56	0	0.48	0.51
A..3:Biomass	0.58	0.47	0	0.52
A..4:Kobold	0.46	0.49	0.42	0

Tab. 8 (environment-oriented)

PROMETHEE II° Complete ranking		
Rank	Actions	Net flow
1	A..2: Wind	0.10576
2	A..3: Biomass	0.08306
3	A..4:Kobold	0.0491
4	A..1:PV	-0.19474

Fig.2 Complete ranking “environment-oriented case”



5. Conclusions

In the case study presented herein, in both the base-case and the cost-oriented scenarios and the meteorological and climatic conditions and territorial characteristics of the site chosen (the province of Messina), from the simultaneous assessment of all the criteria, wind power comes out as top as the best *compromise* solution out of the sustainable energy options selected. In addition, the excellent performance of option A..4 (Kobold) corroborates the undoubted attractiveness of this technology, above all in terms of the energy produced. The market potential of this technology, although still at the prototype stage and subject to further development, is of great interest most of all because it inserts favourably into the environment and operates at highly efficient levels.

Assessment procedures and energy planning may appear complex because of the number and diversity of the items to evaluate, the uncertainty of data and conflicts between interested parties. Nevertheless, multi-criteria analysis, as this paper demonstrates, can provide a technical-scientific decision making support tool that is able to justify its choices clearly and consistently, especially in the renewable energy sector.

References

Barda O.H., Dupuis J., Lencioni P.,. *Multicriteria location of thermal power plants*. European Journal of Operational Research 45, 1990;

Beccali M., Cellura M., Mistretta M, Decision *Decision-making in energy planning. Application of the Electre method at regional level for the diffusion of renewable energy technology*. Renewable Energy, 28, 2003;

Brans J.P., Mareschal B., Multicriteria decision aid the promethee-gaia solution. Working paper Vrije Universiteit Brussel, STOOTW/288, 1998;

Brans J.P., Mareschal B., The Promcalc & Gaia decision support system for multicriteria decision aid. Decision Support System, 12, 1994;

Brans J.P., Vincke Ph., Mareschal B., *How to select and how to rank projects: The Promethee method.* European Journal of Operational Research, 24, 1986;

Brans J.P.,Vincke Ph., *PROMETHEE. A new family of outranking methods in M*CDM. Management Science, 31, 1985;

Cavallaro F., Ciraolo L., *A multicriteria approach to evaluate wind energy plants on an Italian island*, Energy Policy 33 (2005) pp. 235-244;

Cavallaro F., Clasadonte M.T., *The role of renewable energy sources in the field of sustainable development in european policies*, proceedings of International Conference "Ecology of Products 2000", Cracovia, May, 2000;

Cavallaro F., *Un'analisi multicriteriale per la gestione di strategie energetiche alternative nelle isole minori in Sicilia*. Economia delle fonti di energia e dell'ambiente (IEFE-Bocconi) 3, 1999;

Coiro D., *La produzione di energia pulita dalle correnti marine con la turbina brevettata KOBOLD nello Stretto di Messina (Italy),* Seminario "Verso un Futuro energetico sostenibile", University of Molise, 25 March 2004;

Goumas M., Lygerou V., Papayannakis, L.,. *Computational methods for planning and evaluating geothermal energy projects*. Energy Policy 27, 1999.

Roy B., Méthodologie multicritere d'aide à la decision, (1985), Economica, Paris;

Roy B., "The outranking approach and the foundations of ELECTRE methods, in Bana e Costa (editor), Readings in Multiple Criteria Decision Aid, (1990), Springer-Verlag Berlin;

SEC (99) 504, 14/04/99, Documento di lavoro dei servizi della Commissione, Energia per il futuro: fonti energetiche rinnovabili (*Campaign for take-off* CTO);

Siskos, J., Hubert, P.H., 1983. Multi-criteria analysis of the impacts of energy alternatives: a survey and a new comparative approach. European Journal of Operational Research 13.

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