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The problem of windfarm location: A social multi-criteria evaluation framework

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Abstract

Although wind energy has the green image, the location of windfarms is always a source of local conflicts. Opposition may depend on the extensive land use of windfarms, their possible impacts on tourism or their visual impact, as well as NIMBY (*Never In My Back-Yard*) behavior. On the other hand, some social actors are normally in favor of wind parks because they perceive them as a possibility of development or simply a source of income. In these situations, the management of the energy policy process involves many layers and kinds of decisions, and requires the construction of a dialogue process among many social actors, individual and collective, formal and informal, local and non-local. This implies that the political and social framework must find a place in evaluation exercises. This is the objective of social multi-criteria evaluation (SMCE). In this article, SMCE is proposed as a general framework for dealing with the problem of wind park location. The major strength of SMCE is the possibility of integrating both socio-economic and technical dimensions inside a coherent framework. A real-world case study is used as an illustrative example.

JEL classification: C44; D74; Q42

Keywords: Multi-criteria decision analysis; Wind energy; Conflict management

1. Introduction

In the last decade, renewable energies, and specially wind energy, have received a big impulse. Wind energy is presented as one of the strategies for tackling global warming and accomplishing the Kyoto Protocol. Although wind energy has the green image, it is not difficult to find unfavorable positions regarding the installation of windfarms. This opposition may depend on the extensive land use of windfarms, their possible impacts on tourism, the creation of territorial inequalities or their visual impact, as well as NIMBY (*Never In My Back-Yard*) behavior. The policy process itself for deciding the location of the wind turbines can also be a source of conflict. We can then conclude that wind energy location problems are essentially *conflict management problems* (Giampietro et al., 2006).

As a tool for conflict management, multi-criteria evaluation has demonstrated its usefulness in many environmental and energy policy/management problems (see e.g. Beinat and Nijkamp, 1998; Diakoulaki et al., 2005; Georgopoulou et al., 1998; Goumas and Lygerou, 2000; Munda, 2005a; Tzeng et al., 2005; Uemura et al., 2003). Most applications in the field of energy policy can be classified into the following main groups (Diakoulaki et al., 2005, pp. 876–879):

1. comparative evaluation of power generation technologies,

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2. selection among alternative energy plans and policies,
3. sorting out a subset of candidate energy projects,
4. siting and dispatching decisions in the electricity sector.

As a consequence, the use of multi-criteria decision analysis seems very relevant for tackling wind parks location problems. Social multi-criteria evaluation (SMCE) (Munda, 2004), in particular, can supply a powerful framework for energy policy analysis since it is *inter/multi-disciplinary* (with respect to the research team), *participatory* (with respect to the local community) and *transparent* (since all criteria are presented in their original form without any transformations in money, energy or whatever common measurement rod).

The main principles of SMCE can be summarized as follows (Munda, 2004):

1. The classical schematized relationship decision-maker/analyst is indeed embedded in a social framework, which is of a crucial importance in the case of public choice problems such as land use and energy policies.
2. The combination of various participatory methods, which has proven powerful in sociological research, becomes even more so when integrated with a multi-criterion framework. For example, institutional analysis, performed mainly on historical, legislative and administrative documents, as well as on local press and interviews to key persons, can provide a map of the relevant social actors. By means of focus groups, it is possible to have an idea of people's desires and it is then possible to develop a set of policy options and evaluation criteria. Main limitations of the focus group technique are that they are not supposed to be a representative sample of the population and that sometimes people are not willing to participate or to state publicly what they really think (above all in small towns and villages). For this reason, anonymous questionnaires and personal interviews are an essential part of the participatory process (Corral Quintana, 2000; De Marchi et al., 2000; Guimarães-Pereira et al., 2003).
3. Policy evaluation is not a one-shot activity. On the contrary, it takes place as a *learning process* which is usually highly dynamic, so that judgments regarding the political relevance of items, alternatives or impacts may present sudden changes, hence requiring a policy analysis to be flexible and adaptive in nature. This is the reason why evaluation processes should have a *cyclic nature*. By this, it is meant the possible adaptation of

Fig. 1. L'Urgell and Conca de Barberà Comarcas in Catalonia.

Table 1
Socio-economic actors, scale of action and their positioning in relation with the windfarms

Social actor	Scale of action	Position regarding the windfarms
Catalonian government	National	The Catalonian government has launched the Renewable energy plan for the year 2010. It projects the participation of RES to grow, from 72.2 MW to 1.073 MW of installed capacity. It has accepted the petition made by some environmental and social movements of revising the Catalonian renewable energy program. But at the same time, they have the goal of increasing installed capacity of windfarms up to 3000 MW. Then, its evaluation of the different alternatives depends mainly on the installed capacity.
Municipality of Vallbona de les Monges	Local—Province	The municipality wants the windfarms to be installed. They see the economic income as a good opportunity to improve some social services, and/or to create others (like elder nursing).
Municipality of Rocallaura	Local—Province	The municipalities of Vallbona de les Monges, of Rocallaura and of Els Omells de na Gaia are negotiating as a coalition with the companies, trying to obtain equal and better retribution conditions from the promoters. They say that if the economic income is not enough to overcome the present social trend, then they do not want the windfarms to be constructed.
Municipality of Els Omells de Na Gaia	Local—Province	In a similar position than the previous ones, the municipality of Els Omells de Na Gaia supports the installation of the windfarms in their own territory. The windfarms could provide economic resources for the municipality and for some members of it.
Town council of Senan	Local—Province	The town council, supported by Senan's inhabitants, is strongly opposed to the windfarms. They do not want to be surrounded by windmills, They see their welfare at risk, mainly because the *industrialization of the mountains* is viewed as a loss of quality of life and a possible destruction of tourism potentialities (e.g. forests).
President of the Consell comarcal de l'Urgell	Province—National	The president of the council has offered her mediation to reach a compromise solution. But she shares the opinion of the mayors, in the sense that more economic income is needed to revitalize the towns, and to offer more and better services.
Politic representatives	Province	Representatives from different political parties have signed a motion asking for a moratorium to the windfarms *Coma de Bertran* and *Serra del Tallat*. And defending the development of economic activities without interference with local initiatives.
Coordinating committee to defend the land (Urgell, Conca de Barberà, Segarra, Garrigues)	Province	They think that it is not necessary to jeopardize the future of the towns to revitalize them. They are not against wind energy, but they do not approve the way the process has been carried out, for instance, without considering the needs and problems of the local people. They think that the solution has to be discussed by all the towns involved, to avoid any town to be harmed. They act as a regional entity fighting the installation of windfarms at large scale. They support the development of activities in accordance with traditional activities, like the tourist project *Ruta del Cister*. The evaluations are directly related with the amount of windmills. Then, less windmills to be constructed means a better evaluation for them.
Plataform for Senan	Province	They see the projects as an undesirable gift from its neighbors. They do not share the way the process has bean carried out, and they say that to reach more equitable decisions, all the involved towns have to be heard. (See Town council of Senan above).
Association of friends and neighbors of Montblanquet	Local—Province	Most of the people of this association hold a second residence. They *escape* from the city to the country side to look for a quiet place to rest. Most of them reject the planned windfarms due to their proximity to the towns (potential noise annoyance and scenic impact).
GEPEC	National	This is an environmental non-governmental organization, acting at the Catalonian level to redefine the Catalonian Energy Plan, with the participation of some social actors. They ask for a decentralized electricity production system close to the consumption places. Regarding the location of windfarms, they ask for special attention to the habitats of rare and threaten species, and to the biologic corridors. They ask also for applying the Landscape European Convention and for territorial equity.
Enegía Hidroeléctrica de Navarra (EHN)	National	The company is the promoter of one of the windfarms. They are one of the main energy producers from RES in the Spanish territory, and one of their aims is to construct windfarms as big as possible to impulse a strong change "*in the energy production culture*". The current submitted project (ST) is already in the evaluation phase, and they have spent some economic resources on it. It could be said that this alternative is perfect for them. While for other alternatives, their willingness to implement them is related with the amount of installed capacity and of course with the fact that they will be the acting company.
Gerrsa	National	This is the promoter of the *Coma Bertran* project. It has been impossible to organize a meeting with them due to their reluctance of talking with people external to the government. It is assumed that its situation is quite similar with EHN. They support projects in which they are involved.

elements of the evaluation process due to continuous feedback loops among the various steps and consultations among the actors involved. It is extraordinarily important that different participatory and interaction tools are used in different stages throughout the process. This allows for a continuous testing of the assumptions made.

4. Within this framework, mathematical algorithms still play an important role (i.e. to assure that the policy rankings obtained are *consistent* with the information and the assumptions used). For this reason, multi-criteria algorithms, used in a social context, should be as simple as possible (i.e. with a minimum number of exogenuous parameters) and that their axiomatization should be complete and clear.

Main objective of this article is to show the potentialities of a SMCE framework for dealing with wind park location problems. To achieve this goal a real-world problem is used. This is a location problem recently tackled in Catalonia (a region in the North-East of Spain).

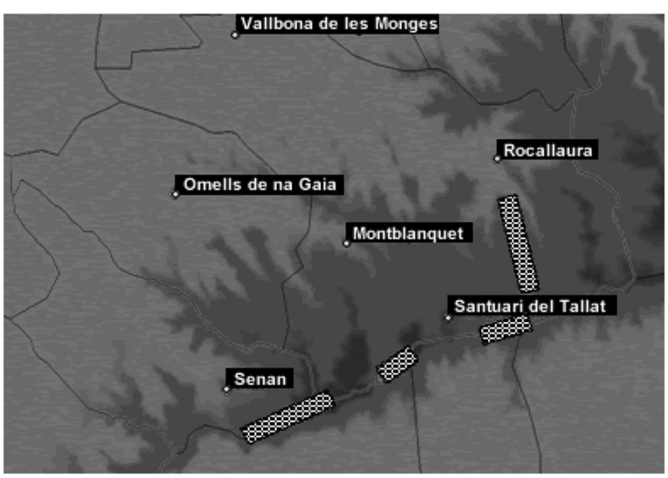

Fig. 2. Technical feasibility zones (wind availability). Source: our own elaboration based on EHN (1999).

2. The real-world location problem

The impact zone is located in the west part of the Catalonian central depression (see Fig. 1) between the *"comarcas"* of Urgell and Conca de Barberà. The projects proposed were two: the *Coma Bertran* project of 11 windmills of 1.5 MW and the *Serra del Tallat* project of 33 windmills of 1.5 MW. In addition, there were other two projects of 75 and 15 windmills, respectively.

Early in this location policy process, there were several positions regarding the construction of those windfarms. On one side, some people started to raise their voices against the windfarms. Firstly, they expressed their will of participating in the design of the future of their *comarcas* and, secondly, they see as territorial inequalities (mainly between the metropolitan area of Barcelona and the rest of the region) the way Catalonia has been planning the energy production scheme.

On the other side, some municipalities and some citizens agreed with the construction of these infrastructures. They see the windfarms as a good opportunity to increase their incomes, to improve social services and to change the declining path that characterizes their territory. By developing an institutional analysis study and applying various participatory techniques, the social *"atmosphere"* understood can be synthesized as in Table 1.

Once the actors' perceptions have been identified, the problem has to be structured in a multi-criterion framework. This means to generate alternatives and to choose evaluation criteria. Next sections illustrate the multi-criterion process and the results obtained.

3. Generation of alternatives

One of the main features of the SMCE framework is that alternatives are constructed considering information from several sources, for instance, the participatory process, the review of the projects, technical interviews, and so on. This process was carried out by the research group. It started considering the preliminary plans of the Coma Bertran (CB-Pre) and Serra del

Table 2
Characteristics of the alternatives

Windfarms features	Alternatives						
	Technocratic	Technocratic and accepted by some part of the population			Modified		BaU
	CB-Pre	CB	ST	CBST	L	R	NP
Number of windmills	16	11	33	44	26	24	0
Power capacity (MW)	13.6	16.5	49.5	66	39	36	0
Rotor height (m)	55	80	80	80	80	80	80
Blades diameter (m)	58	77	77	77	77	77	77

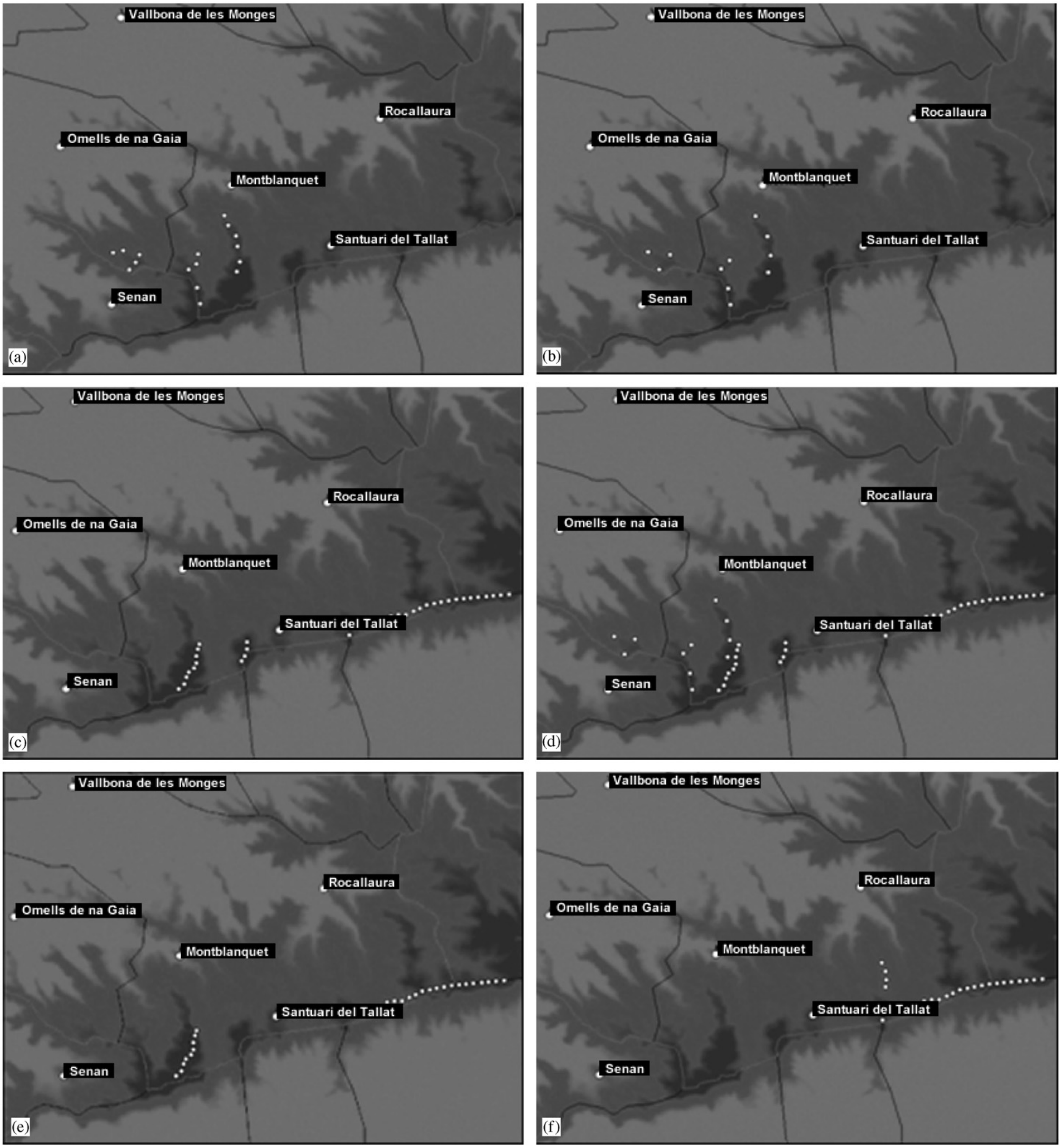

Fig. 3. Location of windmills. (a) CB-Pre: Coma Bertran preliminary project. (b) CB: Coma Bertran project, submitted by Gerr Grupo Energético Siglo XXI S.A. The changes made to the preliminary plan consist in reducing the amount of windmills and increasing their capacity. (c) ST: Serra del Tallat project, submitted by Energía Hidroeléctrica de Navarra (EHN). (d) CBST: Combination of the CB and ST projects. (e) L: Based on CB and ST projects, this alternative considers the windmills located at least 1.5 km from the inhabited centers and potential tourist attractions (Santiari del Tallat). (f) R: This option tries to move the windmills away from the inhabited centers presenting higher resistance to the windfarms (Senan and Montblanquet). Some windmills have been eliminated, and others have been located in the feasibility zones of Fig. 2.

Table 3
Evaluation criteria

Dimension	Criteria	Needs and expectations	Criterion scores
Economic	Land owners' income	• Additional incomes for the farmers. • To stabilize economic income. • To improve quality of life. • There is the worry about who is going to get the benefits, local or external owners.	Overall owner's income per year Unit: €/year Direction: maximize
	Distribution of income	• To avoid the concentration of revenues. • To propel local development.	Percentage of the local incomes related to the companies profit. Unit: % Direction: maximize
Social	Municipalities' income	• To increase the municipalities' revenues. • To offer more social services by the city council. • To keep rural population.	Economic income of the municipalities (construction permission taxes). Unit: € Direction: maximize Economic income of the municipalities (taxes per year). Unit: €/year Direction: maximize
	Number of jobs	• To attract and to keep people in the region. • To reactivate the economic dynamics of the region.	Number of permanent jobs in the operation phase Unit: Number of jobs Direction: maximize
Socio-ecologic	Visual impact	• To avoid mountain industrialization. • To protect tourism in the long run. • To keep rural identity. • To avoid land/houses' value to decrease.	Regional: Addition of all the windmill's view-shed Unit: km^2 Direction: minimize
	Forest lost	• To minimize ecosystems disturbance/ fragmentation. • To avoid soil erosion.	Total deforested area Unit: hectares Direction: minimize
	Noise annoyance	• To protect human health. • To minimize effects over fauna's habitat.	Sound pressure Unit: dB(A) Direction: minimize
	Avoided CO_2 emissions	• To achieve emissions reduction commitments.	Avoided CO_2 emissions, considering the Catalonian energy production vector Units: tons of CO_2 Direction: maximize
Technical	Installed capacity	• To promote a larger share of renewable energies in electricity production. • To warranty economic viability.	Installed capacity Unit: MW Direction: maximize

Table 4
Land owners' income (€/year)

	CB-Pre	CB	ST	CBST	L	R	NP
Number of windmills	16	11	33	44	26	24	—
Owners' income	48,000	33,000	99,000	132,000	78,000	72,000	—

Tallat[1] (ST-Pre) projects, and the combination of both (CBST-Pre) as the three first alternatives. They are called the *technocratic options,* because the investors have defined them relying upon their own criteria only. Then, other three alternatives are the submitted projects (*Coma Bertran* (CB) and *Serra del Tallat* (ST)) and the their combination (CBST). We call these plans as *technocratic and accepted by some part of the population*, because the investors still define the alternatives based on their own criteria, but considering the worries of some social actors.

After this, and considering the worry of some people about the visual impact of the windfarms, new alternatives were generated, relying upon the following criteria:

- Technical (and economic) feasibility, depending on wind availability (see Fig. 2).
- To reduce the visual impact of the original proposals.[2]

Starting from the combination of the preliminary plans, two other alternatives are generated by eliminating the windmills located closer than 1.5 km from the towns (Ls).

Other two alternatives are generated by redistributing windmills that are closer than 2 km from the inhabited zones (Rs). The starting points are the submitted projects. We call these plans *modified,* because they are based on the modification of both the preliminary and the submitted projects.

Finally, there is the possibility of constructing a windfarm managed by a cooperative (e.g. local administration), and the last one is not constructing parks at all (NP). This last is the *BaU* situation, i.e. *Business as Usual*.

These 12 alternatives were submitted to further discussion with social actors and within the scientific team itself. After this further screening process, only *seven* alternatives were left for further evaluation. The detailed description of these seven alternatives is presented in Table 2 and Fig. 3.

4. Selection of evaluation criteria

The evaluation criteria are a *technical translation* of social actors' needs, preferences and desires operated by the research team. So, the evaluation criteria presented in Table 3 are aimed at representing the general objectives and interests of the identified social actors shown in Table 1. It is worth mentioning that the expected effects of the alternatives are not always foreseeable. There are many uncertainties in this kind of decision-making process, for instance the future wind conditions (due to e.g. climate change), tourism trends or human behavior.

[1]Strictly speaking, the preliminary plan of the Serra del Tallat Project was not submitted for governmental evaluation, and it was got from EHN as an internal document. This study was used to identify additional windy zones for locating wind turbines.

[2]It has been considered the worry of *"living surrounded by windmills"*. On the other hand, the Danish Wind Industry stands that the windmills located further away than 500 or 1000 m do not produce shadow effect (i.e. to intercept sun rays).

5. Computing criterion scores

This section deals with the criterion scoring process and the construction of the impact matrixes. This is done at the regional scale.

5.1. Landowners' income

All the chosen sites to locate windmills are private, and a common way of dealing with this situation is that the company pays a certain amount of money to the landowner for every windmill installed. This quantity is fixed around 3.000 €/windmill[3] per year. The overall income for the landowners is presented in Table 4.

5.2. Municipalities income

Here, an attempt to compute the impact on local administration's income due to the construction, installation and operation of windfarms is made.

The local taxation system considers three types of taxes for this situation:

- *The Real Property Tax (RPT)*. It taxes the ownership of a real property where the windfarms are built.
- *The Economic Activity Tax (EAT)*. It taxes the turnover of the operation of the windfarm.
- The Construction, Installation and Building work Tax (CIBT).

5.2.1. Real property tax

This is a yearly tax depending on:

- The valuation of both the land and the construction of the facilities. This is done by the General Land Registry Director's Office.
- The taxation type on the land value, defined by each municipality.

In this case, the affected land is classified as *agriculture land*. But, after the construction of the windfarms, the lands will be classified as *goods of special characteristics*. This change implies the revaluation of lands according to the following criteria (among others):

- the installed capacity of each wind turbine,
- the valuation date,
- the number of windmills in every windfarm and
- the presence of other installations and buildings to operate the windfarm.

A higher land value product of this process implies (a) a superior taxable value and (b) a higher fee to be paid by the

[3]Personal communication from EHN.

Table 5
Different type of taxes in Catalonia

	Minimum share	General share	Maximum share	Reduced share
Urban	0.4%		1.10%	0.1 (6 years)
Rural	0.3%		0.9%	0.075 (6 years)
Special characteristics	0.4%	0.6%	1.3%	Not reduced

Table 6
Municipalities' economic income

	CB-Pre	CB	ST	CBST	L	R	NP
Installed capacity (MW)	13.6	16.5	49.5	66	39	36	—
Municipalities' income (€/year)	12,750	15,470	46,410	61,880	36,570	33,750	—

Economic activity tax (€/year).

Table 7
Municipalities' economic income

	CB-Pre	CB	ST	CBST	L	R	NP
Construction costs	~3360	~2990	~4360	~7350	~3380	~2950	—
Municipalities' income	~61,990	~55,730	~96,520	~152,250	~81,890	~67,650	—

Construction tax (thousands of €).

owner/tenant. In other words, it implies higher incomes to the municipalities.

To have an idea, Table 5 shows a resume of the different types of taxes in Catalonia.

Nowadays, the tax shares for goods of special characteristics are 1.4% in Vallbona de les Monges and 1.3% in Els Omells de Na Gaia. However, the municipalities have the possibility of reducing the payment up to 90% of the tax amount.

The landowners are already paying this tax. Then, the additional income for the municipalities comes from the difference in applying taxes to the old and new valuation of land.

Due to the lack of information, especially regarding the difference between the current and the future land values, this tax has not been calculated. Anyway, according to declarations of the mayor of Vallbona de les Monges, this additional taxation has been negotiated to be paid by the companies.

5.2.2. The economic activity tax

It taxes the turnover of the construction and operation of the windfarm. It is important to be noted that the companies which have a net profit lower than 1,000,000 € can be declared tax free.

For the above-mentioned reason, it is necessary to consider the net profit of the owners of the windfarms. In this case, there are two legal entities:

- Energía Eólica de Cataluña. Energía Hidroeléctrica de Navarra (EHN) owns 100% of it. At the same time, ACCIONA has a participation of the 50% of EHN, SODENA shares 39.58% and Corporación Caja Navarra shares 10.42%.
- Grupo Energético XXI, S.A. shared by the business groups GAMESA and ROS ROCA.

Table 8
Windmills prices

Windmill	Price
850 kW	640,000 €
1.5 MW (Gerrsa)	1,129,500 €
1.5 MW (EHN)	1,150,000 €

Sources: EHN (2003); Entorn (2001); SATEL (2002).

Therefore, the economic balances of these companies have to be analyzed to know whether they should or should not pay this tax.

To obtain the total amount of the municipalities' economic income, the following relationship is used:

$$\text{Minimum fee} = \text{Installed capacity} \times 0.721215\,€/\text{kW}. \quad (1)$$

Finally, the results have to be weighted according to the coefficients defined in the article 86 of the Local Treasury Law, which goes between 1.29 and 1.31. These results are presented in Table 6.

Table 9
Investment costs

	CB-Pre	CB	ST	CBST	L	R	NP
Investment costs (€)	13,590,000	15,324,500	42,300,000	57,624,500	35,800,000	30,550,000	0

Table 10
Distribution of the economic income

	Project						
		CB-Pre	CB	ST	CBST	L	R
Companies income	*M€*	13,130	20,350	59,365	79,715	46,685	43,280
Local authorities income	*M€*	199	240	720	960	610	525
	Participation	1.51%	1.19%	1.22%	1.20%	1.31%	1.22%

Table 11
Number of permanent jobs

	CB-Pre	CB	ST	CBST	L	R	NP
Number of windmills	16	11	33	44	26	24	—
Number of jobs	2	1	4	5	3	3	—

5.2.3. *Construction, installation and building work tax*

According to the article 100 of the Local Treasury Law, the realization of any construction or installation needs a building work license. This tax is based on the real and effective cost of the construction, i.e. the material cost of the building work done.

This tax is defined by every municipality and it must not be higher than 4% (article 102.3 of the Local Treasury Law). The involved municipalities have established the following values:

- Omells de na Gaia: 1.5%
- Vallbona de las Monges: 2%
- Senan: 2%.

The taxable base for this revenue is presented in Table 7. The calculation relies upon the information contained in the environmental impact assessments of the *CB* and *ST* projects[4]:

5.3. *Distribution of incomes*

First of all, there is a need to estimate the financial flow of each project. The time period considered is 20 years (the life of the windmills and the depreciation time). In Catalonia, the current price of the electricity produced from renewable sources is around 0.063 €/kWh, and it is estimated that it will grow at the rate of 2% a year. (Table 8).

The investment costs are presented in Table 9. They have been calculated based on the construction costs (see Table 7) and the price of the windmills (see Table 8):

The maintenance and operation costs are 0.0052 €/kWh for the first 2 years and 0.0078 €/kWh for the remaining 18 years (EHN, 2003; Entorn, 2001; SATEL, 2002). And finally, it has been estimated a discount rate of 2.5%.

Here, the question of how to evaluate the distribution of the economic income rises up. Due to the fact that we are doing a *Social Evaluation*, the incomes to be considered are the *local authorities' income* as a percentage of the *companies' income*. Only the yearly revenues have been taken into account, and not the construction taxes.

Table 10 shows the distribution of incomes. This has been calculated considering the Net Present Value of the yearly incomes of companies and of the local authorities.

As it can be seen in Table 10, the performances of the alternatives present no major differences between them. For this reason, this criterion has been eliminated in the further multi-criteria evaluation.

5.4. *Number of permanent jobs*

The calculation of this criterion score is made considering that in average, for nine windmills one permanent job is

[4]It is well accepted that the cost of one installed kilowatt is around 1000 €. In these projects, the cost of one installed kilowatt varies between 850 and 1000 €.

Table 12
Regional visual impact

	CB-Pre	CB	ST	CBST	L	R	NP
View-shed (km^2)	76.570	71.465	276.550	348.015	220.400	163.290	—

created.[5] The criterion scores of each alternative are presented in Table 11.

5.5. Visual impact

One of the main arguments to oppose the construction of the windfarms is their visual impact.

There are several techniques aiming at evaluating the visual impact of a project. Most of them follow at least two steps:

i. assessment of the visual quality of the landscape where the project is planned, and
ii. evaluation of the visual impact of the project.

There are expert/design approaches—such as *Descriptive inventories*[6]—and perception/experience approaches—such as *Public preference models*[7]—in order to carry out the former task. Most of these methodologies consider the biophysical features of the environment and the human perception as two "essential interacting components" of the landscape quality (Daniel, 2001).

There are theoretical and practical problems in evaluating landscape beauty. On the one hand, descriptive models assume that beauty is embedded in the landscape components, excluding the fact that landscape beauty also depends on the observer. On the other hand, in public preference models, the evaluation is affected by socio-cultural factors, as well as the personality of the observer, its location and many other factors. So, methodologies aimed at considering the interdependence of both sides of the landscape–observer interaction—such as *Quantitative holistic methods*—are needed. (For an overview of these methodologies, see Arthur et al. (1977) or The Macaulay Land Use Research Institute (2005)).

The evaluation of the visual impact of the projected infrastructure is the following task. The determination of zones of visual influence—using, for instance, *viewshed mapping*—and viewpoint analysis—using, for instance, *Photomontages*—are the most common techniques to carry out this step. The former is aimed at both determining and characterizing the area within which the planned development can be seen, and the last is aimed at simulating the view of the planned development from some key viewpoints (More information about different techniques can be found in The Macaulay Land Use Research Institute (2005); for viewshed mapping, see Möller (2005); and for landscape simulation, see Oh (1994)).

Additional factors to consider in the evaluation of the visual impact of any development are the combination of landscape characters, the landscape sensitivity and the landscape's capacity to absorb change (MOPT, 1992). It is worthy mentioning that the visual impact is not only how the windmills look like. Both light reflection from the rotating blades or shadows formation could be negative effects of windfarms. These factors are very difficult to incorporate in the evaluation, and yet the public is not aware of the problem. Anyway, shadow effect is not perceived from distances above 1 km (Danish Wind Industry Association).

Although we are aware of the importance of assessing the scenic quality (task i), and the additional factors to be considered in the evaluation of the visual impact (task ii), these steps have not been performed due to the scarcity of human and time resources. So, in this study, the visual impact of the planned windfarms is evaluated by means of viewshed mapping,[8] an accessible methodology for the research team.

Table 12 shows the cumulative viewshed of the windmills of each projected windfarm. It is important to note that the distance to assess the visual impact would influence the results of the evaluation. Unfortunately, there are divergent recommendations in this respect. So, we have decided to use 10 km as an intermediate distance.

There are also evaluations related to the amount of inhabitants surrounding the installations (in relative terms). In this case, it is considered in absolute terms due to the variability of the frequentation expected in these territories (due to tourism development).

5.6. Forest lost

This criterion aims at reflecting two aspects coming from the social actor perceptions. First, the biodiversity lost and the territorial fragmentation produced by the construction of infrastructure. For instance, the installation of power lines, road construction, ground movement and the spread

[5]Personal communication from EHN.

[6]Descriptive inventories consist in identifying the features of the components of the landscape (lines, colors and textures), and to classify the scenic quality relying upon the combination of the parts.

[7]Public preference models rate the visual quality of the landscape based on the observers' individual preferences of the whole landscape. They use, for instance, questionnaires or verbal surveys to collect peoples' perceptions.

[8]This is a map showing the area within which the wind turbines are likely to be visible. The software Miramon v.5.β.13 has been chosen to do this task. This GIS software has been developed by Xavier Pons at the Autonomous University of Barcelona.

Table 13
Deforestation

	CB-Pre	CB	ST	CBST	L	R	NP
New roads (km)	14	13.5	9	22.5	6.5	4.3	—
Modified roads (km)	—	—	6	6	—	—	—
Forests lost (ha)	8.4	8.1	6.6	14.7	3.9	2.6	—

Table 14
Catalonian energy vector, year 2002

Energy source	Participation (%)
Coal	2.0
#6 oil	3.4
Diesel (#2 oil)	0.9
Natural gas	18.1
Nuclear	62.3
Propane	0.3
Large hydro	11.9
Wind	0.3

Source: ICAEN (2002)

of the spare material generated by the construction itself. Second, deforestation produces both a CO_2 absorption capacity loosing and the probable release of the already stored carbon.

To tackle these issues, it has been decided to measure the deforested area which is produced by new and adapted roads. The effect of the high-voltage power lines to the transport and distribution grid has been considered equal for all the alternatives because there is no information in this respect. To have an idea, a high-voltage power line of 10 km length to reach the grid will be needed.

The total deforested area due to new roads is the total length multiplied by their wide (6 m). For the enlarged roads, the total area comes from the total length multiplied by the expanded area (2 m). The forest lost produced by each alternative is presented in Table 13.

5.7. Avoided CO_2 emissions

It is commonly accepted that wind energy helps to reduce the emission of greenhouse gases (GHG), like CO_2. But looking for information related to positive impacts, some opinions against were found too. The deforested areas to construct infrastructure and the operation of combined cycle power plant at lower efficiencies when windfarms are producing electricity are two arguments in this direction.

On one hand, deforestation produces both a CO_2 absorption capacity loss and the possible release of the stored carbon.[9] This effect is partially evaluated by the previous criterion (*Forest lost*). On the other hand, the production of electricity in Catalonia relies mainly upon nuclear energy (with no GHG emissions at least in the generation phase), which covers the second worry (in the meantime).

Due to the above-mentioned arguments, it was decided to evaluate the avoided CO_2 emissions when electricity produced by wind energy replaces the electricity production from the different types of energy sources in Catalonia, i.e. the energy vector presented in Table 14 (see also Table 15).

5.8. Noise

Noise can be described as unwanted sound. The audible frequency[10] range goes from 20 to 20,000 Hz. Our hearing system is not equally sensitive to all sound frequencies. Then, the A-weighting system is used,[11] which approximates the frequency response of our hearing system.

On the other hand, sound pressure is a basic measure of the vibrations of air that make up sound. These levels are measured in a logarithmic scale which uses decibels as units of measurement (dB(A) means decibels in the A-weighting system).

It can be said that, acoustic discomfort areas are those having sound pressure between 55 and 65 dB(A). Sound pressure levels below 45 dB(A) are not perceived as annoying. But 30 dB(A), for a continuous background noise, could be disturbing to sleep, and individual noise events exceeding 45 dB(A) should be avoided (Nardo, 2004).

Considering the social process in which these evaluations are done, the communication of these results should be done regarding the wide range of people involved. For example, the outcomes of the noise assessment were communicated by means of comparing the potential noise impact of the windfarms with the sound pressure level of common sounds (for instance, the rumor of the leaves of trees: 20 dB(A); residential zones: 40 dB(A); and so on).

[9]In this regard, the emissions due to deforestation do not reach 1% of the avoided CO_2 emissions showed in Table 15 for each alternative. To calculate the CO_2 emissions, it is considered that world template forests storage 56.7 t C/ha. It is also assumed that every hectare of template forest absorbs 6.24 t C/ha/year.

[10]Audible frequency is the number of vibrations per second of the air in which the sound is propagating, and it is measured in Hertz (Hz).

[11]The A-weighting system weights lower frequencies as less important than mid- and higher-frequencies.

Table 15
Avoided CO_2 emissions

	CB-Pre	CB	ST	CBST	L	R	NP
Projected electricity generation (MW h/year)	32,708	42,026	138,071	180,096	103,100	96,207	—
Avoided CO_2 emissions (ton CO_2/year)	4680	6010	19,740	25,750	14,740	13,760	—

Table 16
Noise sensitive zones and noise limits [dB]

Sensitivity zone	Noise limits	
	Day	Night
High (A)	60	50
Medium (B)	65	55
Low (C)	70	60

(A) Zone of High acoustic sensitivity: zones of the territory needing high protection against noise.
(B) Zone of Medium acoustic sensitivity: zones of the territory admitting medium perception of noise.
(C) Zone of Low acoustic sensitivity: zones of the territory admitting high perception of noise.
Source: Catalonian government.

Noise coming from the windmills operation can be classified according to its two mains sources: aerodynamic and mechanic. The former is produced when the rotor blades interact with the eddies caused by atmospheric turbulence. Mechanical noise comes from the rotor machinery operation (gearbox and generator).

In Catalonia, there are no official recommendations about the minimum distance between windmills and residential areas. Some authors suggest 300 m and others, like EHN, proposes at least 1 km.[12] In Catalonia, the noise emissions produced by the activities and the neighborhoods are limited according to the levels indicated in Table 16:

Table 17 shows the possible noise that could be perceived in the closest towns to the windfarms. This has been calculated based on Danish Ministry of the Environment (1991).

5.9. Installed capacity

This criterion evaluates the will of maximizing the installed capacity of renewable energy sources, expressed by the Catalonian government and some ecologist groups in the region. By means of comparing the installed capacity instead of the projected electricity production, this criterion tries to consider the uncertainty related to possible changes in wind conditions. It is basically the amount of windmills multiplied by their nominal capacity. Table 18 shows the installed capacity of the different alternatives.

[12]Personal communication from EHN.

6. Application of a mathematical aggregation convention

6.1. Ranking alternatives

Table 19 presents the multi-criteria impact matrix of the problem we are dealing with. In order to obtain a final ranking of the available alternatives, the criterion scores must be aggregated by means of a mathematical algorithm. Many multi-criteria models have been formulated since the 1960s, each one with advantages and disadvantages (see e.g. Arrow and Raynaud, 1986; Munda, 1995; Roy, 1996). Desirable properties for multi-criteria ranking procedure in the framework of public policy and sustainability issues are discussed in Janssen and Munda (1999) and Munda (2005a). In short, it is very important that such ranking methods are *simple* to guarantee consistency and transparency, *non-compensatory* to avoid that bad environmental or social consequences are systematically outperformed by good economic consequences or vice-versa, *intensity of preference* is not taken into account thus avoiding compensability and allowing for weights being importance coefficients and not trade-offs.[13] A simple ranking algorithm, respecting all these properties, is the following Condorcet consistent rule (see Young and Levenglick (1978) for its social choice characterization and Munda (2005b) for its implementation in a multi-criterion framework).

Given a set of criteria $G = \{g_m\}$, $m = 1,2,\ldots, M$, and a finite set $A = \{a_n\}$, $n = 1, 2,\ldots, N$ of alternatives, let us assume that the evaluation of each alternative a_n with respect to an evaluation criterion g_m is based on an *ordinal, interval or ratio* scale of measurement. For simplicity of exposition, let us assume that a higher value of a criterion score is preferred to a lower one (the higher, the better), that is:

$$\begin{cases} a_j P a_k \Leftrightarrow g_m(a_j) > g_m(a_k) \\ a_j I a_k \Leftrightarrow g_m(a_j) = g_m(a_k) \end{cases}, \tag{2}$$

[13]Weights can be trade-off or importance coefficients. The first ones show the intensity of preference and indicate how much of an advantage on a criterion is sufficient to compensate a disadvantage on another criterion (for example, one might be willing to accept some environmental impact if it is compensated by a sufficient economic income). The second ones indicate how important a criterion is without referring to compensation by means of another criterion. They are used with ordinal criterion scores and originate non-compensatory aggregation procedures. In SMCE, it is more appropriate to use the second type of weights because compensability might lead to disregard some dimensions, which might be important for some groups of social actors.

Table 17
Noise. Sound pressure level (dB(A))

	CB-Pre	CB	ST	CBST	L	R	NP
Vallbona de les Monges	—	—	—	—	—	—	—
Montblanquet	39.9	39.6	26.6	39.6	30.1	13.3	—
Rocallaura	13.1	13.5	18.7	18.7	17.7	26.2	—
Els Omells de Na Gaia	22.0	22.1	6.2	22.1	9.7	0.0	—
Senan	38.6	38.9	21.7	38.9	22.6	0.0	—

Table 18
Installed capacity

	CB-Pre	CB	ST	CBST	L	R	NP
Installed capacity (MW)	13.6	16.5	49.5	66	39	36	—

Table 19
Multi-criteria impact matrix

Criteria	Units	Dir.	CB-Pre	CB	ST	CBST	L	R	NP
Owners' income	€/year	5	48,000	33,000	99,000	132,000	78,000	72,000	—
Economic activity tax	€/year	5	~12,750	~15,470	~46,410	~61,880	~36,570	~33,750	—
Construction tax	€	5	~61,990	~55,730	~96,520	~152,250	~81,890	~67,650	—
Number of jobs		5	2	1	4	5	3	3	—
Visual impact	km^2	6	76.570	71.465	276.550	348.015	220.400	163.290	—
Forest lost	ha	6	8.4	8.1	6.6	14.7	3.9	2.6	—
Avoided CO_2 emissions	ton CO_2/year	5	4680	6010	19,740	25,750	14,740	13,760	—
Noise	dB(A)	6	14.64	23.86	18.6	23.84	20.88	14.66	—
Installed capacity	MW	5	13.6	16.5	49.5	66	39	36	—

Notes: In the case of noise annoyance, the average sound pressure level considering the five involved towns is shown.

where P and I indicate a preference and an indifference relation, respectively, both fulfilling the transitive property (if $a_iP\ a_k$ *and* $a_k\ P\ a_j$, *then* $a_i\ P\ a_j$).

Given that the preference structure is based on Eq. (2), one might wonder if information on intensity of preference (when criterion scores are measured on an interval or ratio scale) is completely lost (since small and big intensities are treated equally). This problem is indeed very old. Its origins may be found in the famous bold paradox in Greek philosophy: how many hairs one has to cut off to transform a person with hairs to a bold one? Luce (1956) was the first one to discuss this issue formally in the framework of preference modeling. He introduced the idea of the existence of a sensibility threshold below which an agent either does not sense the difference between two elements or refuses to declare a preference for one or the other. Mathematical characterizations of preference modeling with thresholds can be found in Roubens and Vincke (1985).

By introducing a positive indifference threshold q, the resulting preference model is the so-called *threshold model:*

$$\left\{ \begin{array}{c} a_jPa_k \Leftrightarrow g_m(a_j) > g_m(a_k) + q \\ a_jIa_k \Leftrightarrow |g_m(a_j) - g_m(a_k)|q \end{array} \right\}. \quad (3)$$

If one wishes to take into account the possible uncertainty around the value of the threshold q, sensitivity analysis and robustness analyses can be used (Saltelli et al., 2004), another possibility is the use of mathematical sophisticated concept such as the one of fuzzy preference modeling (Munda, 1995). Here, starting from the impact matrix presented in Table 19, an ordinal matrix is constructed (Table 20), by considering the indifference thresholds presented in the second column of Table 20.

Let us also assume the existence of a set of criterion weights $W = \{w_m\}$, $m = 1,2,\ldots,M$, with $\sum_{m=1}^{M} w_m = 1$ derived as importance coefficients. The mathematical problem to be dealt with is then how to use this available information to rank in a complete pre-order (i.e. without any incomparability relation[14]) all the alternatives from the best to the worst one.

The mathematical aggregation convention can be divided into two main steps:

1. Pair-wise comparison of alternatives according to the whole set of criteria used.
2. Ranking of alternatives in a complete pre-order.

[14]The relation between each pair of alternatives must be either of preference or indifference.

Table 20
Ordinal impact matrix

Criteria	Threshold	Units	CB-Pre	CB	ST	CBST	L	R	NP
Owners' income	3.000	€/year	3	2	6	7	5	4	1
Economic activity tax	10.000	€/year	3	3	6	7	5	5	1
Construction tax	12.000	€	4	2	6	7	5	4	1
Number of jobs	1	Jobs	3	2	6	7	5	5	1
Visual impact	—	km^2	5	6	2	1	3	4	7
Forest lost	1.5	ha	3	3	4	1	5	6	7
Avoided CO_2 emissions	200	ton CO_2/year	2	3	6	7	5	4	1
Noise	10	dB(A)	3	3	5	3	4	6	7
Installed capacity	1	MW	2	3	6	7	5	4	1

For carrying out the pair-wise comparison of alternatives, the following axiomatic system is needed (adapted from Arrow and Raynaud (1986, p. 81–82)).

Axiom 1. Diversity. Each criterion is a total order on the finite set A of alternatives to be ranked, and there is no restriction on the criteria; they can be any total order on A. In other words, it must be possible to order all alternatives according to each criterion (no incomparability relations are admitted).

Axiom 2. Symmetry. Since criteria have incommensurable scales (that is, they are expressed using different units of measurement), the only preference information they provide is the ordinal pair-wise preferences they contain (they do not give information on the intensity of preference).

Axiom 3. Positive Responsiveness. The degree of preference between two alternatives a and b is a strictly increasing function of the number and weights of criteria that rank a before b.[15]

Thanks to these three axioms, a $N \times N$ matrix, E, called *outranking matrix* (Arrow and Raynaud, 1986; Roy, 1996) can be built. Any generic element of E: e_{jk}, jk is the result of the pair-wise comparison, according to all the M criteria, between alternatives j and k. Such a global pair-wise comparison is obtained by means of Eq. (4):

$$e_{jk} = \sum_{m=1}^{M} \left(w_m(P_{jk}) + \frac{1}{2} w_m(I_{jk}) \right), \tag{4}$$

where $w_m(P_{jk})$ and $w_m(I_{jk})$ are the weights of criteria presenting a preference and an indifference relation, respectively. It clearly holds

$$e_{jk} + e_{kj} = 1. \tag{5}$$

The maximum likelihood ranking of alternatives is the ranking supported by the maximum number of criteria for each pair-wise comparison, summed over all pairs of alternatives considered. More formally, all the $N(N–1)$ pair-wise comparisons compose the outranking matrix E. Call R the set of all $N!$ possible complete rankings of alternatives, $R = \{r_s\}$, $s = 1,2,\ldots, N!$.

For each r_s, compute the corresponding score φ_s as the summation of e_{jk} over all the $\binom{N}{2}$ pairs j,k of alternatives, i.e.

$$\varphi_s = \sum e_{jk}, \tag{6}$$

where $j \neq k$, $s = 1,2,\ldots N!$ and $e_{jk} \in r_s$.

The final ranking (r^*) is the one which maximizes Eq. (6), which is:

$$r* \Leftrightarrow \varphi_* = \max \sum e_{jk} \quad \text{where} \quad e_{jk} \in R. \tag{7}$$

Moulin (1988, p. 312) clearly states that the maximum likelihood approach is "the correct method" for ranking alternatives, and that the "only drawback of this aggregation method is the difficulty in computing it when the number of candidates grows". In fact, the number of permutations can easily become unmanageable; for example when 10 alternatives are present, it is 10! = 3,628,800. The majority of the algorithms which have been proposed in the literature are mainly heuristics based on artificial intelligence, branch and bound approaches and multi-stage techniques (see e.g. Barthelemy et al., 1989; Charon et al., 1997; Cohen et al., 1999; Davenport and Kalagnanam, 2004; Dwork et al., 2001; Truchon, 1998). Recently, a new numerical algorithm aimed at solving the computational problem connected to linear median orders by finding exact solutions has been developed too (Munda, 2005c). In conclusion, thanks to the existence of all these computational algorithms, the maximum likelihood ranking

[15] In social choice terms then the *anonymity* property (i.e. equal treatment of all criteria) is broken. Indeed, given that full decisiveness yields to dictatorship, Arrow's impossibility theorem forces us to make a trade-off between *decisiveness* (an alternative has to be chosen or a ranking has to be made) and anonymity. In our case, the loss of anonymity in favor of decisiveness is even a positive property. In general, it is essential that no criterion weight is more than 50% of the total weight; otherwise the aggregation procedure would become lexicographic in nature, and the indicator would become a dictator in Arrow's terms.

Table 21
Outranking matrix

	CB-Pre	CB	ST	CBST	L	R	NP
CB-Pre	0.00	0.50	0.30	0.40	0.30	0.30	0.70
CB	0.50	0.00	0.10	0.20	0.10	0.10	0.70
ST	0.70	0.90	0.00	0.40	0.70	0.65	0.70
CBST	0.60	0.80	0.60	0.00	0.60	0.60	0.70
L	0.70	0.90	0.30	0.40	0.00	0.65	0.70
R	0.70	0.90	0.35	0.40	0.35	0.00	0.70
NP	0.30	0.30	0.30	0.30	0.30	0.30	0.00

Table 22
Rankings

First	Second	Third	Fourth	Fifth	Sixth	Seventh
CBST	ST	L	R	CB-Pre	CB	NP
CBST	ST	L	R	CB	CB-Pre	NP
ST	CBST	L	R	CB-Pre	CB	NP
ST	CBST	L	R	CB	CB-Pre	NP

procedure can always be applied even when a high number of alternatives to be ranked is the normal state of affairs.

By considering the information contained in the impact matrix shown in Table 20, the following outranking matrix is obtained (see Table 21).

By applying the ranking procedure, among the 5040 possible rankings, the following four present the maximum score (see Table 22) (where the extreme left alternatives are the top ones and the extreme right alternatives are the bottom ones):

7. Enlightening distributional conflicts

One should note that criteria and criterion scores are not determined directly by social actors. The impact matrix is a result of a technical translation operationalized by the scientific team. Even if the criteria are exactly the ones agreed with the social actors, the determination of the criterion scores is independent of their preferences. For example, an interest group can accept the use of a criterion measuring the effects of the various alternatives on the employment, but the determination of the figure cannot be (at least completely) controlled by them. This is the main reason to combine a social impact matrix with the technical impact matrix is highly recommended (Munda, 2005a).

The first step is the construction of the *Social Impact Matrix* i.e. the evaluation every social actor gives to each option (see Table 23). The qualitative impact scores have been determined by the scientific group based on the information obtained in the whole process. The justification for every evaluation is derived from Table 1. Political representatives and GEPEC have not been considered in this exercise due to their indirect involvement in the conflict.

Table 23
Social impact matrix

	Social groups	CB-Pre	CB	ST	CBST	L	R	NP
G1	Catalonia government	+ or – Good	+ or – Bad	Very good	Perfect	Good	Good	Extremely bad
G2	Municipality of Vallbona de les Monges	+ or – Good	+ or – Bad	Very good	Perfect	Good	Good	Extremely bad
G3	Municipality of els Omells de na Gaia	Very bad	Good	Bad	Good	Bad	Bad	Bad
G4	Municipality of Rocallaura	+ or – Good	+ or – Bad	Very good	Perfect	Good	Good	Extremely bad
G5	Municipality of Senan	Very bad	Very bad	Very bad	Extremely bad	+ or – Bad	Moderate	Perfect
G6	Coordinating commitee to defend the land	Very bad	Very bad	Extremely bad	Very bad	Very bad	Bad	Perfect
G7	Platform for Senan	Very bad	Very bad	Extremely bad	Extremely bad	+ or – Bad	Moderate	Perfect
G8	Association of friends and neighbors of Montblanquet	Extremely bad	Extremely bad	Very bad	Extremely bad	Very bad	+ or – Bad	Perfect
G9	EHN	**Extremely bad**	**Extremely bad**	Perfect	Perfect	+ or – Good	Moderate	Extremely bad
G10	Gerrsa	Very Good	Perfect	Extremely bad	Perfect	Extremely bad	Extremely bad	Extremely bad

Starting from this social impact matrix, distributional issues can be taken into consideration by means of an eclectic approach using concepts coming from land use planning, fuzzy cluster analysis and social choice (Munda, 1995). In synthesis, A is a finite set of N feasible policy options; B is the set of different social actors, $B = \{bp\}$ $p = 1, 2, \ldots, P$ considered relevant in a policy problem, $\Lambda = \{\lambda_p\}$, $p = 1,2,\ldots,P$, with $\sum_{p=1}^{P} \lambda_p = 1$ is the vector of weights attached to the set of the P social actors, indicating their relative importance. By using a distance function d_{ij} as conflict indicator, a similarity matrix (achieved by means of the simple transformation $s_{ij} = 1/(1 + d_{ij})$ for all possible pairs of groups can be obtained, so that a clustering procedure is meaningful. The hierarchical clustering approach, in particular, allows an evolutionary view of the aggregation process and can easily be dealt within fuzzy terms. By applying this procedure to the social impact matrix presented in Table 23 (by using the assumption of equal weighting for the various social actors), the dendrogram presented in Fig. 4 is obtained.

- The proximity of aims between the Municipality of Senan (G5) and the Platform per Senan (G7) are reflected in the dendogram. Also the Municipalities of Vallbona de les Monges (G2) and Rocallaura (G4) are working together in looking for their benefits.
- The Association of friends and neighbors of Montblanquet (G8) joints to the first mentioned coalition (G5 + G7) with a medium-high degree of credibility. They meet with others actors in the Coordinating committe to defend the land (G6). Most of them working independently.
- On other side, EHN (G9) has been negotiating with the municipalities and with the Catalonian government in order to push their project forward. This coalition (G2 + G4 + G1 + G9) has a medium degree of credibility.
- A coalition between the municipality of Els Omells de Na Gaia (G3) and Gerrsa (G10) shares a medium degree of proximity with the previous coalition. Nowadays, this coalition depends more or less in the amount of money that can be received from Gerrsa as benefit tax revenue.

In real-world applications, when the actors involved in a policy process look at dendrograms, they generally have a question like: *and so what?* Clearly further elaborations are then needed. In particular, information on rankings of policy options according to each coalition of social actors seems very desirable. This can easily be done by applying again the ranking procedure already used on the multi-criteria impact matrix. The coalitions obtained with the degree of credibility 0.7194 (thus a very high one) are considered.

The coalition C_1, with Municipality of Senan (G5), Platform per Senan (G7), Association of friends and neighbors of Montblanquet (G8) and Coordinating committe to defend the land (G6) present the following rankings as the maximum likelihood ones (see Table 24):

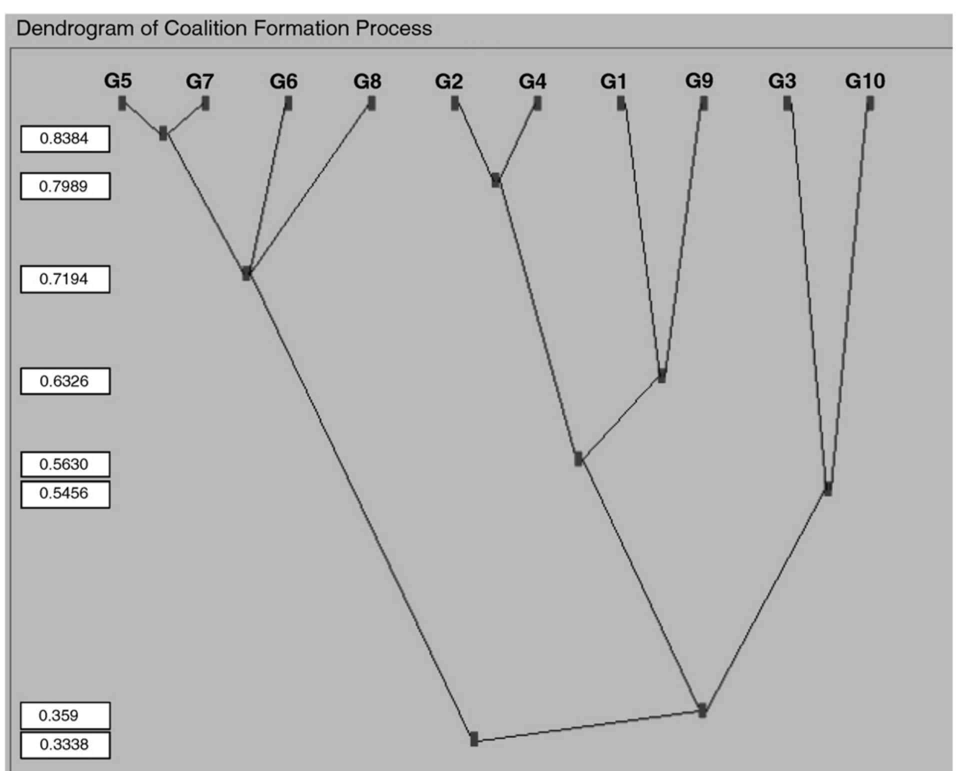

Fig. 4. Coalition dendrogram.

Table 24
Rankings for coalition C_1

First	Second	Third	Fourth	Fifth	Sixth	Seventh
NP	R	L	CB-Pre	CB	ST	CBST
NP	R	L	CB	CB-Pre	ST	CBST
NP	R	L	CB-Pre	CB	CBST	ST
NP	R	L	CB-Pre	ST	CB	CBST

Table 25
Rankings for coalition C_2

First	Second	Third	Fourth	Fifth	Sixth	Seventh
CBST	ST	L	R	CB-Pre	CB	NP
CBST	ST	R	L	CB-Pre	CB	NP
ST	CBST	L	R	CB-Pre	CB	NP
ST	CBST	R	L	CB-Pre	CB	NP
CBST	ST	L	CB-Pre	R	CB	NP
CBST	ST	L	R	CB-Pre	NP	CB
CBST	ST	L	R	CB	CB-Pre	NP
CBST	ST	R	CB-Pre	L	CB	NP
CBST	ST	R	L	CB-Pre	NP	CB
CBST	ST	R	L	CB	CB-Pre	NP
CBST	L	ST	R	CB-Pre	CB	NP
CBST	R	ST	L	CB-Pre	CB	NP

While for the coalition C_2, with Municipalities of Vallbona (G2) and Rocallaura (G4), the following rankings receive the maximum score (see Table 25):

Moreover by looking at Table 23, it is clear that for the Catalonian Government, the alternative CBST is the best one. Anyway all the other alternatives are also more or less OK, except for NP that is considered as extremely bad. For the Municipality of Els Omells, the only acceptable alternatives are CB-Pre, CB and CBST, all the others are considered bad. For EHN, alternatives ST and CBST are good options. L and R are more or less acceptable but NP is considered as extremely bad. For Gersa, alternatives CB-Pre, CB and CBST are at least very good options, all the other possibilities are considered as extremely bad.

At this point, we have to refer to the *normative tradition* in political philosophy, which has also an influence in modern social choice and public policy. The basic idea is that any coalition controlling more than 50% of votes may be converted in an actual dictator. As a consequence, the *"remedy to the tyranny of the majority is the minority principle, requiring that all coalitions, however small, should be given some fraction of the decision power. One measure of this power is the ability to veto certain subsets of outcomes…."* (Moulin, 1988, p. 272).

One should note that to allocate veto power across the various groups of social actors has a deep ethical implication, since it means to attach different weights to different groups. Moreover, if too much veto power is given, cooperatively stable solutions disappear; on the other side, if too little veto power is given, stable solutions are too many. This problem has a unique mathematical solution due to Moulin (1981). The philosophy behind Moulin's theorem is that any group with x percent of social actors must be able to veto any subset containing less than x percent of policy options.

Formally, Moulin's theorem can be adapted to our problem as follows. Given P social actors, N policy options and $C_\alpha = \{c_1, c_2, \ldots, c_z\}$ possible groups of social actors, with $|c_1| \cup |c_2| \cup \ldots \cup |c_z| = P$, $\forall\, c_i \in C_\alpha$, with $i = 1, 2, \ldots, Z$, the corresponding *proportional veto* function is defined as

$$V_{P,N}(c_i) = \left(N \frac{|c_i|}{P} \right) - 1, \tag{8}$$

where (x) is the smallest integer bounded below by x, with $x = (N(|c_i|/P))$.

In our case, the only coalition that can veto 1 option is C_1, which vetoes option CBST.

However, it is important to highlight that veto power is not a technical decision only. For instance, the alternatives as well as the social actors to be considered are defined in the problem structuring phase, which is mainly a technical, political and social process. Important questions arising in this exercise are related, for instance, to representativeness of the actors to be considered (see e.g. O'Neill, 2001), or to the *Degree of credibility* of the coalition formation to be used for the definition of the veto power (e.g. Who defines it? and How?). It can be said that this approach is applicable only if at least these previous questions are answered in an open and transparent decision-making process.

Concluding, we can say that technically speaking, the most defensible alternatives are CBST, ST and L. From a social conflict analysis point of view, it seems that alternative CBST is the one which can generate the maximum conflict. Even if CBST is OK for the majority of the social actors involved, coalition C_1 always ranks it in low positions. R has good evaluations, except by GERRSA which would be excluded in this case. L always ranked in medium positions by all social actors. It might also be a social compromise. NP is not acceptable for most of social actors. In synthesis, we may state that alternatives L and R seem the only ones defensible from both technical and social points of view. All the other options can maximize the social conflict or are not technically acceptable. It is interesting to note that business as usual is definitely not a desirable situation.

It is important to highlight that we are not maintaining that a policy-maker should not be free to take decisions different from the ones considered desirable in this study. What we want to emphasize here is that if different decisions are made, this fact should be *transparent* and *responsibility* of doing so clearly assumed (e.g. to attach an enormous weight to a peculiar social actor…). Not necessarily a public policy-maker is always benevolent in nature; this is the reason why it is important to enlighten distributional issues and corresponding ethical (or unethical) positions. This call for transparency in modern public economics is widely shared by various contemporary authors (see e.g. Stiglitz, 2002).

8. Conclusion

A proper evaluation of wind park location options needs to deal with a plurality of legitimate values and interests existing in society. In empirical evaluations of public projects and public provided goods, multi-criteria decision analysis seems to be an adequate policy tool since it allows taking into account a wide range of assessment criteria (e.g. environmental impact, distributional equity, and so on) and not simply profit maximization, as a private economic agent would do.

One has to note that policy evaluation is not a one-shot activity. On the contrary, it takes place as a *learning process* which is usually highly dynamic, so that judgments regarding the political relevance of items, alternatives or impacts may present sudden changes, hence requiring a policy analysis to be flexible and adaptive in nature. Continuous feedbacks between the social actors and the scientific team are a key success factor in dealing with real-world conflicts (see Table 26 for an example regarding the case study presented here).

In operational terms, the application of a social multi-criteria framework involves the following main steps (Munda, 2005a):

1. *Isolation of relevant social actors*, by means of institutional analysis, individual interviews with key agents or with a random sample, focus groups, etc.
2. *Definition of social actors' values, desires and preferences*, mainly through in-depth interviews and focus groups.
3. *Generation of policy options and evaluation criteria.* This process must be a collective creation resulting from a dialogue between the scientists and the social actors. Criteria are indicators that assess to which extent the different social actors' objectives are achieved by each alternative.
4. *Construction of the multi-criteria impact matrix*. It synthesizes in a matrix form, the scores of all criteria for all alternatives. Each criterion score represents the performance of each alternative according to each criterion.
5. *Construction of the equity impact matrix.* This allows representing the distance between the positions of the social actors, by using a linguistic evaluation of the alternatives that expresses the point of view of each group. By means of a dendrogram, it shows the degree of conflict and the possible coalitions among the groups of social actors on each possible alternative.
6. *Application of a mathematical aggregation procedure.* In order to obtain a final ranking of the available alternatives, the criterion scores must be aggregated by means of a mathematical algorithm. Many multi-criteria models have been formulated since the 1960s, each one with advantages and disadvantages. In each case, the

Table 26
Summary of feedbacks between the research team and local social actors

Activity	Place and date	Participants
Preliminary meeting	Municipality Of Vallbona de les Monges 19/12/2003	2 Mayors
Open presentation of the project	Municipality of Vallbona de les Monges 09/01/2004	~30
Open presentation of the project	Municipality of Rocallaura 10/01/2004	~40
Focus group	Municipality of Vallbona de les Monges 16/01/2004	5
Preliminary meeting	Municipality of Els Omells de Na Gaia 16/01/2004	Mayor and 2 councilors
Open presentation of the project	Bar of the town of Els Omells de Na Gaia 17/01/2004	~30
Focus group	Municipality of Els Omells de Na Gaia 24/01/2004	5
Open presentation of the project	Municipality of Senan 14/02/2004	~25
Open presentation of the project	Central office of Montblanquet 27/03/2004	~15
Presentation of the preliminary results	Municipality of Vallbona de les Monges (and Rocallaura) 12/06/2004	2 Mayors and 4 councilors
Presentation of the preliminary results	Municipality of Els Omells de Na Gaia 25/06/2004	1 Mayors and 2 councilors
Open presentation of results	Bar of the town of Els Omells de Na Gaia 10/07/2004	~20
Open presentation of results	Vallbona de les Monges Municipality 01/08/2004	~25

most appropriate must be chosen, weighting the pros and cons of each model.

7. *Sensitivity and robustness analysis*. Some assumptions are changed or some parameters are given a different value in order to test whether the final ranking changes. This step is very important due to unavoidable degree of uncertainty that characterizes most real-world decision-making processes.

Of course, these steps are not rigid. On the contrary, flexibility and adaptability to real-world situations are among the main advantages of social multi-criteria evaluation.

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