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Energy Policies for Rural Electrification: A Social Multi-Criteria Evaluation Approach

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Abstract: In this article, a real-world case- study is presented with two general objectives: to give a clear and simple illustrative example of application of social multi-criteria evaluation (SMCE) in the field of rural renewable energy policies, and to help in understanding to what extent and under which circumstances solar energy is suitable for electrifying isolated farmhouses. In this sense, this study might offer public decision- makers some insight on the conditions that favour the diffusion of renewable energy, in order to help them to design more effective energy policies for rural communities.

Key Words: *multi-criteria decision analysis, renewable energy policy, rural development, complexity theory, values*

JEL Classification Numbers: *C44, H43, Q12, Q42*

1. Introduction

Most of the 2 billion people worldwide that have no electricity at their disposal live in rural areas (World Energy Council, 1999). According to a World Bank's study, out of 3,3 billion people living in rural areas, only 1,5 have access to electricity (Cabraal et al., 1996). Lack of electrification is an especially important issue in Southern countries, where rural areas are often very isolated, since it is very expensive to extend the electric grid (Chaurey et al., 2002). In fact, approximately 80% of people without electricity live in rural areas of Southern Asia and Sub-Saharan Africa (International Energy Agency, 2002).

However, rural electrification is an important issue not only in Southern countries but also in Europe, where there are some isolated areas in the countryside that still do not dispose of electricity (Vallvé and Serrasolses, 1997). For example, it was estimated that in Catalonia 1.063 households are still to be electrified (Istituto Català d'Energia, 2002).

The reason of the lack of electrification in isolated areas can be found in the high cost of extending the grid. In areas with low population density, difficult terrain and long distance between households and with the generating power plant, cost can rise up to several thousand dollars per household (Gabler, 1998). Also, consumption is lower in the countryside because rural population is more scarce and scattered. As a consequence, revenue per km of grid is much less for electricity companies in rural than in urban areas so that in many cases it is not a profitable business for them. Single users are often not able to afford the considerable expenses that rural electrification trough conventional grid implies.

Moreover, grid-based electrification is characterized by some drawbacks from an environmental point of view. In fact, in forest areas grid extension implies deforestation of a corridor along the line and risk of fire. Pylons and cables can jeopardize avifauna because of possible collision or electrocution. Also, the grid causes an aesthetic impact on landscape. The environmental impact for delivered kWh is much more relevant in low- density areas, where the electric grid must be extended for many km in order to reach the isolated farmhouses.

In this context, solar energy might represent a viable alternative to traditional rural electrification. However, even though photovoltaic is rapidly improving, it still needs to be supported by public policies that make it more economically profitable, stimulating PV market's extension. Niche markets where renewable energy is already competitive or almost competitive, such as remote stand- alone PV installations, might play a key role in this process. In fact, even though they are more expensive than grid- connected systems because of the battery needed to store energy, they will reach economic competitiveness with respect to fossil fuels much earlier, because their alternative (electric grid extension) is very expensive. Solar energy might spill over from sectors where it represents a potentially viable alternative (such as PV stand- alone systems) to applications where a notable technological improvement is necessary to make it really attractive (Masini and Frankl, 2002). This process might eventually drive PV technology to reach cost- competitiveness.

Rural electrification is hence a matter of public policy and a collective problem, where many private and public actors, with different and possibly conflicting values, interests and requirements come into play. Thus, it is important that decisions on energy policies for rural areas are taken as transparently as possible, and that all involved actors can participate in them. Social Multi-Criteria Evaluation (SMCE) can be a useful policy framework to support this process (Munda, 2004), as it will be explained in the next section.

This paper is structured as follows: next section will briefly introduce SMCE and explain why it is a useful tool to support public policies. The third section shows step by step how SMCE methodology was adapted to the Montseny case study (Tagamanent village). Finally, some conclusions will be drawn.

2. SMCE as a tool to deal with complexity

Real world is characterised by deep *complexity*. This obvious observation has important implications on the manner policy problems are represented and decision-making is framed. Any representation of a complex system is reflecting only a sub-set of the possible representations of it. A consequence of these deep subjectivities is that in any normative exercise connected to a public decision problem, one has to choose an operational definition of *"value"* in spite of the fact that social actors with different interests, cultural identities and goals have different definitions of "value". That is, to reach a ranking of policy options, there is a previous need for deciding about *what is important* for different social actors as well as *what is relevant* for the representation of the real-world entity described in the model (Funtowicz et al, 2002; Munda, 2004).

Various authors claim that modern public economic policy needs to expand its empirical relevance by introducing more and more realistic (and of course more complex) assumptions in its models. One of the most interesting research directions is the attempt of taking into account political constraints, interest groups and collusion effects explicitly (see e.g. Laffont, 2000, 2002; van Winden, 1999). In this context, transparency becomes an essential feature of public policies (Stiglitz, 2002).

In empirical evaluations of public policies 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 and not simply profit maximisation, as a private economic agent would do (Munda, 2005a). However, the management of a 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 not. An outcome of this discussion is that the political and social framework must find a place in evaluation exercises. This is the objective of Social Multi-criteria Evaluation. Its main principles can be summarised as follows (Munda, 2004):

(1) Transparency is an essential component to guarantee the quality of any study based on science for policy. In fact all these studies should be *accountable* (accountability is a concept recently proposed by the European Commission in the White Paper on Governance) to the public at large for peer-reviewing.

(2) Multi-criteria methods supply a powerful framework for 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).

(3) Since policy-makers search for *legitimacy* of the decisions taken, it is extremely important that public participation or scientific studies do not become instruments of political de-responsibility. The deontological principles of the scientific team and policymakers are essential for assuring the quality of the evaluation process. Social participation does not imply that scientists and decision-makers have no *responsibility* of policy actions defended and eventually taken.

(4) Asa consequence, *ethics matters*. Let's imagine the extreme case where a development project in Amazon will affect an indigenous community with no contact with other civilizations yet. Would it be ethically more correct to invite them in a focus group… or ethically compulsory to take into account the consequences of the project for their survival?

(5) A positive aspect of participatory approaches is that sometimes the results obtained by the research team, i.e. data, findings, interpretations and insights, can also be returned to the community which may use them not as just given, but rather as an input for deliberative democracy. This is even more important if one considers that the presence of multiple dimensions in a multi- criteria problem imply that in most cases there is no solution that

simultaneously maximizes all objectives. In other words, a compromise must be found, which will favour some social groups more than others. This choice is more democratic if the social actors are provided with information and mechanisms that allow them to be involved in the policy making process.

In SMCE, the pitfalls of the technocratic approach can be overtaken by applying different methods of sociological research. 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. Of course modern Information and Communication Technologies (ICT) may play a fundamental role here (De Marchi et al., 2000, Guimaraes-Pereira et al, 2003).

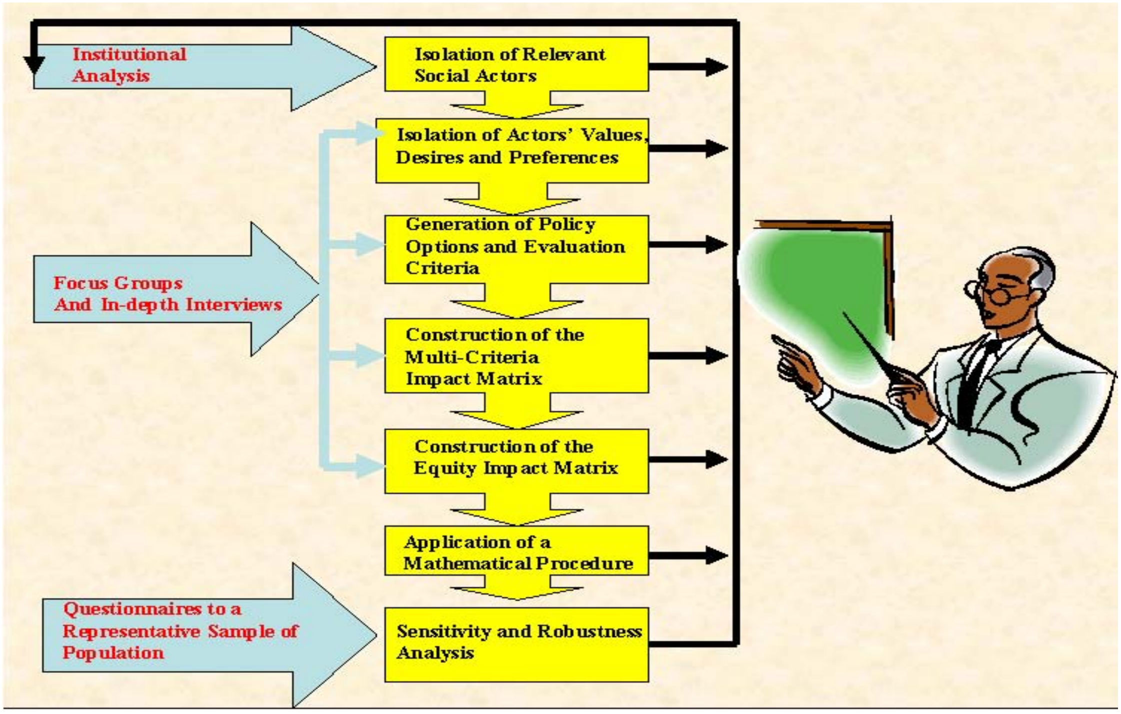
One has to note that policy evaluation is not a one-shot activity. On the contrary, it takes place as a *learning process* which is usually highly dynamic, so that judgements regarding the political relevance of items, alternatives or impacts may present sudden changes, hence requiring a policy analysis to be flexible and adaptive in nature. This is the reason why evaluation processes should have a *cyclic nature*. By this is meant the possible adaptation of elements of the evaluation process due to continuous feedback loops among the various steps and consultations among the actors involved. In this framework, of course mathematical aggregation conventions play an important role, i.e. to assure that the rankings of policy options obtained are *consistent* with the information and the assumptions used along the structuring process. In operational terms, the application of a social multicriteria framework implies the main steps described in Figure 1 (Munda, 2005a).

Of course, these steps are not rigid. On the contrary flexibility and adaptability to realworld situations is one of the main advantages of social multi-criteria evaluation. SMCE is here applied to a conflict on rural electrification in Tagamanent municipality, which is situated in Montseny, one of the most important Catalan Natural Parks. In this article, the Tagamanent case- study is presented with two general objectives:

(1) To give a clear and simple illustrative example of application of SMCE in the field of renewable energy policies.

(2) To help in understanding to what extent and under which circumstances solar energy is suitable for electrifying isolated farmhouses. In this sense, this study might offer public decision- makers some insight on the conditions that favour the diffusion of renewable energy, in order to help them to design more effective energy policies.

Figure 1 The Ideal Problem Structuring in SMCE



3. The social multi-criteria evaluation process in the Tagamanent case study

3.1 Institutional analysis

The social dimension of a problem can be explored using *institutional analysis*, a tool used in sociology to shed light on the values, the interests, the role, the possible alliances and the available resources of the social actors involved in a conflict. Information on these issues is gathered from local and national press, official and informal documents, individual interviews to key agents or to a casual sample, focus groups. The objective of the institutional analysis is to give insights on three aspects (Corral Quintana, 2000):

1. 1. **The problem at hand**: the territorial, economic, social and political context, the legal framework and the chronology of the relevant events that drove to the present situation.
2. 2. **The social actors**: The persons who can influence or whose interests are affected by the decision. For each group of social actors roles, resources (the means that can be used in order to reach an objective [1]), objectives and interests are defined.
3. **The interaction patterns**: the structure of the institutional network, the kind of interactions and the arena where interactions take place, as well as eventual influences and changes in the social actors 'position.

An institutional analysis is here performed to analyze the Tagamanent debate on rural electrification [2]. In the rest of this paragraph the results of the institutional analysis carried out in Tagamanent municipality are presented.

The problem at hand.

The context. Montseny Natural Park is situated in northern Catalonia, between Girona and Barcelona (see map). It is only 40 km far away from the Barcelona metropolitan area, so that it is a very popular place for weekend outdoor excursions. It has an extension of 301 km^2 and a population of almost one thousand inhabitants, mostly scattered inside the Park. It is very interesting both under a biological and a social point of view.

As regards the first aspect, the Park is characterized by an extraordinary landscape and ecosystem diversity, due to the coexistence of the three main western European biomes: the Mediterranean, the middle European and the northern European[3] (Boada and Juncà, 2002). Under a social point of view, Montseny diversity can be partly explained as the outcome of a very long history of interactions between humans and ecosystems, since human presence moulded its landscape along the centuries[4].

[1] The resources can be economic (amount of money), political (capacity of influencing the decision- making process), legal (advantages given by a law), cognitive (knowledge on the topic or on the decision process, or ability to understand other agents' behaviour).

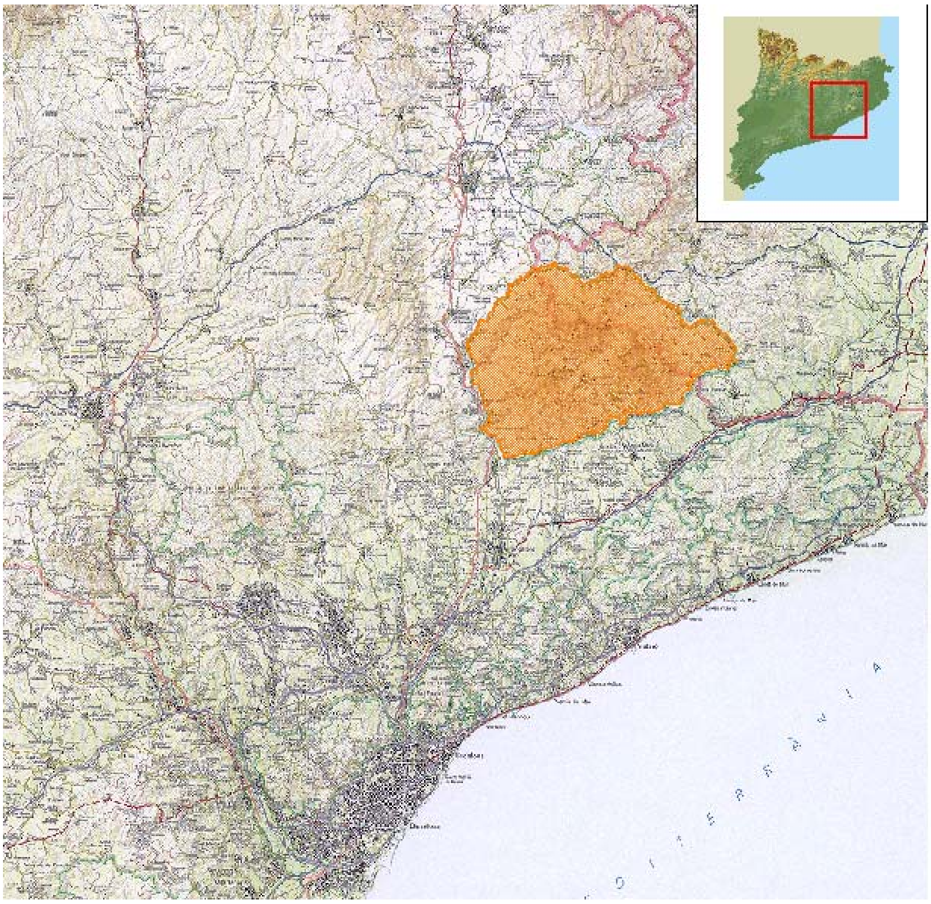
[2] Information was obtained analyzing the documents related to the conflict that could be found in the archives of the Municipality and of the institution that manages the Park, the *Servei de Parcs Naturals* (SPN). Moreover, two in-depth interviews with the SPN's technician in charge of the issue and with the Tagamanent's Mayor were carried out, which allowed reconstructing the different stages of the conflict. Then, some in-depth interviews with owners and inhabitants allowed ascertaining their values, desires and preferences. Finally, two interviews with Martí Boada, a natural scientist who has been studied Montseny for decades, were of big help for knowing the history and the general characteristics of the massif, as well as the strategy of the Park administration.

[3] The middle European and the northern European biomes represent the inheritance of the last glacial period, ended 10.000 years ago.

[4] Agriculture, which was practiced especially in the lower part of the massif, introduced new species and created new ecosystems that interacted with the original species. Moreover, forest management through traditional methods, such as for example controlled fire and use of sheep for cleaning the wood brushes, limited the diffusion of the predominant trees and allowed the development of new vegetation. This equilibrium between human activities and ecosystems allowed protecting the environment and at the same time sustaining Montseny inhabitants.

Most farmhouses inside the Park were built centuries ago by *carboneros* (charcoal makers), farmers and stockbreeders, and they constitute an important architectonic heritage. Most of them were abandoned due to the structural change that took place in Catalonia when the traditional activities turned to be not more profitable and oil substituted coal as the main energy source (coal was produced in Montseny and sold in the neighbouring towns). The abandonment of the old farmhouses is a particularly serious problem (and hence contrasting it is one of the political priorities of the Park administration) because if they are left alone they become ruins in a very short time. In fact, the old farmhouses require a continuous maintenance, because, among other reasons, of the hard meteorological conditions.

Fig. 2. Map of Montseny natural Park



Source: Panareda et al., 2003

However, in the last years the new interest in nature and the increase of income dedicated to "post-material goods" produced an expansion of the tertiary sector inside the Park. Activities dedicated to tourists became profitable, mainly restaurants and rural pensions, and also artisan production of some "genuine" food, such as honey and cheese. Moreover, a moderate repopulation process is taking place, driven by neo- rurals coming from the cities.

Legal frameworks[5]. The Special Plan of Montseny Natural Park establishes a comanagement of Girona and Barcelona's province administrations (Girona only controls around 6.000 ha). Privates own almost 87% of the Park territory, whereas 12% belongs to Barcelona province administration and less than 1% to the Catalan autonomous government. Barcelona's *Servei de Parcs Naturals* (Natural Park Service, SPN) administrates the Park. The total budget of the Park is 4,8 million €.

Comisión Provincial de Urbanismo, 1977.

The establishment of the Natural Park implies a strong control on the activities carried out, in order to avoid any kind of environmental impact. Inside the Park authorization must be asked for every even very little modification to the landscape. It is not possible to construct new buildings, but only to restore pre-existent farmhouses.

As regards the rules on electric lines, the Special Plan states that they require studies on their location in order not to alter the landscape and must be carried out respecting some environmental criteria (for example, the poles must be painted green or grey, according to where they are installed). Also, a favourable report of SPN is needed to extend the electric grid inside the Park.

Chronology and interaction pattern. In order to solve the electrification deficit inside the Park, in 1994 SPN entrusted SEBA (*Associació de Serveis Energètics Bàsics Autònoms*, Autonomous Basic Energy Service Association) with a report on the deficit of electrification in the Park (Trama Tecno Ambiental, 1995). SEBA is a non-profit-making association created in 1989 by solar energy users in order to support the installation of autonomous PV panels in isolated households.

SEBA individuated 105 not yet electrified farmhouses (16 in Tagamanent municipality), so that SPN decided to undertake a rural electrification plan in Montseny Natural Park, with the objective of promoting autonomous PV panels. An agreement was reached with SEBA, which would have the task of managing the entire process, from determining energetic needs to installing the equipment. In exchange for a monthly share of about 20 €, SEBA would provide users with technical supervision, an insurance and free maintenance. The reason of this agreement was that past experiences showed that many times solar energy results in a failure because providers do not have any further responsibility after PV panels are installed, so that in case of breakdowns users find themselves in difficulties (Vallvé and Serrasolses, 1997).

The panels were to a large extent subsidized. After five years from the beginning of the plan it was estimated that SPN took charge of 45% of the total expense, whereas SEBA financed 34% by means of subventions given by the Spanish Ministry of the Environment, the Energy Department of Catalan Government and the European Union.

The plan worked well. Between 1995 and 2000 it managed to electrify about 32 isolated farmhouses, that is, almost 30% of the permanently inhabited farmhouses (Argemi and Serrasolses, 2001). The total installed power was 38,7 kWp, which supplied an annual consumption of 45.000 kWh (ICAEN, undated).

However, in Tagamanent municipality (235 inhabitants, 43,48 km^2), PV was not really accepted and the program reinitiated the debate on rural electrification, which was already an issue. In fact, since 1993 the Municipality asked FECSA, the electricity company operating in the area, to prepare a project for electrifying the isolated households inside the Park, in order to have an idea about costs and modalities. In 1996 FECSA was ready for providing electricity to the not yet electrified farmhouses in Tagamanent. However, SPN did not approve the project and argued that, since more than 8 km of the electric line were planned to pass through a forested area, a high environmental impact would have been produced in terms of deforestation and risk of fire. Because an agreement seemed not easy to reach, SPN charged SEBA with a second study, this time focused only on Tagamanent (Trama Tecno Ambiental, 1998). Not surprisingly, SEBA report affirmed that the best modality for rural electrification was solar energy.

In the following years PV panels were installed in seven out of twenty-four scattered farmhouses[6]. However, the conflict between the Mayor, supported by most farmhouse owners (in favour of grid extension) and SPN (in favour of PV panels) has not been solved. During the last six years, many projects on rural electrification of scattered farmhouses in Tagamanent followed one another, comparing prices of PV and grid extension but the parts did not reach an agreement. In some heated meetings Tagamanent's Mayor unsuccessfully tried to convince SPN to grant electric line extension with the same incentives promised for PV panels and also to participate to the expenses with the two properties owned by SPN (a restaurant and an etnomuseum). Without these two conditions, conventional electric grid would be very expensive.

The social actors

Servei de Parcs Naturals (SPN)

SPN's institutional task is the protection of Montseny environment. It is interested in the electrification of the isolated farmhouses because it is a way of helping the repopulation of the Park. However, it is only in favour of electrifying by means of PV panels and strongly against the possibility of extending the conventional electric line, because of its environmental impact. This position has been very firm during the last ten years.

Owners

Owners do not usually live inside the Park, where life conditions are quite hard, but in the towns nearby. They mostly use their farmhouse as a weekend house or rent it to neo-rurals, whereas some leave them unoccupied. In some cases, they use the land as pasture for their cattle, which they entrust to local breeders. Owners are interested in raising the value of their farmhouses. Traditional electricity seems to better suite this purpose because PV panels have a limited lifetime and they must be substituted from time to time. On the contrary, traditional electrification can bring long-term benefits, such as the possibility of running a restaurant or a rural pension, or eventually renting the farmhouses at a higher price. However, traditional electricity is more expensive than solar energy inside the Park, and owners are not willing to undertake the entire cost, so that they ask SPN to contribute.

Inhabitants[7]

Most inhabitants are *"neo-rural"* that lease the farmhouse where they live[8]. They do not live on primary activities. They escape from the chaos and the pollution of the city, but they want to stay nearby, in order to enjoy its services and opportunities. In exchange for the privilege of living in such an enchanting place they are willing to suffer some disadvantages, the hardest of which is the difficulty in communication (e.g. the pathway to their houses is often in very bad conditions). The inhabitants suffer from the lack of services with respect to urban population probably more than owners. In fact, they must experience everyday the discomforts and the difficulties of the life inside a Natural Park. Inhabitants want to have a sufficient amount of energy at a reasonable cost. Most are not interested in the energy source in itself, even though some of them are favourable to solar energy for ideological reasons. However, if the costs were the same, most would prefer traditional electricity from the grid, because it imposes no limits on consumption. Finally, inhabitants are very interested in reliability of the energy supply, especially if they are running an economic activity.

It must be observed that many of the not yet electrified farmhouses are ruins. Electrification could be a good incentive to repair and use them in two ways. In a first place, it is easier to repair a house with electricity. In the second place, electricity might constitute a strong incentive to repair the houses, because it implies the possibility of setting up an enterprise, such as a restaurant or a rural pension. This is an important aspect, because the cost of rehabilitating a ruin is very high, so that it is unlikely that owners take it upon themselves

if they are not able to obtain an income from their property. 7

In the inhabitants' category the people running a restaurant, rented from the Park administration, are also included. In fact, even though they do not live inside the Park, they lease the restaurant and their interests can be assimilated to those of the inhabitants.

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Only two of the farmhouses are inhabited by the owners. The first one is a small rural pension, where the owner lives and works, together with some partners. The second one is currently being repaired by neo- rurals coming from the city that want to set up some activity in the primary sector (above all biological agriculture), and eventually a rural pension.

Municipality

In Tagamanent municipality, the most active person in the rural electrification issue is the Mayor. According to his opinion, the only way to encourage the repopulation of the Park is to increase the comfort and the supply of services. The main reasons why the Mayor wants to promote the grid extension are two. On the one side, traditional electricity does not imply limits on consumption, so that it increases comfort more than PV. On the other side, PV does not supply energy enough to found economic activities that require some machinery, such as for example little dairies. In other words, even if PV is cheaper it has a very high opportunity- cost. It can be noted that this is a positive aspect of PV panels for SPN, because it contributes to hinder industries that could cause an environmental impact. In the rest of this study the Mayor's point of view is assimilated with the one of owners. In fact, he affirms to limit himself to represent their point of view.

3.2 Generation of policy options

After SPN refused to give its approval and to finance the electric grid extension, PV panels were installed in many of the farmhouses that were not ruins. A retroactive analysis is here performed in order to explain the reasons of this choice. The objective is to make clear which factors favoured the affirmation of solar energy, and which were the pros and cons of each option. The three alternatives here analyzed for the 14 households[9] to be electrified (that is, excluding the farmhouses in a ruinous state, which were not planned to be rehabilitated) are the ones formulated in SEBA's report (Trama Tecno Ambiental, 1998): **1) Electric grid extension in one single stretch**, such as in FECSA project of 1996. It included 12,2 km of middle voltage (25 kV) and 3 km of low voltage (380V) line, seven current transformers, of 50 kVA each, and 81 metallic tours. The total cost was 110,82 million PTAs (around 666 thousand €)[10] .

2) Electric grid extension by means of two stretches, and with some environmental measures[11] , such as proposed by SEBA. The total cost was 121,54 million PTAs (about 730 thousand €). **3) <u>PV panels</u>**. It is here assumed that the need of electricity is the average electricity consumption[12] of Spanish households (192 kWh/month). In SEBA's report, the cost of solar energy was notably lower than the traditional electricity's one. This result depended in part on the fact that the cost was calculated for very low levels of consumption (on average 84 kWh/month). However, it is more correct to compare PV and grid extension, assuming that the consumption is the same. Also, the cost calculated for PV in SEBA's report was very much lower than the one estimated for traditional electricity because the replacement cost was not taken into account. However, in the analysis here performed it is considered that after some times all PV components must be replaced.

[9] In reality, the houses included in the original project were 11, but five of the households that are not included in

FECSA estimation but are included in SEBA proposal are near to other ones that FECSA proposes to electrify. Therefore, assuming that this project will allow electrifying 14 households, such as in SEBA proposal, causes only a small mistake.

10 All the costs indicated in this paper include Value-Added Tax.

11 The proposed environmental measures are to bury some stretches of the line (which considerably increases the costs), to extend the low- tension length, to reduce the medium-tension length. Also, it is suggested not to use aerial transformers but to put them on the ground. Moreover, SEBA proposes to modify the itinerary in order not to affect the most environmentally sensitive areas.

12 Ministerio de la Industria y de la Energía, 2000. Ten years passed since the first SEBA's report was written and the first PV panels were installed. In a short time the first batteries will have to be changed. In Tagamanent municipality the issue of rural electrification is not over yet. The farmhouses where solar panels have been installed only enjoy a limited supply of energy, which imposes many limitations to everyday life. Taking the opportunity offered by batteries' replacement, it might be planned to install more power. In fact, needs changed in the last ten years. Moreover, new dwellings might need to be electrified. SPN feels that after ten years a new study is needed that evaluates the performance of the rural electrification program. Also, Tagamanent Mayor has not given up the idea of promoting traditional electrification of the farmhouses. The retroactive analysis, by explaining the position and the choices of the social actors when the first panels were installed, can give useful insight on weak and strong points of the rural electrification process, in order to improve it in the future.

The choice between solar energy and PV panels is here analyzed under the point of view of three groups of social actors: firstly the public administration (SPN), secondly the farmhouses' owners and thirdly the inhabitants. In fact, decisions on rural electrification must be taken at three stages. a) First of all, SPN has to decide whether it wants 1) to allow and 2) to partly finance PV.

Moreover, it must establish if 3) allowing 4) partly financing 5) and sharing the expenses of grid extension as owner of two farmhouses. b) If SPN allows and makes affordable both traditional and solar energy, the farmhouses' owners must decide between the two alternatives. c) In the third place, if owners do not want to take upon themselves the expenses, leaseholders might decide to pay by themselves for electrification, and in this case they will weigh the pros and cons of the two options.

Hence, the decision process is here represented using three different matrixes, which represent the consequences of the two options for each one of the three groups of social actors.

3.3 Construction of multi-criteria impact matrixes

The third step of a SMCE consists in selecting the criteria that will be used to evaluate the alternatives. Both objectives and criteria are obtained from the in-depth interviews with all relevant social actors. Criteria are here divided in four dimensions: economic, environmental, social and technical.

In this case-study, instead of constructing one unique technical impact matrix and then an equity matrix (see Figure 1), distributional conflicts are dealt with directly in the building of the impact matrixes. For this reason, we present three different impact matrixes, one for each main social actor. The point is that each group of social actors has a different point of view on a problem, or, in other words, each one considers important different criteria when deciding among alternative energy sources. The power structure in the society determines which set of criteria (and therefore which final decision) will impose on the other ones. In the Tagamanent case the Park administration is the most powerful social actor. In fact, it is able to hamper one of the options, the grid extension. In this sense, multi-criteria evaluation increases the transparency and the public accountability of political decisions taken. In fact, from the policy decisions proposed citizens can go back to the criteria (and to the objectives) that where considered important by the politicians who took the decision and eventually argue about that[13].

Servei de Parcs Naturals

Economic criteria

1. Total cost

SPN represents the public interest, so that it should evaluate to what extent the two modalities of rural electrification are beneficial for the society, considering economic, environmental and social factors. One of the factors it should take into account is which source of energy is cheaper for the society as a whole, in order to evaluate whether it is better to promote renewable energy or it is better to support the grid.

As regards PV panels, the cost of the two options is here calculated on the basis of the average electricity consumption of Spanish households in 1998, that is, 192 kWh/month, which corresponds to a power of around 2,9 kWp. This figure is multiplied by the average cost of a PV equipment, as indicated by SEBA (around 18,3€ per installed Wp). It results that the total cost is on average around 53 thousand € per household (743 thousand € for 14 households) Also, the share SEBA asks for PV maintenance (around 240 € per year) must be taken into account

Nowadays, it is estimated that a battery's lifetime is about ten years. Solar plaques' lifetime is considered to be about twenty years if one does not allow the power to decrease more than a 5%. We can assume that regulating machinery and inverters will be obsolete after around fifteen years and that the structure has to be changed with plaques' replacement. In this analysis a twenty-year temporal horizon is taken, in order to take into account the replacement costs. The expenses that take place in the future must be discounted, using equation (1)[14]:

$$DC = C_b + C_{ps} + C_m + \frac{C_b}{(1+r)^{10}} + \frac{C_m}{(1+r)^{15}} + \frac{C_{ps}}{(1+r)^{20}} + \sum_t \frac{C_v}{(1+r)^T} \qquad t = 1, 2, \ldots, 20$$

Where DC means discounted cost, **Cb, Cm, Cps** represent respectively the cost of batteries, regulating machinery and inverters, and solar plaques. **Cv** stands for the annual share that users pay to SEBA. **t** is the period the discounted cost is calculated for, that is, 20 years. **r** stands for interest rate[15].

13 *Dimension:* is the highest hierarchical level of analysis and indicates the scope of objectives, criteria and criterion scores. For example, sustainability policy problems generally include economic, social and environmental dimensions. *Objective:* an objective indicates the direction of change desired. For example, within the economic dimension GDP has to be maximised; within the social dimension social exclusion has to be minimised; within the environmental dimension CO_2 emissions have to be minimised. *Evaluation Criterion:* it is the basis for evaluation in relation to a given objective (any objective may imply a number of different criteria). It is a *function* that associates each single alternative with a variable indicating its desirability according to expected consequences related to the same objective. For example, GDP, saving rate and inflation rate inside the objective "growth maximisation".

14 In order to calculate the discounted cost for a ten and twenty years time horizon, some strong assumptions are made. First of all, it is assumed that the cost of PV components will not change in the next twenty years. It is a strong assumption, because PV market is developing very fast and the price of PV elements is quickly decreasing, so that the price of replacement is certainly overestimated. However, the outcome of this calculation can be taken as a benchmark: if solar panels turn out to be cheaper, then the result will be very robust. Secondly, it is supposed that SEBA share and the consumption of an average household does not change in twenty years. Thirdly, solar panels' efficiency is held stable (they are assumed to produce the same kWh per Wp). Fourthly, neither the expense for the electrogenerators, which are used in some farmhouses in order to complement solar energy, is taken into account, nor the difference in the cost of energy- saving households appliances with respect to normal ones. Finally, possible changes in figures such as interest rate and inflation are not considered, because of two reasons. In the first place, they cannot be easily predictable. In the second place, it can be argued that social actors do not have this kind of information when they take their decision. However, these figures will not probably change so much that the result of the analysis can significantly change.

SWAP rates are used by financial entities for discounting future expenses. They are formulated by combining the interest rate and some parameters that take into account forecasts on future trends of the economy. SWAP rates increase with the period of time to discount[16]. This is because they take into account uncertainty, which increases with the time. This is one of the reasons that makes appropriate to use SWAP rates instead of simply interest rates in order to take into account the dynamic of the solar energy market. In fact, the cost of PV components is steadily decreasing, so that in the future plaques and batteries will probably be cheaper than they are now. Applying SWAP rates allows reducing the future costs, so that the analysis is more realistic.

The cost of PV panels for the 14 households included in the analysis results to be **1.193 thousand €**. A conclusion that can be drawn from these calculations is that **solar energy is more advantageous if consumption is low and if the temporal horizon is short**. For example, using the same assumptions and considering an electricity consumption of 84 kWh/month per household (as SEBA does) would lead to a total cost of 551 thousand €, whereas if the temporal horizon is only 10 years, the total cost would be 859 thousand €. Combining the two latter assumptions we would obtain a total cost of 355 thousand € instead of 1.193 thousand €.

As regards the grid, the costs are taken from FECSA and SEBA report respectively for the original FECSA project and SEBA proposal (grid extension in two stretches, with a lower environmental impact and a higher cost). They are discounted with SWAP rates, considering a temporal horizon of twenty years. The variable cost of electricity is also taken into account, which is obtained multiplying the average consumption of Spanish households by the price of electricity for 1998[17]. With these assumptions, the total cost of FECSA original project is **731 thousand €** whereas SEBA proposal implies a cost of **796 thousand €**.

2. Cost for SPN When deciding whether financing a project, the cost is a relevant criterion for public administration, even though it is not the only one. It has been calculated that up until

now SPN financed around 45% of PV installed within the framework of Montseny rural electrification plan. If this percentage does not change, it would mean that the cost for SPN for rural electrification would be around **510 thousand €,** maintaining all assumptions explained above and including the replacement cost. On the contrary, SPN does not finance grid extension, as a way of hindering it.

Environmental criteria

3. Risk of fire.

15 SEBA's document does not specify the cost of the PV equipment's components, but it indicates only the whole cost (around 18,3€ per Wp). The components' cost is estimated using information found in TMF, 2002. According to this report, the battery, the PV plaques and the supporting structure constitute respectively 21%, 53% and 18% of the total cost, whereas the regulation, control, data gathering and protection elements represent the remaining 18%. Applying these percentages to SEBA's estimate, the cost of the solar equipment's component can be estimated. This procedure gives only a rough approximation, but it is enough for the purposes of this paper (what is important is the difference among alternatives, so that small inaccuracies do not make a substantial difference).

16 For example, the SWAP rates calculated in 2004 for ten, fifteen and twenty years are respectively 4,224, 4,629 and 4,848 (Bloomberg Professional data-base).

17 Boletín Oficial de España, N. 210, 27/12/1997, pages 8161- 8168. The established price for a contracted power under 15 kW in 1998 is respectively 257 PTAs/kw (1,54 €/kw) per month plus 14,61 PTAs/kWh (0,09€/kWh). To these figures 16% VAT and some further taxes (around 5%) must be added, plus around one € for the rent of the equipment. It is assumed that user contract 4,4 kW of power, as it is usual in private households. One of SPN's main concerns is risk of fire. A measure of the threat that fire represents for forests can be given by the number of programs, seminars and resources specifically dedicated to fire prevention by the public administration. Risk of fire is the main reason for SPN to oppose to the electric grid, which can provoke dangerous sparkles.

However, opinions on risk of fire diverge significantly according to the interviewees' interest: Tagamanent's Mayor affirms that there is not risk at all, whereas SPN technician claims that risk is very high. According to FECSA, the number of fires provoked by the electric line is negligible (FECSA/ Endesa, 1999).

According to a technician of the Catalan *Servei de Prevenció d'Incendis Forestals* (Forest Fire Prevention Service), the fire risk of the grid in the Tagamanent municipality is something between "medium" and "high". Out of the 224 forest fires that occurred in the Vallès Oriental between 1993 and 2002, nine were provoked by electric lines (that is, 4%). Between 1960 and 2002, 10% of all forest fires in Montseny Natural Park were caused by the grid[18]. It can also be noted that the two most frequent species in the Montseny Natural Park, oak and pine, are classified among the species that are very inflammable the whole year round (Peix and Massip, 1999). Also, according to the Catalan Department of Environmental Statistics, the Vallès Oriental (the area where Montseny is located) is characterized by a high risk of fire in summer.

The criterion "risk of fire" is difficult to quantify, so that it is given a qualitative score. In this way the analysis is made more transparent because the uncertainties are not hidden by means of a set of assumptions that allow coming out with a number.

In the rest of the analysis, the qualitative criteria are evaluated by assigning one of the three following scores: "high", "low", "none". Using this scale, it can be affirmed that the degree of risk that FECSA project entails is “**high**”, because the entire length of the electric line is aerial, whereas SEBA proposal implies a “**low**” risk, because part of the line is buried. PV panels do not cause forest fire, so that the risk they cause is “**none**”

4. Deforestation Forest vegetation is an essential part of the Park ecosystems, which SPN must protect by statute. Deforestation is relevant here because, as explained before, electric grid requires deforesting a corridor along the line. According to the Decree 268/1996[19], a corridor of six and two meters along respectively low and medium- tension line must be free from vegetation. This means that FECSA project implies a deforestation of **67 thousand m^2**, whereas SEBA proposal only need to deforest **57 thousand m^2** (actually, this is its main advantage). Obviously, stand- alone PV systems do not imply deforestation at all.

5. Risk for birds SPN’s duty is not only protecting the vegetation but also the fauna inside the Park. Impact on biodiversity is here relevant because the electric line can jeopardize birds trough the electrocution or the collision of the birds against the poles or the electric line (Asistencias Técnicas Clave, S.L., undated). Electric lines are among the first causes of non-natural death for many endangered species. In the last 10 years the number of birds' deaths for electrocution increased notably, due to electric lines installed in rural areas (Tintó and Real, 2003).

Risk of collision is inversely proportional to visibility, so that it is worst in wet areas or riverbeds, steppe zones, migration areas and rocky areas where birds of prey nest or sleep (Fernandez and Azkona, 2002). In this sense, Montseny is not so a dangerous area. Elettrocution takes place when a bird simultaneously touches two conductors or, more frequently, one non-isolated conductor and a grounded device, such as a pylon. Bird electrocution not only jeopardizes avifauna but it can also damage electric lines and provoke blackouts. Sometimes, birds fall down from the pole burning and cause forest fires. According to Fernandez and Azkona (2002) the risk of electrocution increases if an electric grid is located 1) in spacious landscapes where there are not trees as an alternative for alighting, 2) in areas where ecosystems are well conserved (because birds are likely to use the poles for looking for food), 3) in ecotones (transition areas between two distinct habitats), 4) in areas where many different species live. Montseny Natural Park only fulfils the second and the fourth condition (and in some areas also the third), so risk is not so high.

18 Data of the Forest Fire Prevention Service.

19 Diari Oficial de la Generalitat de Catalunya. N. 2236, 29/7/1996

This opinion is shared by the ornithologist that was interviewed for this research, who is specialized in damages to avifauna caused by electric grid. According to his opinion, risk that an electric grid jeopardizes Montseny’s avifauna is not so strong. In fact, normally risk decreases in a forest because birds can use trees for perching, which reduces risk of electrocution. Therefore, the risk can be defined “**low**”, because there is some possibility that some birds are killed by electric line, but it is not probable due to the characteristics of Montseny forest. Moreover, the length of the proposed electric line is not so extended. On the other side PV panels do not affect avifauna, so that their impact is "**none**".

6. Emission of greenhouses gases

The idea that solar energy allows reducing the greenhouse emissions associated with the traditional generation of electricity was never mentioned by SPN technician during the interview. His environmental concerns regard a more local scale. However, if SPN represents the point of view of public administration, a criterion must be introduced that takes into account the emission of greenhouse gases. In fact, with Kyoto Agreement, Spain committed itself not to surpass 15% of 1990 greenhouse emission by 2008-2012 (and by now it has exceeded 40% with respect to 1990). This target requires a combined effort of the local administrations that must contribute to reach it.

It can be calculated that for each kWh produced in Spain, approximately 0,5 kg. of CO_2 equivalent is emitted[20]. Multiplying this number by Spanish households' average energy consumption, it results that **96 kg of CO2 equivalent** are spared by means of PV[21].

7. Limitation to enterprises

As already said, SPN encourages human presence inside the Park. However, SPN must hamper the activities that damage the environment. In this sense, PV can play an important role. In fact, it is a technology that supplies some energy, so that it allows living and carrying out small-scale activities, but at the same time it hinders activities that potentially cause a high environmental impact, because of the small amount of supplied energy.

The choice of the modality for rural electrification might be an important factor in determining the Park's kind of development. Therefore, SPN will tend to choose the modality that helps it to limit the economic activities inside the Park. All interviewed social actors (the SPN technician, the Mayor, the owners and the inhabitants) agreed on the fact that solar energy constitutes a strong limitation on the economic activities inside the Park. Therefore, the check on economic activities of PV can be defined "**high**". On the other side, traditional electricity's limitation on economic activities is "**none**", because it provides a virtually infinite supply of energy.

[20] For calculating gas emissions related to the use of electricity, the structure of electricity production in Spain is used, that is the share of each source of energy in total Spanish energy consumption (Bundesamt Für Umwelt, Wald Und Landschaft, 1996). Then multiplying the share of each source by its equivalent CO_2 content, the average CO_2 content of a kWh produced in Spain can be obtained. Greenhouse emissions are calculated in equivalent CO_2, using the Global Warming Potential (GWP) for a temporal horizon of 100 years (Houghton et al., 1994), that is, CO_2 =1; CH_4 =21; N_2O = 310. It can be noted that the CO_2 content of the energy sources is high because the CO_2 consumption of the entire life- cycle is calculated, including extraction, transport and transformation phases.

[21] In reality the greenhouse effect the PV panels are responsible for is not zero, because energy (in a large extent produced with fossil fuels) must be used in order to produce them. However, it has been calculated that the energy payback of a solar panel (the period that it needs to supply the same amount of energy that was necessary to produce it) is two to four years (Knapp and Jester, 2000). The mistake that is here made by considering that PV panels do not produce greenhouse gases is therefore negligible.

Social criteria

8. Educational effect

One of the objectives of the Natural Park is to allow citizens to be in contact with nature and to learn about ecosystems and traditional activities. It can be noted that education is one of the most important activities inside the Park, and a well-equipped infrastructure is[22] dedicated to this objective . As explained before, education and spread of information is a very important factor in the diffusion of renewable energy, because its wide diffusion is indispensable to reach the economic break- even point.

PV panels in Montseny Natural Park can be used in this sense. Visits to PV installations in the Park are often organized. PV panels have a "**high**" educational effect, because they allow carrying out not only a direct educational work, but they favour the development of a consciousness on energy saving. In fact: a) They can improve environmental consciousness of Montseny inhabitants and visitors.

Being in contact with PV panels might incentive people to get informed about the greenhouse effect and local pollution

b) By means of hindering the industrial activities that require much energy, they show that it is possible to live inside a Natural Park developing enterprises with a low environmental impact.

c) Since they do not supply much energy, they accustom people to spare energy and to eliminate unnecessary consumption, as well as to use low- consumption household equipment.

On the contrary, traditional electricity's educational effect is "**none**".

9. Impact on landscape. The concern for the impact on landscape is crucial for SPN. Human presence must be integrated inside the Park and it is not allowed being a perturbing element. Many rules are established in the Special Plan for maintaining the landscape, and the Park administration is usually quite strict with landscape protection. Impact on landscape is a social criterion because it is a matter of social perception: it depends on esthetical and on ethical factors.

Electric lines have an impact on landscape, especially in the forest. In fact, in order to reduce the risk of fire, the trees around the electric line must be cut. The impact on landscape is especially high in mountainous areas, where the area where the trees have been cut (which has the colour of the ground) appears from a long distance as a yellow line zigzagging in the middle of the green forest area. Also, the poles have a visual impact. The impact on landscape of electric lines can be minimized burying the line.

According to SEBA's analysis, FECSA proposal implies a high visibility near the Turó del Tagamanent, because it is a very flat area. SEBA proposal reduces visibility thanks to three measures: 1) part of the line is buried, 2) the itinerary is partially changed in order to avoid the flat area and 3) transformers in boxes on the ground are used instead of aerial ones. PV panels barely have effects on visibility. Therefore, visibility is "**high"** in the case of FECSA project and "**low**" in the case of SEBA proposal. PV panels are not really visible from a distance, so that their impact on landscape is "**none**".

8 information points, 4 information centres and 15 "schools of nature" give information about the

ecosystems, the traditional activities and the history of Montseny Natural Park.

Table 1 indicates the impact matrix for SPN.

Table 1. Impact matrix for SPN

Dimension	**Criteria**	**Unit**	**Score**		
			FECSA	*SEBA*	*PV*

Economic	*1. Total cost*	*Thousand €*	*731*	*796*	*1328*
	2. Cost for SPN	*Thousand €*	*0*	*0*	*570*
Environmental	*3. Risk of fire*	*Qualitative*	*High*	*Low*	*None*
	4. Deforestation	*Thousand m^2*	*67*	*57*	*0*
	5. Risk for birds	*Qualitative*	*Low*	*Low*	*None*
	6. Emitted CO_2	*Kg CO2 eq.*	*96*	*96*	*0*
	7. Limitation to enterprises	*Qualitative*	*None*	*None*	*High*
Social	*8. Educational effect*	*Qualitative*	*None*	*None*	*High*
	9.Impact on landscape	*Qualitative*	*High*	*Low*	*None*

Owners and inhabitants

Economic criteria

1. 1. Cost per household Most users remarked very strongly during the interviews that the cost is a crucial aspect for them. The costs are calculated as explained before, and taking into account that users only take upon themselves 22% of the cost of PV installation and 50% of the cost of grid extension. The results for FECSA project, SEBA proposal and PV are respectively **28**, **31** and **21 thousand €** per household.

2. 2. Possibility of setting up an enterprise The preferences about energy sources are influenced by the use of the farmhouse. As already explained, all social actors agree on the fact that one of the main reasons that can explain the hostility against PV is that it hinders the possibility of setting up an enterprise. In fact, on the one side the possibility of founding an enterprise given by traditional electricity is "**high**" because it guarantees a virtually infinite supply of energy. If an enterprise decides to use more energy it has only to increase the contracted power. Increasing the power of an electricity installation from 4,4 to 5,6 kW would cost

approximately 60 €, that is, around 50 € per kW . On the other side, PV only provides a limited, and to a certain extent unpredictable amount of electricity, so that the possibility of founding an enterprise offered by solar energy is "**low**". In Tagamanent municipality there are a restaurant and a little rural pension, which function in part with solar energy. However, both complement the energy supplied by PV with electricity generators.

It can be noted that this criterion is the same as the one formulated for SPN and called "Limitation to enterprises". However, the direction of the criterion is the opposite. For the Park administration the "Possibility of setting up an enterprise" is to be minimized, and therefore the "Limitation to enterprises" must be maximized. For owners and inhabitants the former is to be maximized and the latter is to be minimized. Moreover, this is an environmental criterion for SPN, whose objective is to protect the environment and an economic criterion for owners and inhabitants, who aim at increasing their economic income. This is an example on how a criterion can change according to the different objectives that it evaluates.

This information was obtained by means of a telephonic interview with a technician in charge of new installation in FECSA, carried out in September 2003.

3. Farmhouse's revaluation For the owners, the possibility of an increase in the value of their properties is also a good reason to take upon themselves the cost of electrifying their households, even though they do not want to live there. Since the increase of the farmhouses'

value in monetary terms depends on many uncertain factors, here a qualitative evaluation is preferred. PV elements' lifetime is between ten and twenty years, so that it cannot really be said that installing PV is a long- lasting investment. On the contrary, electric grid has a virtually infinite timehorizon, so that once extended to the farmhouses, the value of the properties increases permanently. In fact, once the grid is installed, FECSA commits itself to maintain it, without additional expenses for users. Also, comfort is higher and there are not constraints on use of energy (so that, for example, it is possible to set up an enterprise). Therefore the revaluation of the farmhouses is "**none**" in the first case and "**high**" in the second one. Obviously, this criterion is important only to owners and not to leaseholders.

Environmental criterion

4. Risk of fire Forest fire constitutes the most important environmental risk for owners and inhabitants because it directly affects their property. Forest fire can provoke economic damages, since the forest is a source of income, and it can jeopardize the farmhouses, the surrounding area, and even the safety itself of owners and inhabitants. The criterion's scores are illustrated before.

Social criteria

5. Discomfort In rural areas the feeling of being cast out with respect to people living in an urban agglomeration is often pretty strong, and it is mentioned in many of the interviews. People living in scattered farmhouses inside the Park enjoy fewer services with respect to people living in cities. In fact, all activities such as administrative offices, hospitals, schools, cinema and restaurants are concentrated in cities. Public transport is not provided inside the Park. The path to the farmhouses is often in bad conditions. They are quite isolated since they do not have telephone (and consequently they cannot use Internet), and often mobile phones do not work well in these zones. To a certain extent, they feel the lack of services as an injustice, because they feel that the Public Administration does not acknowledge and reward enough the fact that they contribute to maintain the biodiversity and the architectonic patrimony of the Park.

Owners and inhabitants of scattered farmhouses inside the Park feel discriminated in their energy use in two ways: because of the higher price and because of the lower degree of comfort. Electricity in rural areas is much more expensive than in cities. In fact, in an urban context installing traditional electricity in a new house (which is the cheapest modality of getting electricity) costs around 200 € for a power of 4,4 kW (the standard one) . However, once installed the electric line, there are not differences among users because of their location. PV panels might contribute to the feeling of discrimination more than conventional electric line because of the restrictions that they impose in daily life. PV panels imply a lower comfort because users have to worry on whether batteries are charged enough or whether they are using too much household equipment at the same time. On the contrary, with conventional electricity, one only has to turn the switch on and have as much electricity as he is willing to pay. Therefore, discomfort is "**high**" for people using solar energy and "**low**" for traditional electricity users.

See previous note.

Technical criterion

6. Reliability All people interviewed underlined that reliability of electricity supply is crucial to the farmhouses' inhabitants (but probably not a lot to the owners that do not live in the farmhouses because they do not directly experience possible breakdowns). Users want to be sure that they can use electricity when they need it and that breakdowns are not frequent. For the ones that run a restaurant or a rural pension this is a major problem because when PV break down they are not able to offer a good service to their clients. Worry of blackouts is one of the main reasons that explains the hostility against PV panels: people do not trust solar energy and are convinced that renewable energy is not able to supply enough energy.

Solar energy users affirm that sometimes their PV equipment suffers breakdowns (especially in the first period of use, when they are not yet familiar with them and do not use them properly).The solar panels technicians interviewed confirm that from time to time some of the PV components break. Therefore, it can be said that reliability is "**low**" in the case of solar energy. Electric line can also suffer from black outs. SPN technician affirms that the probability that an electric line breaks is much higher in isolated areas than in urban conglomerations because maintaining them and fixing the damages is very expensive for electricity companies. However, after having asked the persons who have extended the grid to their farmhouse in the area under study, we conclude that the grid breaks are very seldom. In this sense we can say that their supply security is "**high**".

Tables 2 and 3 resume the criteria's scores for users and inhabitants.

Table 2. Impact matrix for owners

Dimension	**Criteria**	**Unit**	**Score** FECSA	SEBA	PV
Economic	*1. Cost per household*	*Thousand €*	*28*	*31*	*23*
	2. Possibility of setting up an enterprise	*Qualitative*	*High*	*High*	*Low*
	3. Farmhouse's revaluation	*Qualitative*	*High*	*High*	*None*
Environmental	*4. Risk of fire*	*Qualitative*	*High*	*low*	*None*
Social	*5. Discomfort*	*Qualitative*	*Low*	*low*	*High*

Table 3. Impact matrix for inhabitants

Sphere	**Criteria**	**Unit**	**Score** FECSA	SEBA	PV
Economic	*1. Cost per household*	*Thousand €*	*28*	*31*	*23*
	2. Possibility of setting up an enterprise	*Qualitative*	*High*	*High*	*Low*
Environmental	*3. Risk of fire*	*Qualitative*	*High*	*Low*	*None*
Social	*4. Discomfort*	*Qualitative*	*Low*	*Low*	*High*
Technical	*5. Reliability*	*Qualitative*	*High*	*High*	*Low*

3.4. Application of a mathematical procedure for criterion aggregation

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 Sixties, 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[25].

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 $G=\{g_m\}$, $m=1,2,...,M$, and a finite set $A=\{a_n\}$, $n=1,2,...,N$ of alternatives, let's 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's assume that a higher value of a criterion score is preferred to a

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

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

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 noncompensatory aggregation procedures. In SMCE it is more appropriate to use the second type of weights because in public policy problems the value and the interests of all social actors should be taken into account.

Compensability might lead to disregard some dimensions, which might be important for some groups of social actors.

derived as importance coefficients. The mathematical problem to be dealt with is

$$\sum_{m=1}^{M} w_m = 1$$

then how to use this available information to rank in a complete pre-order (i.e. without any incomparability relation[26]) all the alternatives from the best to the worst one. The mathematical aggregation convention can be divided into two main steps:

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

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 . Thanks to these three axioms a *N*×*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

j and *k*. Such a

global pair-wise comparison is obtained by means of equation (3).

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

where and are the weights of criteria presenting a preference and an indifference relation $w_m(P_{jk})$ $w_m(I_{jk})$

respectively. It clearly holds $e_{jk} + e_{kj} = 1$. (4)

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, $R=\{r_s\}$, $s=1,2,...,N!$. For each r_s, compute the corresponding score

φ_s as the summation of e_{jk} over

all the pairs *j*,*k* of alternatives, i.e.

$$\binom{N}{2}$$

The relation between each pair of alternatives must be either of preference or indifference. 27

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 favour 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.

. (5)

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

The final ranking () is the one which maximises equation (5), which is: $r*$

$$r* \Leftrightarrow \varphi_* = \max \sum e_{jk} \qquad where\ e_{jk} \in R \quad . \qquad (6)$$

By applying this ranking algorithm, the outranking matrix described in Table 4 is obtained (where A is *FECSA*, B is *SEBA* and C is *PV*).

Table 4. Outranking matrix deriving from Table 1 (SPN)

	A	**B**	**C**
A	0	0.4	0.3
B	0.6	0	0.3
C	0.7	0.7	0

The maximum likelihood ranking of alternatives deriving from this outranking matrix is the following:

Table 5. Maximum likelihood ranking of alternatives deriving from Table 1 (SPN)

C	**B**	**A**	**1.9**
C	A	B	1.7
B	C	A	1.6
A	C	B	1.4
B	A	C	1.3
A	B	C	1

Clearly *PV* is the most preferred option for the Servei de Parcs Naturals, the *FECSA* solution is the worst one.

By applying the same ranking algorithm to Tables 2 and 3, the following results are obtained:

Table 6. Maximum likelihood ranking of alternatives deriving from Table 2 (owners)

A B C 1.7
B A C 1.7

A	C	B	1.5
B	C		A1.5
C	A	B	1.3
C	B		A1.3

Table 7. Maximum likelihood ranking of alternatives deriving from Table 3 (inhabitants)

A B C 1.7
B A C 1.7

A	C	B	1.5
B	C		A1.5
C	A	B	1.3
C	B		A1.3

It is interesting to note that for owners and inhabitants the ranking of policy options is the same. For both groups, *PV* is the worst option, both *FECSA* and *SEBA* options might be acceptable.

One has to note that in this ranking exercise all the criteria receive the same importance since no weight coefficient is used. This implies that e.g., in the case of SPN the environmental dimension has a bigger weight than other dimensions since five of nine criteria used belong to the environmental dimension. Let's then perform a sensitivity analysis of the obtained rankings according to the weight given to dimensions. By given the same weight to all dimensions used, the following rankings are obtained.

Table 8. Sensitivity analysis for SPN's rankings:
C B A 1.7

C	A	B	1.6
B	C		A1.6
A	C	B	1.4
B	A	C	1.4
A	B	C	1.2

Table 9. Sensitivity analysis for owners' rankings B
A C 1.7

B	C		A1.6
A	B	C	1.5
C	B		A1.5

A	C	B	1.4
C	A	B	1.3

Table 10. Sensitivity analysis for inhabitants' rankings B

A C 1.8

A	B	C	1.7
B	C		A1.6
A	C	B	1.4
C	B		A1.3
C	A	B	1.2

The previous results are corroborated substantially. Again *PV* is the best option for the *Servei de Parcs Naturals* and both inhabitants and owners present the same preferences; this time the *SEBA* option seems slightly better than the *FECSA* one, *PV* is not a defensible option.

It is interesting to note that for owners and inhabitants the only criterion clearly in favour of *PV* is cost. Thus only if cost can be considered a dictator in Arrow's terms, i.e. it receives a much bigger weight than all the other criteria, then *PV* is the best option for them. This explains the fact that many of them complain about *PV*: according to the analysis here performed, they would prefer traditional electricity, even though it is more expensive.

4. Conclusion

This study is an example of the way in which SMCE can be used to enlighten social conflicts. This analysis was begun with a focus only on the energy issue. The problem that it intended to solve was the best way to electrify some isolated farmhouses in a natural park, taking into account environmental, social and economic criteria. However, as the research went on, the social actors underlined various aspects of the problem that were not evident at first sight. The interviews were of big help in understanding that the problem of energy was strictly bound with other issues that were not solved yet inside the Park, especially the water supply and the access. As a matter of fact, the issue of rural electrification is not a technical problem only, but it is a part of a larger political issue: what there is no agreement on is the long term political strategy for Montseny Natural Park.

In order to explain this point Ravetz's distinction between technical and practical problems can be helpful (Ravetz, 1971; Strand, 2002). The first ones can be solved by a specialized, technical knowledge, whereas the second ones have to do with the objectives and the values of part of the society, such as the whish of a clean environment, an economic growth or a more fair distribution of wealth. Modern societies are characterized by the attempt of reducing complex practical problems to many different technical problems to entrust the experts with. Using this terminology, one can say that the solution of the technical problem (how to electrify the isolated farmhouses in Tagamanent municipality) depends on how to give an answer to the practical problem that is at the root of it: the conflict between different views on the Park's development.

In fact, on the one side SPN tends to adopt a conservationist view, that is, to limit human intervention as much as possible, in order to reduce its interference with the natural ecosystems. Its most important objective is environmental protection, which is evaluated in the impact matrix by means of five criteria out of nine. Extending the grid to the isolated farmhouses would cause an impact on the environment and the landscape, and it might also incentive the foundation of enterprises inside the Park. This concern is here expressed with the criterion "*Limitation to enterprises*". On the other side, people living in or owning a farmhouse in Montseny think that the policies encouraging the economic activities should be privileged. Therefore, the criterion "*Possibility of setting up an enterprise*" was included in the analysis, which corresponds to the criterion "*Limitation to enterprises*" but goes in the opposite direction. Also, during the interviews, most inhabitants and owners affirmed that for them the economic factors were more important than any other consideration (even though environmental, social and technical issues were also relevant), so that in the evaluation matrix more criteria were referred to the economic dimension.

In conclusion, it might be argued that a debate should be raised on how and by whom the decisions on Park management are to be taken. This study showed that the relevant criteria, and hence the preferred alternative, were different for each group of social actors, so that three different impact matrixes had to be built. The political choices to be taken are different according to whom is given the right to decide about the future of the Park, or, in other words, to impose his/her set of evaluation criteria. Also, it can be discussed on who the social actors are: the people living inside the Park, the owners of part of the Park (87% is private), the inhabitants of the surrounding area that use the Park as a place for their outdoor excursions, humanity in general (Montseny Natural Park was declared Biosphere Reserve by UNESCO), the future generations? As pointed out by Giampietro (2003) scale is a key issue.

Finally, some observations on the suitability of solar energy for rural electrification can be made. First of all, the public incentives can modify the preferences of the users very much. In Tagamanent case, even though the PV panels are more expensive (the electricity consumption being equal), they are cheaper for the final users, because the public administration contributes by 88% to the total expense, whereas grid extension is subsidized only by 50%. A lesson that can be drawn is that the role of the public administration is crucial in promoting renewable energy.

In the second place, the choice between solar energy and traditional energy depends on the temporal horizon. In fact, whereas once installed, the electric grid provides electricity for a virtually infinite period of time, the PV components must be replaced from time to time. Therefore, solar energy appears to be more suitable if the users are planning to stay in the farmhouse for a limited period of time, such as for example in the case they are not the owners of the house where they live. Surprisingly enough in this case the shortest time horizon option is also the most environmental correct one!

Thirdly, the activity carried out in the farmhouses is crucial in deciding the relative convenience of solar energy. In fact, solar energy seems to be more appropriate for private households, which are characterized by limited energy consumption. On the contrary, people running an activity complain about the limits of renewable energy, both in terms of their reliability and of the available supply of electricity.

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