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PhD thesis

Social Multi-Criteria Evaluation and renewable energy policies

Two case-studies

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PART I

SOCIAL MULTI-CRITERIA EVALUATION AND RENEWABLE ENERGY POLICIES

Social Multi-Criteria Evaluation and Renewable Energy Policies

1 Energy policies

The European Union is increasingly concerned because of its high energy demand and great dependency on fossil fuels. Fossil fuels bear the main responsibility for the increased greenhouse effect, which is recognized as one of the most worrying environmental problems. On a local scale, polluting emissions from fossil fuels cause a raising number of ailments ranging from respiratory diseases to cancers. Also, the high dependency on Middle East for oil and Russia for gas[1] makes Europe vulnerable and potentially subject to political pressures. Finally, fluctuations in oil prices have a worrying impact on inflation and economic growth. Whether nuclear energy should be considered an alternative is arguable, because of risk of accidents, the unsolved disposal of radioactive residues and military proliferation.

For these reasons, reducing the European dependency on fossil fuels by energy saving and renewable energy is considered a political priority, as also indicated by the commitments assumed with the Kyoto Protocol of reducing European greenhouse gas emissions by 8% with respect to the 1990 level within 2012.

In order to reach this objective, a coordinated and resolute set of policies at the European, national and local scales in favour of energy saving and renewable sources are needed.

In particular, the Green Paper on Renewable Energy establishes a target of 12% of renewable energy in total energy consumption by 2010[2]. The latest energy strategy of the European Commission, presented on 10th January 2007, establishes that renewable energy should represent by 2020 at least 20% of the total energy use[3]. Renewable energy sources cannot by themselves fuel an industrialized society (Trainer, 1995), but they can at least make a contribution towards the reduction of fossil fuel consumption.

The increase in the share of renewable energies is not only a technical problem. On the contrary, social aspects can determine the success or failure of an energy policy. For example, under certain conditions, renewable energies might raise some discontent on a local scale because of their impact (e.g. extensive land requirement, noise, landscape alteration). The NIMBY effect (Not In My Back Yard - i.e. approval of a project theoretically, but refusal to have it nearby) might cause opposition against renewable energies, as it frequently happens with wind power plants.

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[1] The White Paper on renewable energy states that European energy dependency could rise up from the present 50% to 70% by 2020, if no action is taken.
[2] COM/96/0576 final.
[3] http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/29&format=HTML&aged=0&language=EN&guiLanguage=en.

Also, the diffuse nature of renewable energy allows a partial decentralization of energy production, requiring the involvement of an increasing number of citizens in the choice and the implementation of the energy policies.

For these reasons, an early analysis and involvement of social actors is important to obtain information on the local conditions, including the values and the expectations of citizens, in order to increase the transparency and legitimacy of the decision-making process (Hobbs and Horn, 1997). Participation should play a key role in this sense.

Also, the diffusion of renewable energy has many different impacts on the economic, environmental and social dimensions. However, many studies just analyze one or another aspect, giving only a partial indication of the possible consequences of a policy. In some cases, the results are doubtful recommendations. For example, policies that seem positive on a local scale might have adverse effects on a larger scale. On the contrary, when a political measure in a complex environment is evaluated, a plurality of issues should always be taken into account in an integrated way.

Finally, the investment cost per unit of energy obtained is normally high for renewable energy, making it in most cases not competitive with fossil fuels. As a consequence, renewable energy must be supported with incentives and other policies. For this reason, a careful analysis of where and how it is more advisable to invest public resources is needed, which can take into account all relevant impacts at different scales and the long-term effects.

In this context, Social Multi Criteria Evaluation (SMCE), as defined by Munda (2004), can be helpful in structuring analyses and decisions on energy policy because it allows taking into account the points of view of the involved social actors and the various impacts in different dimensions and scales, without imposing a single language of valuation.

In the next section, the philosophical background of SMCE is presented and its main steps are described.

2 Social Multi-Criteria Evaluation

2.1 Social Multi-Criteria Evaluation as a response to post-normal problems

Traditional science is facing a crisis, because it is less and less able to give credible answers to the new challenges that are arising in modern societies (Funtowicz et al., 1999). In the words of Funtowicz and Ravetz (1991), a rising number of political problems have a “post-normal” nature, which they define as follows:

“Scientists now tackle problems introduced through policy issues where, typically, facts are uncertain, values in dispute, stakes high and decisions urgent. When research is called for, the problem must first be defined, and this will depend on which aspects of the issue are most salient. Hence political considerations constrain which results are produced and thereby which policy implications are supported. In general, the post- normal situation is one where the traditional

opposition of 'hard' facts and 'soft values' is inverted. Here we find decisions that are 'hard' in every sense, for which the scientific inputs are irremediably 'soft'" (p. 138).

One clarifying example is the decision on whether to allow the use of genetically modified organisms (GMOs) in agriculture. In this case, science cannot forecast all consequences of the use of GMOs on agricultural diversity, farmers' income, human health, etc., because they depend on many other factors that cannot be taken into account all together and are quite unpredictable. Also, conflicting interests are involved, e.g. those of farmers, seed enterprises, ecologists, citizens[4]. Moreover, most research aimed at assessing the risks associated with GMOs is financed by one or the other involved actors, mainly seed enterprises, and so it cannot be considered neutral. Finally, policy makers cannot wait to have a sufficient degree of knowledge on the consequences of their choices, but decisions must be made quickly[5].

In a post-normal context, traditional science alone is not able to give decisive and legitimate answers, and must be complemented by other kinds of knowledge. Local people can contribute with information and ideas that are not at the disposal of the experts. Involving lay-people in the evaluation and decision-making process increases not only the democracy (and hence the legitimacy) of the scientific process but also its quality.

Social Multi-Criteria Evaluation (SMCE) can be seen as an operationalization of the concept of post-normal science, because it allows using as input different types of knowledge, generated by the experts and the social actors. SMCE is a type of Multi-Criteria Analysis (MCA) that takes into account the social dimension of a problem.

MCA is a tool designed to help decision-making in the presence of different objectives. It can be used when each available alternative is better according to some criteria and worse according to others, as it often happens when dealing with investment projects or policy design. In these cases, there is no optimal solution and a compromise must be found.

MCA allows to respond to what Martinez-Alier et al. (1998) call *incommensurability of values*, i.e., the absence of a common language across plural values, or, in other words, the impossibility of expressing by means of a single unit of measurement the effects of a decision on different dimensions.

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[4] Strand (2001) identifies three systems of values, from which different opinions on GMOs can be derived: technological optimism, shallow ecology movement and deep ecology. The first one sees technological progress, and hence biotechnology industry, as a way to assure welfare to humanity, with minor inconveniences (which are controllable and reparable). The second one is concerned about the effects of a technology on the environment because of the possible impact on human health. The third one defends the plant and animal survival for itself, and not for the possible benefits they can supply to humans.

[5] Funtowicz and Ravetz (1994) state: "*To wait until the relevant high-precision natural science were available before doing anything about global warming or species preservation would be a counsel of perfection indistinguishable from a counsel of despair*" (Funtowicz and Ravetz, 1994, p.200)

According to Martinez-Alier et al. (1998), incommensurability does not imply incomparability (impossibility of comparing different alternatives), but *weak comparability*, which means the need for different kinds of measurements to evaluate alternative options.

Therefore, evaluations based on one only unit of measurement, such as money in Cost-Benefit Analysis, but also energy, emergy (Odum, 1996) or exergy (Szargut et al. 1988, Ayres and Ayres, 1999), material flows (Eurostat, 2001), land requirement (Wackernagel and Rees, 1996) are not enough by themselves to assess the various impacts of a policy. On the contrary, MCA considers a wide range of assessment criteria, without translating the criteria into a single common unit.

As a consequence, SMCE allows and promotes multi-disciplinarity and inter-disciplinarity. The former is the ability to use different disciplines together for analyzing a problem, each one explaining a different aspect. Inter-disciplinarity is reached when the different disciplines not only put together the results of their analyses but also interact, applying the competencies of each discipline in unusual fields. In other words, inter-disciplinarity allows a methodological discussion across disciplinary borders (Strand, 2001).

The main innovation provided by SMCE (Munda, 2004) with respect to other kinds of MCAs is the focus on the social aspects. SMCE allows taking into account what Munda (2004) calls “social incommensurability”, i.e. the plurality of multiple and conflicting, yet legitimate, values and interests in a decision.

The existence of different values and interests in a policy problem implies that in most real-world cases no optimal solution exists. Any policy may be better from certain points of view and worse from other ones, or, in other words, it may favour certain groups of social actors over others. Therefore, a compromise solution must be found among the interests of the social actors.

Analyzing the position and the role of the stakeholders is particularly important when dealing with “post-normal” problems, i.e. in situations where there is neither a single truth nor optimal decisions, and the stakeholders have conflicting and legitimate opinions about the possible solutions of problems. In such cases, the institutional, environmental and social forces play a big role in shaping the decision processes.

In this context, transparency plays a crucial role because it allows showing which values and which groups of stakeholders are favoured by each option. An integrated assessment of all impacts of a policy, such as the one allowed by SMCE, favours accountability of public decision-making and promotes a wide social debate.

In SMCE, participation is used as an input of the analysis, but alternatives, criteria and weights are not derived directly from participation (Munda, 2004). This is the main difference between SMCE and Participative Multi-Criteria Analysis (Stagl, 2006) or Deliberative Multi-Criteria Analysis (Proctor and Drechsler, 2006).

The reasons are manifold. First of all, some actors might be under-represented in a purely participative process, e.g. the ones who do not normally participate in a politically active or organized group, future generations, people living far away. Existing socio-political structures might lead to “participatory exclusions” (e.g. of women, of immigrants, see Agarwal, 2001). However, the interests of these actors should be also taken into account when evaluating a policy. Also, the groups of social actors are not necessarily homogeneous and the individuals belonging to them might have different opinions and objectives. One citizen can belong to different social groups and have different, and possibly conflicting, interests (e.g. as an environmentalist I am in favour of increasing taxes on oil, yet as a car driver I am against that). Moreover, the analyst might include in the evaluation criteria that stakeholders are not conscious of.

Finally, the role of the analyst is useful to “translate” the evaluation of the social actors into criteria, in order to assure consistency and avoid redundancy. For a discussion on the limitations of participation, see Kallis et al. (2006).

2.2 The steps of a SMCE

A SMCE is carried out in six steps (Munda, 2004):

1) Definition of the problem
2) Institutional analysis
3) Generation of the policy options
4) Construction of the multi-criteria impact matrices
5) Application of the mathematical procedure
6) Sensitivity analysis

2.2.1 Definition of the problem

Since complexity implies multiplicity of legitimate views, it is very important to analyze the different perceptions of the involved social actors on a problem. Each agent perceives the problems according to his or her objectives and interests, knowledge, resources and role. As an example, the conflict between the possibility of tourist development and the establishment of a natural park in an environmentally sensitive area can be defined by the environmentalists as a problem of how to protect the valuable ecosystem, whereas for the local population the issue might be how to promote economic growth and employment.

These different representations can significantly diverge, and give rise to *social incommensurability*. In other words, there is not a single and objective way to describe a problem, and an optimal solution does not exist. The definition of a problem is a political process, and can change because of changes in the political context, of interactions among agents, of the course of events.

For this reason, information provided by social actors should be used as an input in all phases of the research, including the definition of the problem. In any case, it should not be forgotten that subjectivity is unavoidable, and different analysts could define the same problem in different ways.

2.2.2 Institutional analysis

In order to explore the social dimension of a problem, SMCE uses institutional analysis, a method frequently used in sociology and public policy analysis. The institutional analysis helps shed light on the values, the interests, the available resources, the role and the possible alliances of the social actors involved in a conflict.

An institutional analysis is carried out in three steps (Dente, Fareri and Ligteringen, 1998; Ferrari, 1998; Funtowicz and al., 1998; Corral Quintana, 2000; Martí, 2001; Gamboa, 2006).

First of all, a **chronology** of the relevant events that led to the present situation is reconstructed, together with information on the political and legal framework.

Secondly, **social actors** are identified, by means of information gathered in the previous phase. Obviously, the affected actors are not only those who have an institutional role, but also individual citizens and groups who can influence or whose interests are affected by the final decision. According to Dente, Fareri and Ligteringen (1998), an **actor** is any collective or individual subject that participates in a decision-making process in any of its phases.

For each social agent, information is gathered on their functions and role, objectives, interests and available resources. In many cases, this information is not totally explained by the social actors to analysts, but must be inferred observing their behaviour. Moreover, it should be kept in mind that objectives can vary along the time. In the framework of the institutional analysis, interests are seen not only as moulded by purely economic factors but also as objectives legitimated and influenced by a social context.

Resources are means that can be used in order to reach an objective. They 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).

In the third place, the network of the **interaction patterns** among social actors is described, including the structure of the institutional network, the kind of interaction, and the arena where such interactions take place. This part helps the analyst understand the evolution of the problem in a more dynamic way and the reasons of the social actors' position.

Different written and oral sources are used for carrying out an institutional analysis. In the first category we can list the local press, official documents, books, articles, and so on. In the second group we find individual interviews to key agents or to a casual sample and focus groups. Normally, many sources are simultaneously used, since they complement each other.

2.2.3 Generation of policy options

The third step of a SMCE is the generation of the policy options. This process must be a collective creation resulting from a dialogue between the analyst and the social actors. In this sense, SMCE is a much more creative instrument than either the CBA or technocratic types of MCA, where the alternatives are defined by the analyst without a real confrontation with the social actors.

On the contrary, in SMCE not only the criteria and the scores, but also the very generation of the options among which to choose, should be undertaken by the analyst together with the social actors. As underlined by Munda (2004), the contribution of the stakeholders, and the debate that arises from it, sometimes allows defining new possible options which had not occurred to the policy-makers before.

2.2.4 Construction of the multi-criteria impact matrix

Once the options among which to choose have been established, the criteria to evaluate them must be chosen. In SMCE, criteria derive from the objectives of social actors.

In fact, in the presence of different and legitimate interests on a policy decision, the social actors may have divergent opinions on what is relevant for the choice to be made. In cases where an optimum solution does not exist and a compromise must be found, democracy implies that each group of social actors should have the right to suggest some of the criteria to be taken into account.

In this sense, in SMCE criteria are used to assess to what extent each alternative allows to reach an objective, which belongs to some groups of social actors. For example, when dealing with energy policies, for environmentalists the reduction of the greenhouse effect is an important objective, and in order to take it into account, the criterion “greenhouse emissions” might be included in the analysis.

After criteria are defined, a score is attributed to each criterion, using knowledge deriving from a variety of disciplines and from the social actors. The information gathered in this process is summarized in the *multi-criteria impact matrix*. Table 1.1 shows the structure of a typical multi-criteria impact matrix, which can be explained in the following way (Janssen and Munda, 1999). If it must be decided among *n* feasible alternatives a_1, a_2, … a_n according to *m* relevant criteria g_1, g_2, …g_m, the alternative a_1 is preferred to the alternative a_2 according to the criterion g_i if $g_i(a_1)>g_i(a_2)$. Hence, a multi-criteria problem can be represented by a n x m matrix, where the element $g_i(a_j)$ represents the performance of the alternative a_j according to the criterion g_i.

Table 1.1 The multi-criteria impact matrix

Criteria	Units of measurement	Alternatives			
		a_1	a_2	…	g_n
g_1	…	$g_1(a_1)$	$g_1(a_2)$	…	$g_1(a_n)$
g_2	…	$g_2(a_1)$	$g_2(a_2)$	…	…
g_4	…	…	…	…	…
g_5	…	$g_m(a_1)$	$g_m(a_2)$	…	g_m (a_n)

2.2.5 Aggregation and sensitivity analysis

Many multi-criteria models have been formulated since the 1960s, each one with advantages and disadvantages.

Munda (2005) defines the desirable properties that they should have when applied to environmental policies:

1) Simplicity, in order to guarantee consistency and transparency
2) non compensability, in order to avoid that a good economic performance can counterweight strong environmental or social impacts or vice versa.
3) intensity of preference should not be considered, in order to avoid compensability
4) use of weights as importance coefficients and not trade-offs[6]

The last step is the sensitivity analysis, which allows determining whether the final ranking changes when some assumption is changed.

Munda (2004) notes that the sensitivity analysis of the set of weights assumes a crucial importance in SMCE. In fact, weights are not decided by the social actors as in Participative Multi-Criteria Analysis but reflect some ethical position. For example, assuming a position for sustainable development implies giving the same weight to the social, the environmental and the economic dimensions; a higher sensitivity to the environmental problems would result in assigning more weight to the criteria belonging to the environmental dimension.

In this context, a sensitivity analysis can show which ranking is obtained with different ethical positions. In this way, the values underlying the decisions of the policy makers are made explicit, increasing public accountability and transparency.

[6] Weights can be trade-off or importance coefficients. The first ones show the intensity of preference and indicate how much of an advantage in a criterion is sufficient to compensate for a disadvantage in another criterion (for example, one might be willing to accept some environmental impact if it is compensated for by a sufficient economic income). The second ones indicate how important a criterion is without referring to its score, 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.

3 Applying SMCE to energy problems

This thesis intends to show how SMCE can provide a useful framework to structure an integrated analysis of energy policies[7], shedding light on aspects that would otherwise be ignored in a more partial or technocratic analysis. This is done through two case studies.

The first one deals with a conflict on rural electrification in Montseny Natural Park, near Barcelona. In this area, a debate on the way to solve a lack of electrification for isolated households arose in the early 1990s among the park administration (in favour of solar energy) and the owners and the inhabitants of the households (in favour of grid extension). A retrospective analysis shows the reasons at the basis of the two positions, providing some insight on the factors that favoured the diffusion of off-grid photovoltaic panels.

Like the analysis on electrification in Montseny, most SMCE performed up until now (e.g. de Marchi et al., 2000; Martí, 2001; Gamboa, 2003) were meant to evaluate the conflict raised by a project on a local scale. However, SMCE can be used also to evaluate policies on a larger geographical scale. The second application reported in this thesis is an evaluation of the Italian biodiesel policies. The objective is to assess whether to invest public resources to support biodiesel, as asked by the European Directive 2003/30/EC on biofuels, is an advisable strategy.

[7] Many application of MCA to energy policy can be found in literature (see for example Haralambopoulos and Polatidis, 2003; Cavallaro F. and Ciraolo L., 2005; Gamboa and Munda, in press). To my knowledge, there is only one application of SMCE to an energy policy (Gamboa and Munda, in press).

PART II

SOCIAL MULTI-CRITERIA EVALUATION OF RURAL ELECTRIFICATION. THE CASE OF MONTSENY NATURAL PARK

1 Introduction

1.1 Rural electrification and solar energy

Providing households with electricity was traditionally a task for public energy enterprises, whose capillary network reached in the last century most of the industrialized world. Notwithstanding that, this process is not over yet, and some of the most isolated rural regions are still to be electrified, especially in Southern Europe.

Grid-based electrification is more expensive in the countryside than in urban areas because rural population is more scarce and scattered and also consumption is normally lower. In areas with low population density, difficult terrain and long distances between households and to power plants, costs can rise up to several thousand euros per household (Gabler, 1998). As a consequence, in many cases on the one side it is not worth for electricity companies to finance the electric grid extension because the revenue per km of grid is much lower[1]. On the other side, single users cannot often afford the considerable expenses that rural electrification through the conventional grid implies.

The ongoing process of liberalization and privatization of the energy sector will probably worsen the problem. In fact, public enterprises also take into account public interests in their choices, and might decide to electrify isolated farmhouses, even though it is not profitable for them from a purely economic point of view. On the contrary, private enterprises that are competing in a liberalized market do not normally accept to make a non-remunerative investment, such as electrifying isolated areas.

Also, grid-based electrification is characterized by some drawbacks from an environmental point of view. In fact, in forested areas grid extension implies deforestation of a corridor along the power line and risks of fire. Pylons and cables of the electric grid can jeopardize avifauna because of possible collisions or electrocutions. Moreover, the electric grid also causes an aesthetic impact on landscape. The ecological 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.

Lack of electricity notably worsens life standards, hampers the development of productive activities and contributes to the countryside depopulation process. Also, it contributes to the marginalization of rural population, who feel that the state is not providing it with an acceptable level of public services.

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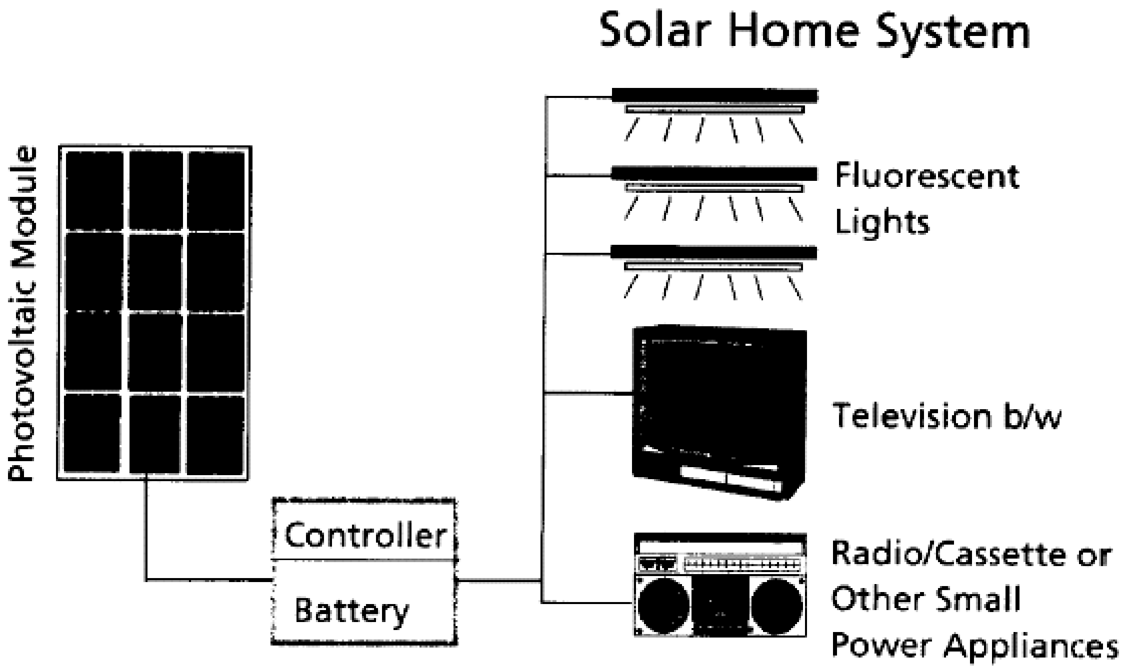
[1] Moreover, the ratio of average demand (which determines financial and economic benefits) to peak demand (which determiners investment cost) is much lower in rural than in urban areas, because in the latter energy is above all needed in the night time, whereas demand remains low during the day (World Bank, 1995).

In this context, renewable energy might represent a viable alternative to traditional electrification. In fact, in isolated areas renewable energy can turn out to be not much more expensive, and in some cases even cheaper, than conventional electricity, the cost of which is very high. Also, whereas costs for extending the electric grid do not depend on consumption, alternative sources are relatively flexible, i.e. the amount of the investment can be adjusted to the forecasted energy use. From a social and environmental point of view, the advantages of renewable energy are manifold: lower environmental impact, both on a local and on a global scale, decentralization, autonomy for local communities, high labour intensity and creation of specialized jobs.

For all these reasons, governments are (or should be) very interested in promoting renewable energy. For example, in the Green Book on renewable energy, the European Union committed itself to attaining, by 2010, a minimum penetration of 12% of renewables in the energy market (European Commission, 1996).

Solar energy is the most used renewable source for rural electrification. The so-called SHS (Solar Home System) is rapidly imposing itself as a suitable option. A SHS is a system that supplies a single dwelling with a small amount of energy, thanks to PV (photovoltaic) modules, a rechargeable battery for energy storage, a battery charge controller, one or more lights and other low-power appliances, as it is shown in Figure 1.1. Since power supplied by a SHS is very low, it can only be used for lighting and small household devices (Gabler, 1998; Ciscar, 97).

Figure 1.1 A typical Solar Home System



Source: Gabler, 1998

1.2 Solar energy and public policy

Unfortunately, even though solar energy is rapidly improving, it is still characterized by low intensity[2], dispersion and discontinuity, making it not (yet?) competitive with traditional energy from an economic point of view. The cost gap between solar and non-renewable technologies can be in part overcome by means of technological progress, which may allow building more and more powerful batteries, more efficient machinery, etc. Recent projections by the European Photovoltaic Industry Association report that the break-even point with conventional electricity is expected to be reached by 2010 in southern Europe and by 2020 in northern Europe (EPIA and Greenpeace, 2006).

At present, in order to be economically feasible, solar energy needs to be supported by public policies that modify relative prices. Subsidizing renewable sources is a necessary intermediate step for the sector to develop, until it is so technologically mature that it can compete with traditional sources. Also, PV penetration in the energy market needs a strong investment in research, which in turn is made possible by a strong expansion of the sector.

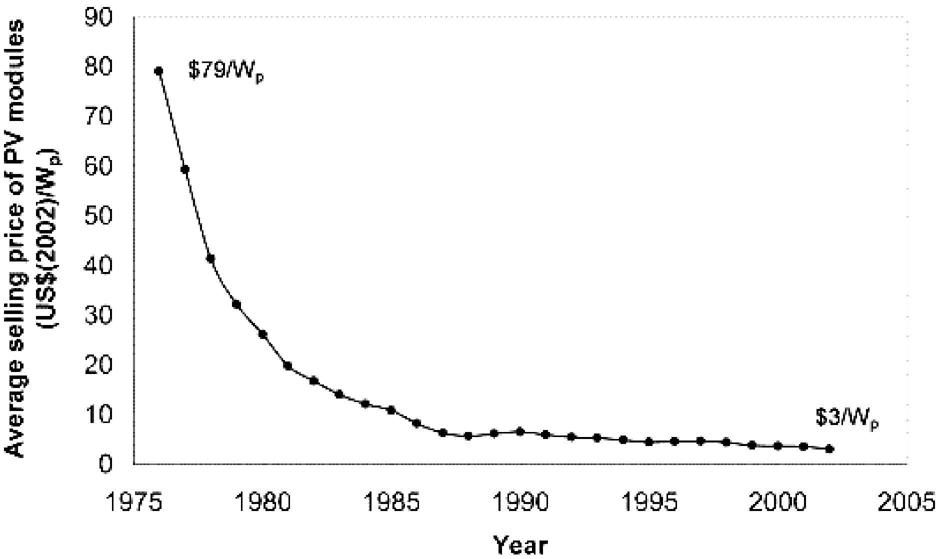
Rural electrification could be an interesting opportunity for promoting renewable energies because in isolated areas they become comparatively more economical than in an urban context. Niche markets where renewable energy is already competitive or almost competitive, such as remote stand-alone applications (Hoffmann, 2005), might play a key role in the process of PV affirmation on the market.

Renewable energy is expected to spill over from sectors where it represents a potentially viable option (such as PV stand-alone systems) to applications where a notable technological improvement is necessary to make it really attractive. The progressive penetration between market sectors is essentially driven by scale economies and learning-by-doing processes. If demand is strong enough in a niche market, it can stimulate investments that allow scale economies and technological improvements, which in turn can reduce prices and make PV economical for the next market segment (Masini and Frankl, 2002). This process might eventually drive PV technology to reach cost-competitiveness.

PV niche markets might be large enough to generate scale economies because the solar sector is still relatively young, and there is still much room for improvement. This progress is already taking place: the price of PV panels, both in terms of modules and of BOS (balance of system) dramatically decreased in the last years (see Figure 1.2).

[2] Some energy analysts use the term “low quality”, where quality is intended as capability of carrying out work.

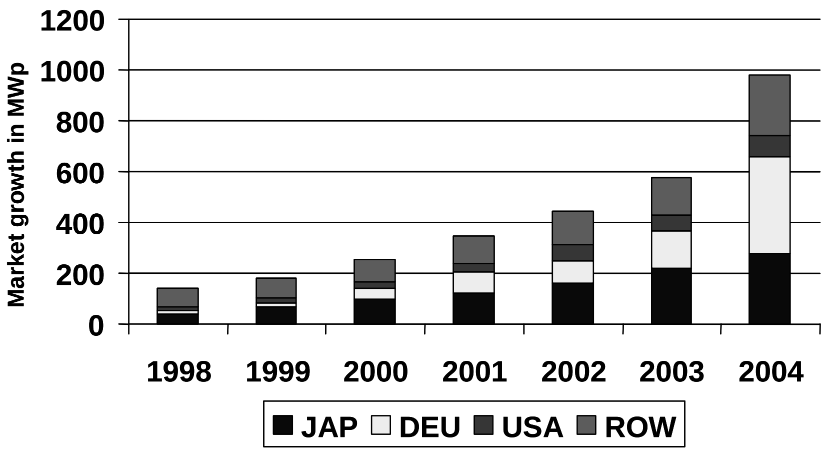
Figure 1.2 World Price for Photovoltaic Modules, 1975-2000, ($ per watt)



Source: Poponi, 2003

PV market is developing very fast, as can be seen in Figure 1.3. Probably the sector will be characterized by a strong growth at least for some years, because some countries, such as Japan and Germany, are implementing very resolute policy measures in favour of the sector, and other countries will probably follow this example[3] (Goetzberger et al., 2003).

Figure 1.3 Development of world PV market

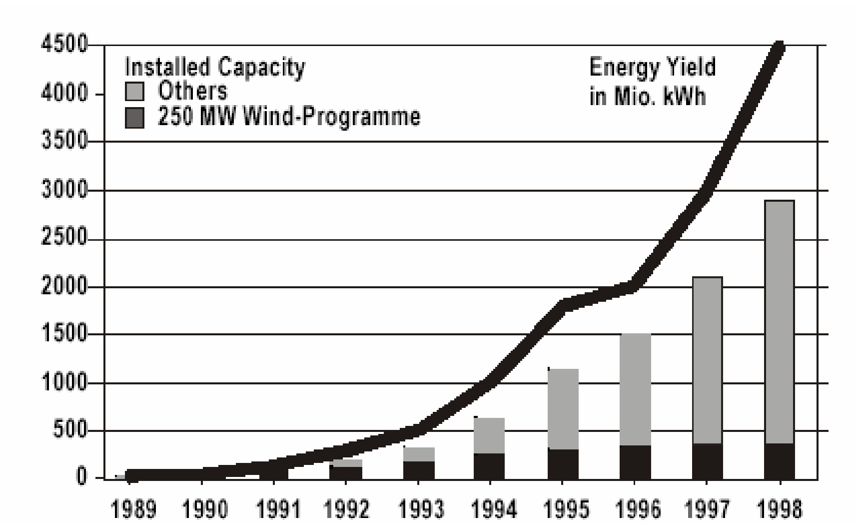


Source: Hoffmann, 2005

[3] See for example the Japanese 70,000 Roof Program, which allowed an increase by 63% of PV production in Japan. In Germany the 100,000 Roof Program, together with a law that establishes a rebate rate of 0.5 € for each kWh of electricity generated by means of PV, is strongly supporting the solar sector.

However, the State is an indispensable actor in the take-off of renewable energies. This idea can be well illustrated with an example. The impressive success of wind parks in Germany (see Figure 1.4) can be explained to a certain extent with the well-known ”250 MW Wind” funding programme undertaken by the central government in 1989 (Durstewitz and Hoppe-Kilper, 1999). In the early Nineties most of the wind power plants were built thanks to the programme subventions. In this way an industry and a market were created in Germany. Later on, subsidies were not so strongly needed and already since 1994 most German wind power plants had no financial support from the program. This policy allowed the German wind sector to become one of the world leaders.

Figure 1.4 Development of wind energy use in Germany



Source: Durstewitz and Hoppe- Kilper, 1999

1.3 Rural electrification and Social Multi-Criteria Evaluation

Keeping in mind what has been said so far, it can be argued that rural electrification might be a good chance for a strong public engagement in favour of renewable energy.

In fact, in the first place rural electrification is an important policy issue because it is a crucial prerequisite for improving rural life conditions, and reducing countryside depopulation. Secondly, the environmental impact associated with conventional electrification is higher in rural areas, in terms of risk of fire, possible damages to avifauna and deforestation. Thirdly, stand-alone (off-grid) photovoltaics is competitive or close to competitiveness in remote areas. As a consequence, with a relatively modest public support it can contribute to a “virtuous cycle” that might be fundamental in the solar energy taking-off process.

Rural electrification is hence a matter of public policy 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 are taken as transparently as possible, and that all involved actors can participate in them.

Social Multi- Criteria Evaluation (SMCE) appears to be an appropriate instrument to structure and analyze electrification policies. In fact, it improves the transparency of public decision-making and, by clarifying the pros and cons of the possible alternatives, clarifies which social group is favoured by each option. In this way it can be useful as a basis for debate among stakeholders, helping to reach an agreement.

This study analyzes the Tagamanent case in order to illustrate the main issues involved in rural electrification. In Tagamanent, a village located in Montseny Natural Park, near Barcelona, a conflict arose in 1994 on how to provide some isolated farmhouses with electricity. In this area, the Park administration launched in 1996 a programme for promoting and partly financing the use of solar energy in not yet electrified farmhouses. Most households installed PV panels, but many farmhouse owners kept asking for traditional electricity, claiming that solar energy was not covering their needs properly.

In order to understand the reasons of the conflict, I performed a retrospective SMCE, with the objective of understanding the factors which favoured the affirmation of solar energy and the pros and cons of each option.

The Tagamanent case-study is presented with two objectives: 1) to give a clear and simple illustrative example of the application of SMCE in the field of renewable energy policies; 2) to help understand to what extent and under which circumstances solar energy is suitable for electrifying isolated farmhouses, and offer public decision-makers some insight on the conditions that favour the diffusion of renewable energy.

This work is structured in the following way.

- Chapter 2 explains the methodology.
- Chapter 3 illustrates the results of the institutional analysis.
- Chapter 4 defines the alternatives and criteria used for the evaluation.
- Chapter 5 presents the criterion scores and the impact matrices.
- Chapter 6 builds a ranking among alternatives and performs a sensitivity analysis.
- Chapter 7 draws some conclusions, both on the methodology and rural electrification in Montseny Natural Park.

2 Methodology

I structured the retrospective analysis of the conflict on different modalities of rural electrification in the Tagamanent municipality, following the typical SMCE steps as indicated by Munda (2004) (see part I):

1) Definition of the problem (Chapter 1)
2) Institutional analysis (Chapter 3)
3) Generation of the policy options and choice of the criteria (Chapter 4)
4) Construction of the multi-criteria impact matrices (Chapter 5)
5) Aggregation of the criteria scores and sensitivity analysis (Chapter 6)
6) Discussion on the results (Chapter 7).

2.1 Institutional analysis

First of all, I pieced together the chronology of the conflict, using information obtained from all documents related to the conflict that I could find in the archives of the Municipality and the institution that manages the Park, the *Servei de Parcs Naturals* (SPN). Moreover, I carried out two open in-depth interviews with the SPN technician in charge of the issue and with the Tagamanent Mayor, which allowed reconstructing the different stages of the conflict.

By means of the research in the archives and the in-depth interviews, I individuated the relevant social actors. At first, only three groups of social actors emerged: the public actor, represented by the Park administration (SPN), the Municipality and the potential users of electricity. However, as the research went on, it became clear to me that I had to include another group of social actors in the analysis, i.e. the owners of the isolated farmhouses that were not living inside the Park but decided to lease their properties. In fact, most Montseny inhabitants are leaseholders.

Also, some open in-depth interviews with owners and inhabitants allowed me to ascertain their values, desires and preferences. The interviews were used for identifying the activities actually carried out in the farmhouses, as well as the plans and the interests of their owners or leaseholders. Also, they helped to identify the objectives, the resources of the social actors and the interaction patterns among them.

Table 2.1 shows the interviews to social actors, which were carried out between May 2003 and February 2004.

Table 2.1 Interviews to social actors

N.	Date	Social actor interviewed	Modality
1	May 2003	Mayor	Face to face in-depth interview
2	April 2003		Face to face in-depth interview
3	May 2003	SPN technician in charge with rural electrification	Face to face in-depth interview
4	May 2003	People running a restaurant in a farmhouse belonging to the Park administration - Bellver	Telephone interview
5	December 2003		Face to face in-depth interview
6	May 2003	Owner of a farmhouse a little livestock farming (caws) and a some land to cultivate - Figuera	Telephone interview
7	May 2003	Owners of a little pension – La Vila	Telephone interview
8	December 2003		Face to face in-depth interview
9	December 2003	Inhabitant of a rented house - El Cruells	Face to face in-depth interview
10	June 2003	Owner of a farmhouse in ruinous conditions that was not planned to be immediately restored at the moment of the interview - La Codina	Telephone interview
11	June 2003	Inhabitant of a rented house - Soler	Face to face in-depth interview
12	February 2004	Owner of a farmhouse, which he and his family use a second residence - Bellit	Face to face in-depth interview
13	February 2004	Owner of a farmhouse, which he and his family use as a second residence - Castellseguer	Face to face in-depth interview
14	February 2004	Owners of a farmhouse, which they are rehabilitating in order to live there and carry out some primary activities	Face to face in-depth interview

Finally, two interviews with Martí Boada, a natural scientist who has been studying Montseny for decades, were of big help for knowing the history and the general characteristics of the park, as well as the strategy of the Park administration over the last twenty years and the problems that the Park management faces.

2.2 Generation of the policy options

The third step of a SMCE is the generation of the policy options. It would have been possible to evaluate various projects because between 1996 and 1998 different electrification plans were drawn by the Municipality (in favour of an electric line) and by the Park administration (which tried to promote solar energy) in order to convince the counterpart. However, for the reasons that will be explained later, I decided to analyze the original projects that initiated the debate in 1998.

2.3 Construction of the multi-criteria impact matrices

In order to formulate the criteria, I asked the interviewed social actors which were the factors that they considered important when choosing among different modalities of rural electrification. However, for the reasons explained in Part I, even though I used the information obtained through the interviews when structuring the problem, I was the one who chose the alternatives and defined the final set of the criteria. In fact, according to Munda (2004), in SMCE the participation should be used as an input to the problem structuring but alternatives, criteria and weights should not derive directly from participation.

In the Tagamanent case, a further reason not to derive the set of criteria directly from participation is that the preferences differed even among the people belonging to the same group, making it necessary to choose a set of criteria that tried to represent the point of view of the majority within each group

However, I did discuss the criteria with some of the social actors, in order to make sure that they represented their point of view.

I assigned scores to the criteria with the help of experts in various disciplines. Table 2.2 shows the interviews to experts carried out and the criteria scores that they helped define. Also the social actors were asked about their point of view on the performance of the criteria in the alternative options.

Table 2.2 Interviews with experts

<table>
<tr><th>Criteria</th><th>Experts interviewed</th><th>Institution</th></tr>
<tr><td>Grid extension cost</td><td>Technician in charge of rural electrification</td><td>FECSA (electricity company)</td></tr>
<tr><td>PV cost</td><td>PV installers, who used to work for SEBA (which installed PV panels in Montseny)</td><td>• Ecotecnia
• TMF</td></tr>
<tr><td>Risk of fire</td><td>Expert in forest fire prevention</td><td>Servei de Prevenció d'Incendis Forestals, Departament de Medi Ambient, Direcció General de Prevenció de Riscos del Medi Natural (Forest Fire Prevention Department of the Catalan Government)</td></tr>
<tr><td>Deforestation</td><td>Technician in charge of rural electrification</td><td>FECSA (electricity company)</td></tr>
<tr><td>Risk for birds</td><td>Ornithologist expert in damage to avifauna provoked by electric lines</td><td>Animal Biology Department, Barcelona University</td></tr>
<tr><td>Greenhouse gas emissions</td><td>Expert in Life Cycle Analysis</td><td>Instituto de Ciencia y Tecnología Ambiental (ICTA, Institute for Environmental Science and Technology), Autonomous University of Barcelona</td></tr>
<tr><td>Impact on landscape</td><td>Biologist</td><td>Centre de Recerca Ecològica i Applicacions Forestals (CREAF, Centre for Ecological Research and Forest Studies), Autonomous University of Barcelona</td></tr>
<tr><td>Comfort</td><td rowspan="2">PV installers, that used to work for SEBA (which installed PV panels in Montseny)</td><td rowspan="2">• Ecotecnia
• TMF</td></tr>
<tr><td>Reliability</td></tr>
</table>

Finally, I synthesized the information on the criterion scores in the Multi-Criteria Impact Matrix, which presents the performance of each alternative according to each criterion.

2.4 Aggregation of the criteria scores and sensitivity analysis

I used the method proposed by Munda (2005a and 2005b) to aggregate the information gathered in the impact matrix and define a ranking among the alternatives (see Part I).

The last step of a SMCE is the sensitivity analysis, which allows assuring the robustness of the analysis by changing some assumptions and verifying whether the final ranking varies.

Since I attributed the same weight to each criterion, the weight of the environmental, social and economic dimensions depended on the number of criteria belonging to it.

I performed a sensitivity analysis by giving the same weight to the three dimensions, along the line of the sustainable development concept.

3 Institutional analysis

3.1 The problem at hand

3.1.1 The context

Montseny Natural Park is situated in northern Catalonia, between Girona and Barcelona (see Figure 3.1). It is only 40 km from the Barcelona metropolitan area, and for this reason it is a very popular place for weekend outdoor excursions. It was declared a Biosphere Reserve by UNESCO in 1978. 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 from 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[1] (Boada and Juncà, 2002).

From a social point of view, diversity of Montseny can be partly explained as the outcome of a very long history of interactions between humans and ecosystems, since the presence of humans moulded its landscape throughout the centuries[2].

Most farmhouses inside the Park were built centuries ago by *carboneros* (charcoal makers), farmers and stockbreeders and they constitute an important architectonic heritage. Most were abandoned due to the structural change that took place in Catalonia when the traditional activities became less profitable and oil replaced 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 it is one of the political priorities of the Park administration because if left uninhabited the old farmhouses quickly degenerate to ruins. In fact, they require continuous maintenance, because, among other reasons, of the hard meteorological conditions.

However, in the last few 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.

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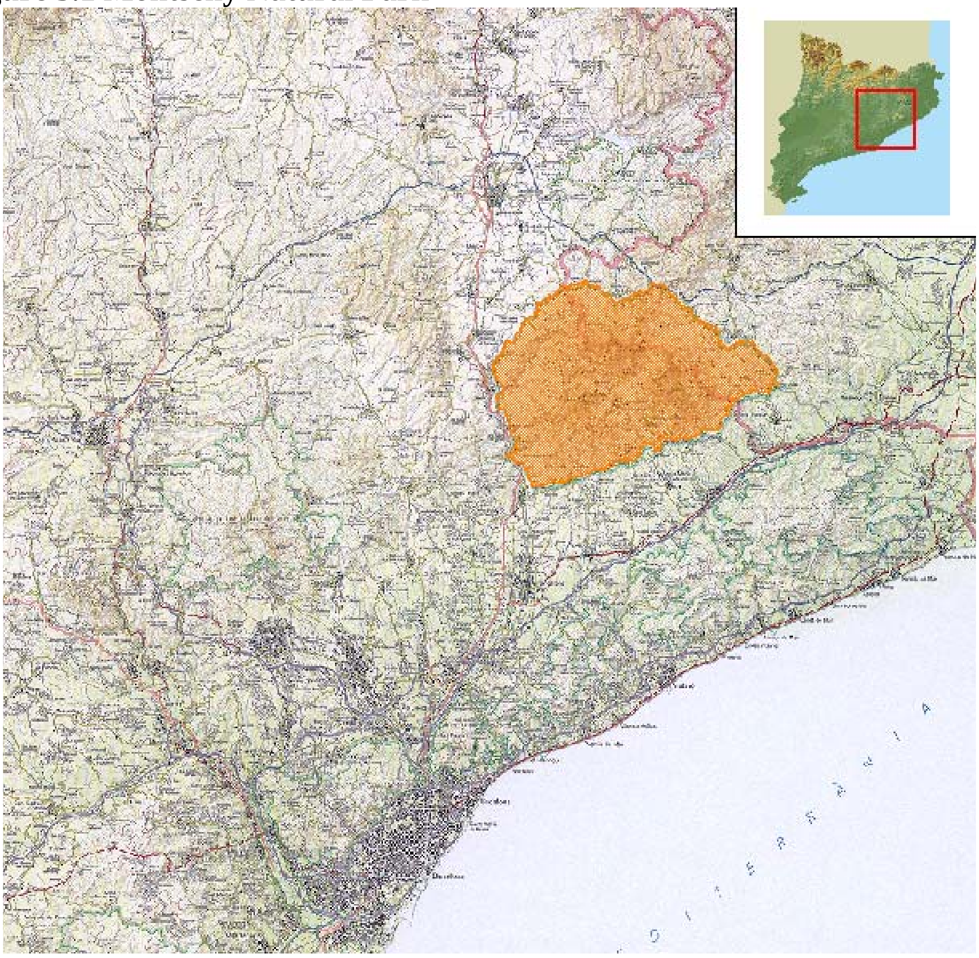
[1] The middle European and the northern European biomes represent the inheritance of the last glacial period, ended 10,000 years ago.

[2] 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.

Figure 3.1 Montseny Natural Park



Source: Panareda et al., 2003

3.1.2 Legal framework

The Special Plan of Montseny Natural Park establishes a co-management of the Girona and Barcelona province administrations (Girona only controls around 6,000 ha). Privates own almost 87% of the Park territory, whereas 12% belongs to the 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 €.

The establishment of the Natural Park implies a strong control on the activities carried out, in order to reduce all kinds of environmental impact. Inside the Park authorization must be asked for every modification to the landscape. It is not possible to construct new buildings, but only to restore existing farmhouses.

With regards to the regulations on electric lines, the Special Plan states that studies are required on their location in order to prevent the landscape from being altered. Electric lines must respect some aesthetic and environmental criteria (for example, the poles must be painted green or grey, according to where they are installed).

Also, a favourable report by SPN is needed to extend the electric grid inside the Park.

3.1.3 Chronology and interaction pattern

In order to solve the electrification deficit inside the Park, in 1994 SPN commissioned SEBA (*Associació de Serveis Energètics Bàsics Autònoms*, Autonomous Basic Energy Services Association) to write a report on the electrification deficit in the Park (Trama Tecno Ambiental, 1995). SEBA is a non-profit association founded in 1989 by solar energy users in order to support the installation of stand-alone photovoltaic systems (PV) in isolated households.

SEBA identified 105 unelectrified farmhouses (16 in the Tagamanent municipality), prompting SPN to undertake a rural electrification plan in Montseny Natural Park, with the objective of promoting stand-alone PV systems.

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, insurance and free maintenance. The reason for 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 systems are installed, with the consequence that in case of breakdowns users find themselves in difficulties (Vallvé and Serrasolses, 1997).

The solar systems 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 expenses, whereas SEBA financed 34% thereof 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 out well. Between 1995 and 2000 it managed the electrification of 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 the Tagamanent municipality (235 inhabitants, 43.48 km^2), PV was not really accepted and the programme reinitiated the debate on rural electrification, which was already an issue.

In fact, in 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 to provide electricity to the unelectrified farmhouses in Tagamanent. However, SPN did not approve of 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 resulted in terms of deforestation and risk of fire.

Because an agreement did not seem easy to reach, SPN commissioned SEBA to carry out a second study, this time focused only on Tagamanent (Trama Tecno Ambiental, 1998). Unsurprisingly, since SEBA is an association that promotes off-grid photovoltaic systems, the conclusion was again that the best modality for rural electrification was solar energy.

In the following years PV systems were installed in 7 out of the 24 scattered farmhouses in Tagamanent, as shown in Table 3.1. However, as it will explained in more detail in Chapters 4 and 5, the amount of installed PV power was less than that theoretically necessary to supply enough electricity in the lower irradiance winter months.

Table 3.1 Farmhouses in Tagamanent municipality situated inside the Park that have installed solar systems

N	Farmhouse	*Finca*	Use	Superficie (ha)	User	Electricity supplied[3] (kWh/month)
1	El Clot de la Móra	El Clot de la Móra	First residence	450	Leaseholders	67
2	El Bellit	El Bellit	Second residence	300	Owners	50
3	El Cruells	El Cruells	First residence	57	Leaseholders	67
4	El Bellver	El Bellver	Restaurant	287	Lease-holders	56
5	La Caseta del Clot	El Clot de la Móra	Second residence		Owners	11
6	La Vila	La Vila	Rural pension	10	Owners	167
7	El Soler	El Soler	First residence	92	Leaseholders	67

Source: Trama Tecno Ambiental, 2000

Most of the non electrified farmhouses were in ruins[4], or abandoned, as shown in Table 3.2.

[3] One kWp produces around 66 kWh/month under winter season irradiance (1,300 kWh/m^2 per year).
[4] Electrification could be a good incentive to repair and use the farmhouses in ruins in two ways. In the first place, it is easier to repair a house with electricity. Secondly, electricity might be a strong incentive to repair the houses, because it implies the possibility of starting a business, such as a restaurant or a rural pension. This is an important aspect, because the cost of rehabilitating a ruin is very high, making it unlikely for owners to take it upon themselves if they are not able to obtain an income from their property.

Table 3.2 Farmhouses in Tagamanent municipality situated inside the Park that have no installed solar systems

N.	Farmhouse	*Finca*	Sup. (ha)	Use	User
1	Vallforners	Vallforners	700	None	Nobody
2	Casanova de Vallforners			Sheep breeding?	?
3	El Forn del Vidre			Ruins	Nobody
4	La Codina	La Codina	250	Ruins	Nobody
5	La Perera	El Clot de la Móra	450	None	Nobody
6	Castellsaguer	Castellsaguer	40	Owners	Second residence
7	La Figuera	La Figuera	600	?	?
8	Els Fondrats			None	Ruins
9	Viladerbó	Viladerbó	237	First residence/ breeding?	Leaseholders
10	Can Perellada	Can Perellada	3	?	?
11	Casanova del Bellit	El Bellit	300	None	Ruins
12	Jaça del Bellit			None	Ruins
13	Masovería del Bellver	El Bellver	287	SPN	Agriculture/ Breeding
14	Les Planes	L'Augustí	190	None	Ruins
15	L'Augustí	L'Augustí		SPN	Eco museo
16	El Passarell	L'Augustí		None	Ruins
17	Santuari del Tagamanent	Santuari del Tagamanent		?	?

Source: Trama Tecno Ambiental, 2000

Even after the installation of the PV systems, the conflict between the Mayor, supported by most farmhouse owners (in favour of grid extension) and SPN (in favour of PV systems) has not been solved. During the following six years, many projects on rural electrification of scattered farmhouses in Tagamanent followed each another, comparing prices of PV and grid extension but the social actors did not reach an agreement.

In some heated meetings, Tagamanent Mayor unsuccessfully tried to convince SPN to grant electric line extension with the same incentives promised for PV systems and also to contribute to the expenses with the two properties owned by SPN (a restaurant and an ethno-museum). Without these two conditions, conventional electric grid would be very expensive.

3.1.4 The social actors

After Martí (2001), in this section the groups of social actors are presented, together with their objectives, their position on rural electrification and their resources. The information gathered was useful in understanding the behaviour of the social actors in the conflict on rural electrification, which began in the early Nineties.

Servei de Parcs Naturals (SPN)

Description. *Servei de Parcs Naturals (Natural Park Service)* is the institution that administrates Montseny Natural Park. It depends on the Barcelona province (*Diputaciò*). When the analysis was carried out *Diputació* was controlled by PSC (Catalan Socialist Party), the main social-democratic party, which was also governing both *Generalitat* (since December 2003) and Barcelona municipality. The institutional task of SPN was the preservation of Montseny environment.

Objectives. The interviews and the documents produced by SPN clarified that its main objective was to protect the *status quo* inside the Park as much as possible. This means that it wanted to prevent new economic activities from being set up inside the Park which could cause some environmental impact. SPN was not in favour of massive tourism, because it would imply risks of fire and possible damage to ecosystems. What it tried to spur was a moderate, informed, and well-educated tourism. The technician in charge of rural electrification explained to me the objectives of SPN as follows:

"Por un lado el Parque tiene como objetivo y como tarea favorecer que la gente viva dentro el Parque y que no haya despoblación, que se mantengan las actividades tradicionales, que se mantenga la vida en el Parque, que se mantenga el patrimonio, las casas, etc., los ecosistemas que dependen del hombre. El Parque del Montseny es una reserva natural de la biosfera precisamente por esto, por que su objetivo principal es mantener la relación entre hombre y naturaleza que ha hecho posible estos paisajes. La perdida del hombre dentro del Parque comporta también la pérdida de ecosistemas"[5].

Moreover, since SPN had a limited budget, it had to minimize its costs. Also, as part of the Public Administration, SPN had to try to choose options characterized by a low cost for the entire society. Concluding, its objectives can be summarized in this way:

⇒ **ECONOMIC DIMENSION: cost minimization, both for for SPN and for society**
⇒ **ENVIRONMENTAL DIMENSION: environmental protection**
⇒ **SOCIAL DIMENSION: integration between human and environmental system**

Position on electrification. SPN was interested in the electrification of the isolated farmhouses because it was a way of helping the repopulation of the Park. In fact, nowadays few people would be willing to live without electricity. As already explained, human presence is indispensable for maintaining the architectural and natural patrimony of the Park: if the farmhouses are left alone, they become ruins in few years.

[5] *"On the one side, the Park has the objective and the task to favour that the people live inside the Park and that there is no depopulation, that the traditional activities are maintained, and that life is maintained inside the Park, that the patrimony, the houses, etc., the ecosystems that depend on humans, are maintained. Montseny Park is a natural reserve of biosphere precisely for this reason, because its main objective is maintaining the relationship between men and nature, which made possible these landscapes. The loss of the human presence inside the Park implies also the loss of the ecosystems"*

However, SPN was only in favour of electrifying by means of PV systems and strongly against the possibility of extending the conventional electric line. Montseny rural electrification program through PV systems was promoted by SPN, which financed around 45% of the necessary investment. On the contrary, SPN wrote a negative report on the Municipality's project on the electric grid extension. This position has been very firm during the last ten years.

SPN's strong opposition against traditional electrification can be explained with different reasons. First of all, the electric line would have caused an environmental impact, in terms of deforestation, risk of fire and damage to avifauna. Also, electric poles and cables would have had a visual impact.

Secondly, putting PV systems instead of extending the electric line was also a way of hindering the economic activities that would possibly cause an environmental impact inside the Park. In fact, the energy provided by PV systems was not enough to support the use of big machinery. This is consistent with SPN's strategy.

Thirdly, SPN was also interested in promoting an environmentally friendly image of the park, and in reaching the Park's independence in energy terms. Moreover, the environmental education allowed by PV systems was another important factor for SPN. In fact, people owning solar systems get used to sparing energy and in general become more aware of energy issues than others do. For example, they have to know how much energy each household appliance uses in order to organize themselves according to solar energy availability.

Resources. SPN had legal and economic resources for pursuing its objectives. First of all, it had the legal power of writing a negative report and hindering the grid extension (art. 22.6 of the Special Plan and 5.2 of Generalitat's 105/87 Decree). Secondly, SPN could modify the relative prices between two options by granting some funds to one of them. Thirdly, SPN could obstruct any electrification project in Montseny Natural Park by means of not participating in it with its two properties. In fact, if SPN's farmhouses do not share the cost, electrification becomes too expensive for the others. SPN used these three resources for hampering the electric line extension in the Tagamanent municipality.

Tagamanent Ajuntament (Municipality)

Description. Tagamanent town council consists of five councillors, including the Mayor. At the time of this analysis, the Mayor was from CiU (the Catalan nationalist centre-right party, which uninterruptedly governed Catalonia between 1980 and 2003), and this could perhaps in part explain the conflict with the administration of the Park, which depended from Barcelona province (*Diputaciò*), governed by the social democrats.

Objectives. In the Tagamanent municipality, the most active person in the rural electrification issue was the Mayor. His objective was to improve the conditions of the Montseny farmhouses. According to his opinion, the only way to assure that the farmhouses would not be abandoned was to increase the comfort and the services supply inside the Park.

Moreover he presumably wanted to demonstrate to its electors that he was doing a good job. In order to reach this aim, he had to show commitment towards improving life conditions for Tagamanent inhabitants. Promoting rural electrification of the scattered farmhouses inside the Park could notably help him reach this objective. He could obtain much gratitude from Tagamanent inhabitants if he could boast having enabled electrification of isolated zones.

Position on rural electrification. The Mayor had been trying for many years to convince SPN to allow extending the electric grid to the isolated farmhouses inside the Park. Also, the Mayor had been putting pressure on SPN to persuade it to financially contribute to the grid extension in two ways: 1) contributing to the costs of electric grid extension (SPN owned two properties in Tagamanent municipality); 2) granting conventional electric grid with subsidies. The failure of these attempts produced resentment against SPN.

The main reasons why the Mayor wanted to promote the grid extension were two. Firstly, he claimed that traditional electricity did not imply limits on consumption, so it could increase comfort more than PV. Secondly, he thought that PV did not supply enough energy to found economic activities that required some machinery, such as for example small dairies. In other words, even if PV was cheaper (because subsidized and because only a limited amount of power was installed) it had a very high opportunity-cost. It can be noted that this was a positive aspect of PV systems for SPN, because it contributed to hinder industries that could cause an environmental impact.

Another factor that could explain the Mayor’s strong opposition to PV systems was the feeling of discrimination that is common among people living in rural areas with respect to people living in cities. In fact, whereas with conventional electric grid one only had to turn the switch on and have as much electricity as he or she was willing to pay, PV system owners had to worry on whether batteries were be charged enough or whether they were using too much household equipment at the same time.

Also, supply security was an issue: PV systems were not perceived as reliable electricity providers[6].

Other arguments in favour of the electric grid extension were flexibility (installing some new machinery implied increasing the contracted power in the case of traditional electricity, and installing more power in the case of solar energy, which

[6] This is a curious issue: supply security was also mentioned by SPN technician but it was used to defend solar systems. In fact, he stated that providing isolated farmhouses with electricity was not a good business for the electricity company, because of the low revenues, with the result that normally in rural areas the grid was not properly maintained. The consequence of this would be frequent black outs.

was more expensive) and insecurity on the prices (whereas prices and conditions of the conventional electricity supply were regulated through a Decree at a state level, PV system prices seemed to be much more arbitrary).

Another interesting issue to be noted is that the Mayor claimed that electricity is clean. This is not wrong if one considers the scale Tagamanent residents are interested in. At a local end-use scale, conventional electricity is really clean, no matter if produced with nuclear energy or with fossil fuels. On the contrary, electricity generators used in some farmhouses for complementing PV systems produced polluting emission and noise at the end use-level. In the same way, solar energy supporters did not seem interested in saving CO_2, but in avoiding local environmental problems, such as risk of forest fire, bird electrocution and deforestation[7]. In other words, scale matters (Giampietro, 2004).

Also, risks of fire or deforestation did not worry the Mayor very much. According to his opinion, the amount of deforestation needed to extend the electric grid would not be a problem, since forests were steadily increasing in Catalonia.

In this study the Mayor's point of view was assimilated with the one of the owners. In fact, as he pointed out, he limited himself to representing their point of view.

"A ver, nosotros íbamos siempre de acuerdo, Ayuntamiento y propietarios. Intentamos montarlas, y hacer la petición conjunta con todos los propietarios, que era de lo que se trataba, y el Ayuntamiento hizo un poco de interlocutor"[8]

Resources. The Mayor could use as resource his political weight as representative of one of the municipalities included in the Park. Also, he had the power to allow or not allow any modification of landscape or farmhouses. Since the municipality was very small, the financial resources at his disposal were not enough to finance the grid extension, so the only way to reach his objective was to persuade SPN to pay for it.

Owners

Description. Most Montseny properties belonged to few families of landowners who had been there for many generations. Owners did not usually live inside the Park, but they lived in the towns nearby (with some exceptions). Some of them rented their farmhouse to neo-rurals (people who were born and lived in cities and decide to live in rural areas), whereas some left them unoccupied or used the surrounding land as pasture for their cattle, which they entrusted to local breeders.

[7] In a sense, this is reasonable, because the emissions of few isolated farmhouses are not really significant, if compared with the total emissions of a country: sparing energy at this level would not really contribute to a relevant reduction of the greenhouse effect.

[8] *"Let's see, we always agreed, the Municipality and the owners. We tried to install [the grid] and to present a joint application together with all owners, which was what all was about, and the Municipality acted as an interlocutor".*

Objectives. Montseny owners did not want to permanently live inside the Park, because it would have implied to give up some comfort. They had a long-term perspective: they did not need an immediate profit (they had sufficient means not to need further incomes), but they were interested in increasing the value of their properties. In fact, there were some farmhouses that were abandoned because the owner preferred to let them fall apart than rent them to unknown people and lose control over their property. However, with appropriate infrastructure in terms of communication, electricity, etc., they could have thought about setting up an economic activity such as a restaurant or a rural tourism pension.

Also, owners belonged to few rich families with a long tradition in the Montseny area. Probably, part of the reasons why they kept buying farmhouses (such as in the recent case of La Codina) or not selling them had to do with their relationship with the Park. They wanted to extend their control on the Park and help preserve it. In other words, owners were not only interested in getting an income from the Park, but also environmental protection was important to them. In any case, the two objectives were interrelated, especially in the case of tourist activities: if the environment were compromised, the income would be lower.

Another aspect to consider is that there was a widespread feeling that rural areas were discriminated with respect to cities, because they were provided with a considerably lower level of services. Also, in many cases the owners felt that their contribution in maintaining the architectural and natural patrimony of the Park was not sufficiently recognized. Human presence was necessary to maintain the particular landscape of the Park, which was a product of a long history of interaction between agriculture, forest exploitation, breeding and natural ecosystems. Therefore, the owners whished that their effort would be compensated for by the Public Administration, giving them more subsidies and facilities.

Summarizing, three main objectives can be defined for owners:

⇒ **ECONOMIC DIMENSION: income maximization/cost minimization**

⇒ **ENVIRONMENTAL DIMENSION: environmental protection**

⇒ **SOCIAL DIMENSION: reduction of disparities with respect to urban population**

Position on rural electrification. Most owners were not interested in installing solar systems because they did not live in the farmhouses. The solar systems had a limited lifetime (the batteries were expected to last between ten and fifteen years, the solar modules and the structure about twenty and the regulating machine fifteen[9]). For this reason, in general it did not make sense for the owners to buy a photovoltaic system if they did not have it in mind to use their farmhouses in the short term.

On the contrary, traditional electrification could have brought long-term benefits. In fact, electrification would have allowed running some economic activities such

[9] Personal communication of a PV installer working for the company TMF (December 2003).

as restaurants and rural pensions, or eventually renting the farmhouses at a higher price. In any case, it would have raised the value of the farmhouses. Moreover, some owners showed a strong distrust against PV systems, which was in part due, besides the limitations of solar energy, to prejudices and in part to a feeling of discrimination with respect to urban areas, where there were no limits on electricity use and electrification was very cheap and easy to obtain.

In principle, most owners would have preferred the traditional grid to PV systems. However, they were not willing to undertake the entire cost, which was quite high. Instead, they asked *Servei de Parcs Naturals* (SPN) to partly finance the grid, as part of the subventions in infrastructure granted to the farmhouses inside the Park, as a way to compensate for their effort in maintaining a public patrimony.

Some owners did not want to pay for electrification because they did not live in the farmhouses and did not want to invest in them. These owners were neither in favour of PV systems nor of the traditional electric grid.

Resources. Owners could count on their vote to influence public authorities. The vote was particularly influent in the municipality elections, since the Tagamanent inhabitants were only around two hundred. Also, they could influence SPN’s decisions because they owned a considerable part of the park, so they could exercise a certain pressure. Moreover, they could determine the success or failure of an electrification program by deciding to join or not to join it. This was especially true in the case of the electric line extension, the cost of which depended on how many people would share the expenses.

Inhabitants

Description. Most people living in Montseny Natural Park came from outside, often from cities. They decided to move to the Park because they liked nature and wanted to live in a beautiful, peaceful and healthy environment. For some of them this choice had a strong ideological meaning, which had to do with the rejection of the stressful routine and unsustainable habits of modern cities and with the search for an alternative way of life. They escaped from the chaos and the pollution of the city, but they wanted to stay nearby, in order to enjoy its services and opportunities. Most worked in Barcelona and did not live on agriculture.

In exchange for the privilege of living in such an enchanting place they were willing to suffer some disadvantages, the most serious one being the difficulty in communication (the path to their houses was often in very bad conditions). In the inhabitants category the people running the restaurant El Bellver (rented from the Park administration) were also included. In fact, even though they did not live inside the Park, they leased the restaurant and their interests could be assimilated to those of the inhabitants.

In the Tagamanent municipality most Park inhabitants were leasing the farmhouse where they lived. Only two of the farmhouses were inhabited by the owners. The first one was a rural pension called La Vila. The second one was being repaired by neo-rurals coming from the city, who wanted to set up some activity in the primary sector (above all biological agriculture), and eventually a rural pension.

Objectives. One of the most important objectives of the inhabitants was to minimize their expenses, and to benefit from as much public money as they could for improving their houses. Like the owners, they expected the public administration to financially help them because they were indispensable actors for maintaining the Park diversity. Moreover, some inhabitants ran economic activities, mostly in the tertiary sector. Therefore, they were interested in gaining as much income as they could from them.

As already explained, most Montseny inhabitants came from the cities because they were attracted by the beauty of the environment. As a consequence, they wanted the environment to be protected.

Moreover, the inhabitants suffered from the lack of services with respect to urban population probably more than the owners did. In fact, they had to experience everyday the discomforts and the difficulties of life inside a Natural Park.

Finally, the inhabitants were very interested in the reliability of the services, especially if they were running an economic activity. Therefore, the modality of rural electrification had to guarantee that they could use energy whenever they need it.

The objectives of the inhabitants can be resumed as follows:

⇒ **ECONOMIC DIMENSION: Income maximization/costs minimization**
⇒ **ENVIRONMENTAL DIMENSION: Environmental protection**
⇒ **SOCIAL DIMENSION: Reduction of disparities with respect to urban population**

Position on rural electrification. The inhabitants wanted to have a sufficient amount of energy at a reasonable cost. Most were not interested in the energy source in itself, even though some were in favour of solar energy for ideological reasons. However, if the costs had been the same, most would have preferred traditional electricity from the grid, because it imposed no limits on consumption. For the inhabitants, the reliability of the energy supply was also very important, especially for those running a hotel or a restaurant. In this sense, they wanted to be assured that the installation (either PV or electric line) would work well.

Resources. The main resource that the inhabitants had at their disposal was their vote. As already said, votes could be a notable pressure instrument in the municipal elections because of the reduced dimensions of Tagamanent. Also, like the owners, the inhabitants could decide whether to participate in a rural electrification plan, largely determining its success or its failure.

4 Problem structuring

4.1 Alternatives

Many projects were drawn between 1996 and 1999 by SPN and the Municipality, including different farmhouses. However, I decided to analyze the projects published in the second report on rural electrification that SEBA made for SPN (Trama Tecno Ambiental, 1998) for three reasons.

First of all, they were elaborated better and more information was available on the route, on the length of the line and on the costs, making the definition of the criterion scores easier. Secondly, they were the first projects that compared the different aspects of the alternative modalities of rural electrification for Tagamanent municipality, initiating the debate among the social actors. Finally, these projects comprised almost all the farmhouses present in the area (they excluded the ruins that were not planned to be restored). On the contrary, the projects prepared afterwards only included few farmhouses, because, since some PV systems had already been installed, many owners were not interested in electricity from the grid anymore.

After SPN refused to give its approval and to finance the electric grid extension, PV systems were installed in many farmhouses that were not ruins (7 out of 14). I performed a retrospective analysis in order to explain the reasons for this choice. The objective was to clarify which factors favoured the affirmation of solar energy, and the pros and cons of each option.

The three alternatives analyzed for the 14 households to be electrified were the ones formulated in the report by SEBA (Trama Tecno Ambiental, 1998):

1) Electric grid extension in one single stretch, like in the FECSA project of 1996. It included 12.2 km of middle voltage line (25 kV) and 3 km of low voltage line (380V), seven current transformers, of 50 kVA each, and 81 metallic towers. The total cost was 110.82 million PTAs (around 666,000 €).
2) Electric grid extension by means of two stretches, and with some environmental measures, as proposed by SEBA. The total cost was 121.54 million PTAs (about 730,000 €).
3) Stand-alone PV systems.

For the latter alternative, it was assumed that the need for electricity was similar to the average electricity consumption of Spanish households (192 kWh/month).

In SEBA’s report, the cost of solar energy was notably lower than that of traditional electricity. This was due to the fact that the cost was calculated for very low levels of consumption (on average 84 kWh/month). However, I thought it would have been more correct to compare PV and grid extension, assuming that the consumption would be the same.

Therefore, the following assumptions were made regarding the PV option:

• The energy requirement would be 192 kWh/month per household = 2688 kWh/month in total. This was done with the purpose of setting the playing field level, assuming that the people in the park would require the same amount of electricity irrespective of the technological option whereby such electricity was to be provided.

• This amount of electricity would have to be guaranteed even during the winter months. Therefore, considering an average irradiance in winter equal to 1,300 kWh/(m^2*yr) and a cautelative assumption of a 60% performance factor (accounting for power losses caused by atmospheric depositions, orientation, etc.), I calculated an overall requirement for 40.6 kWp installed power.

• Costs were evaluated according to SEBA's estimate of 18.3 €/Wp, plus 240 €/yr for maintenance.

• The replacement cost for PV components was also included in the analysis, assuming that the batteries would have to be replaced after ten years, the solar modules and the structure after twenty years, the regulating machinery and inverters after fifteen years[1].

The choice between traditional electricity and PV systems was analyzed from the point of view of three groups of social actors: firstly the public administration (SPN), secondly the owners of the farmhouses and thirdly the inhabitants. In fact, decisions on rural electrification had to be taken at three levels.

a) First of all, SPN had to decide whether it wanted to allow and to partly finance PV. Moreover, it had to establish whether to allow, partly finance and share the expenses of grid extension. In fact, two isolated farmhouses in Tagamanent municipality (a restaurant and an ethno-museum) belonged to the Park administration.
b) If SPN had allowed both traditional and solar energy to be installed and made them affordable, the farmhouse owners would have had to decide between the two alternatives.
c) Thirdly, if the owners had not wanted to take the expense upon themselves, the inhabitants (mainly leaseholders) could have decided to pay for electrification, and in this case they would have weighted the pros and cons of the two options.

Hence, the decision process was here represented using three different matrices, which represented the consequences of the three options for each one of the three groups of social actors. In other words, instead of constructing a single impact matrix for the entire society and then an equity matrix, as it is normally done in SMCE (e.g. De Marchi et al. 2000; Martí 2001; Gamboa, 2006), I dealt with distributional conflicts directly in the building of the impact matrices.

The point is that each group of social actors had a different point of view on a problem, or, in other words, each one considered different criteria when deciding. The power structure in society determined which set of criteria (and therefore

[1] Personal communication of a PV installer working for the company TMF (December 2003). The cost calculated for PV in SEBA's report for PV systems was much lower than the one estimated for traditional electricity also because the replacement cost was not taken into account.

which final decision) prevailed: the Park administration was the most powerful social actor and was able to hamper one of the options, the grid extension. In this sense, the retrospective multi-criteria evaluation increased the transparency and the public accountability of the decision-making process. In fact, citizens can possibly go back to the criteria (and the objectives) that were considered important by the politicians who took the decision, and argue about them.

4.2 Criteria

4.2.1 The choice of criteria

I chose the criteria after having carried out in-depth interviews with all relevant groups of social actors. Interviews were of great use for establishing which the important criteria were for the different social actors when choosing between PV and traditional electricity, and to get information on the performance of each alternative according to the different criteria.

Criteria indicate to what extent each alternative helps each group of social actors achieve its objective. They stem directly from the objectives listed in Chapter 3, and belong to three dimensions: economic, environmental and social. In the rest of this section, the most relevant criteria for the social actors are presented, and their relevance in the choice among different sources of energy is explained.

4.2.2 Criteria for Servei de Parcs Naturals

ECONOMIC DIMENSION: cost minimization, both for SPN and society

Costs are an important factor for Public Administration when deciding among different alternative policies. In this case, two aspects were important: the expense that SPN must take upon itself and the cost for the collectivity.

1. Total cost

SPN represented the public interest, so it had to evaluate to what extent the two modalities of rural electrification would be beneficial for society, taking economic, environmental and social factors into account. One of the important issues in this sense was which source of energy would have been cheaper for the society as a whole.

2. Cost for SPN

SPN had a limited budget (4.5 million €), and had to use its resources in the most efficient way. When deciding whether to finance a project, the cost was therefore a relevant criterion, even though it was not the only one. SPN would probably not have accepted to finance one policy if its cost had been too high, because it would have meant to take resources away from other objectives that could be of public utility.

ENVIRONMENTAL DIMENSION: environmental protection

Even though I am aware of the fact that there are many environmental impact categories that could in principle be considered when comparing PV systems and traditional electricity (e.g. global warming, acidification, eutrophication, resource depletion, etc.), for the purposes of the present analysis I decided to restrict myself to addressing those impact categories that were relevant to the involved social actors on the local scale of the Park. The only exception was the global warming category, which was included because of the growing concern that it raises at all levels of public administration.

The institutional task of SPN is to protect the environment in Montseny Natural Park. The Special Plan states:

"*La flora, la fauna, los ecosistemas por ellos formados, la configuración geológica de la montaña, las edificaciones rústicas o monumentales e incluso las actividades agropecuarias de sus habitantes constituyen elementos de un conjunto del mayor interés natural, paisajístico, forestal, rústico e histórico, que se protegerá y mejorará*" (art. 2)[2]

Some of the most important criteria to measure the grade of achievement of this objective in the case of rural electrification can be derived from the words of the SPN technician that I interviewed:

"El impacto de las placas puede minimizarse mucho más que una extensión de líneas eléctricas que atraviesa una parte mucho mayor de territorio forestal. Hay un tema de impactos paisajísticos, una parte de impacto sobre el riesgo de incendios…"[3]

3. Risk of fire

From this quotation it is clear that one of SPN's main concerns was risk of fire. In general this is a very important issue when speaking about forest management. A measure of the seriousness of the threat that fire represents for forests can be given by the number of programmes specifically dedicated to it in the public administration, and the means invested in programmes for the prevention and management of fire. For example, the Catalan government organizes a volunteering corp against fire, which is instructed, equipped and then mobilized in case of forest fire[4]. In fact, once started, it is very difficult to control a fire, and large extensions of forest can be burned, causing large damage. The issue of forest fire is relevant when speaking about rural electrification because it can be caused by the electric grid.

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[2] *"The flora, the fauna, the ecosystem constituted by them, the geological structure of the mountain, the rural or monumental buildings, and the agricultural breeding activities of its inhabitants constitute elements of a whole of a major natural, forest, rural and historical interest, which shall be protected and improved".*

[3] *"The impact of the PV modules can be minimized much more than an extension of the electric line crossing a much larger extent of forest territory. There is an issue of impact on landscape, some impact on fire risk…".*

[4] Diari Oficial de la Generalitat de Catalunya. N. 1022 25/7/1988.

4. Deforestation

Forest vegetation is an essential part of the Park ecosystems, which SPN must protect by statute. Hence, deforestation is an important criterion when deciding if allowing some work inside the Park. Deforestation was relevant here because, as explained before, extending the electric grid would have required deforesting a corridor along the line.

5. Risk for birds

SPN's duty was not only to protect the vegetation but also the fauna inside the Park. Impact on biodiversity was relevant in the debate on electrification because the electric line could have damaged the avifauna trough electrocution or collision of birds against the poles or the electric line. Electric lines are among the first causes of non-natural death for many endangered species (Tintó and Real, 2003).

6. Greenhouse gas emissions

The idea that solar energy would have allowed reducing the greenhouse emissions associated with the traditional generation of electricity was never mentioned by the SPN technician during the interview. His environmental concerns regarded a more local scale. However, if SPN represented the point of view of the Public Administration, a criterion must be introduced to take into account the greenhouse gas emissions. In fact, with the Kyoto Agreement, Spain committed itself not to surpass 15% of the 1990 greenhouse gas emission by 2008-2012 (and at present it has already exceeded them by 40%). The achievement of this target requires a combined effort of the local administrations.

7. Limitation to enterprises

SPN encouraged human presence inside the Park, and therefore was in favour of the establishment of some economic activities that could allow people to permanently live inside the Park. However, SPN had to hamper the setting up of enterprises that could potentially damage the environment. In this sense, PV could play an important role. In fact, on the one side, it would provide energy, allowing living in the Park and carrying out small-scale activities. On the other side, the amount of energy supplied would be small, making it difficult to carry out businesses with high environmental impact, such as for example industrial activities. The SPN technician stated that this was a relevant criterion for him when choosing between different sources of energy:

"Hay otro elemento interesante, es que las energías renovables, por así decirlo, tienen un limite, y [por] esto dentro de un Parque, donde las normas impiden actividades industriales, el uso de energía alternativas representa una garantía, un control, y también evita un proceso especulativo del terreno. […] Es decir que la energía renovable es un tipo de energía que se adapta mucho mejor a la normativa del Parque, por que deja hacer lo que se puede hacer"[5].

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[5] *"There is another interesting element, that is, the renewable energies, so to say, have a limit, and therefore inside a Park, where the rules prevent carrying out industrial activities, the use of renewable energy represents a guarantee, a control, and also avoids speculative uses of the land.*

SOCIAL DIMENSION: integration between human and environmental system

SPN's task is not only to preserve the environment inside the Natural Park, but also the farmhouses and the traditional activities. However, the human presence must be integrated inside the Park and is not allowed to be a perturbing element. The SPN technician stated:

"*El Parque necesita aquellos servicios y las condiciones óptimas para que la gente no se vaya, e incluso para recuperar población, recuperar actividades, etc. Pero, por contra, esto se tiene que hacer de forma compatible con la protección del medio y con el respecto a las normas del parque natural*"[6].

8. Educational effect

In order to reach this objective, educational work must be done. One of the objectives of the Natural Park is to allow citizens to be in touch with nature and to learn about ecosystems and traditional activities. This is one of the most important activities inside the Park, and a well-equipped infrastructure is dedicated to this objective. 8 information points, 4 information centres and 15 "schools of nature" are dedicated to providing information about the ecosystems, the traditional activities and the history of Montseny Natural Park.

As explained in Chapter 1, education and information are very important factors in the diffusion of renewable energy, which is indispensable for creating scale economies and invest in technological development. Since SPN was interested in favouring the diffusion of renewable energy, it wanted to use PV systems in Montseny Natural Park to spread information and show the public how PV systems worked. In fact, as the SPN technician related in the interview, visits to PV installations in the Park were often organized in the framework of seminars:

"*A veces se han hecho jornadas técnicas o a veces ha venido gente a visitar, y luego lo que se hace es montar una visita, van a ver las instalaciones, se habla con los usuarios, se les da una ficha técnica. En esta vertiente de fomento se ha trabajado durante estos años bastante*"[7]

PV systems allowed carrying out not only a direct educational work, but they also favoured the development of a consciousness on energy saving. For example one of the users said:

"Eres mucho más consciente, nunca vas a dejar una luz abierta. El tema de la educación es muy importante. Es un tema de hábitos. Yo creo que si yo tengo hijos, si van a nacer en esta casa, pues no tendrán ningún problema con la electricidad porque ya habrán nacido en este entorno. Cuando

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[…] In other words, renewable energy is a kind of energy that adjusts itself much better to the Park regulations, because it lets one do what it is allowed to do".

[6] *"The Park needs services and optimal conditions in order for people not to leave, and also in order to recover population, to recover activities, etc. However, this must be done in a manner compatible with environmental protection and with respect for the Natural Park rules"*

[7] "*Sometimes daily workshops have been organized, sometimes people came to visit [the PV panels], and then what we do is to organize a visit, people go to see the installations, they speak with the users, they are given technical information. This aspect of promotion has worked quite a lot in these years"*.

es invierno y ha llovido toda la semana y no hay sol, pues se hace otro tipo de actividades, no sé está allí con luz encendida"[8]

9. Impact on landscape

The concern on the impact on landscape was crucial for SPN. Landscape conservation is a very important issue in a Natural Park, and many rules established in the Special Plan were directed to maintaining the landscape. SPN was usually quite strict regarding landscape protection. For example, one of the users related:

"Los paneles solares en nuestra casa no nos los dejan poner en el tejado de la masía porque tienen un impacto visual. Lo tenemos que tener medio escondido, que tampoco es óptimo. [Los que trabajan en la administración del Parque] van muchisimo por el impacto visual"[9]

Impact on landscape was included among the social criteria because landscape is a matter of social perception: it depends on aesthetical and on ethical factors. This criterion was relevant because electric lines would have had an impact on landscape, especially in the forest.

In Table 4.1 the objectives and the criteria that were relevant for SPN's decisions are summarized.

Table 4.1 Relevant criteria for Servei de Parcs Naturals

Dimensions	Objectives	Criteria
Economic	**Cost minimization both for SPN and for society**	*1. Total cost*
		2. Cost for SPN
Environmental	**Environmental protection**	*3. Risk of fire*
		4. Deforestation
		5. Risk for birds
		6. Greenhouse gas emissions
		7. Limitation to enterprises
Social	**Integration between human and environmental system**	*8. Educational effect*
		9. Impact on landscape

4.2.3 Criteria for owners and inhabitants

Like it was done for SPN, the criteria representing the point of view of the owners and inhabitants were derived from the objectives defined in Chapter 3.

[8] *"You are much more conscious, you would never leave the light switched on. The issue of education is very important. It is a matter of habits. I think that if I have children, if they are born in this house, they will have no problem with electricity because they will have been born in this environment. When it is winter and it has been raining the entire week and there is no sun, then one carries out other kinds of activities, one does not stay with the light switched on".*

[9] *"They [the Park administration] do not allow us to put solar panels on our farmhouse roof because they have a visual impact. We have to put them half-hidden, which is not optimal. [The people who work in the Park administration] are very much concerned about visual impact".*

ECONOMIC DIMENSION: income maximization/cost minimization

1. Cost per household.

The cost of the different options was a very important criterion. This aspect was remarked very strongly by some of the users during the interviews. For example, one of them said:

"[los motivos que me han llevado a instalar paneles solares son] económicos, puramente [...] con los precios que hay para pagar la línea eléctrica es imposible, o sea es que únicamente por un tema económico. Y luego también sí que me gusta funcionar con placas solares, lo que pasa es que es muy caro y muy molesto"[10]

However, some farmhouse owners stated that they did not consider the cost a very important factor and decided more on the basis of environmental or comfort considerations, but they were a minority. One of the owners stated that she did not trust PV systems even though they were cheaper, because other issues, such as supply security, were more important to her.

In any case, if the price of one of the options had been much higher than the other one, it would have been possible that neither the owners nor the inhabitants of the farmhouses could have afforded it. In other words, costs were important, especially for private actors, which had a limited amount of financial means.

2. Possibility of founding an enterprise

Energy was not only important because it increased comfort, but also because it allowed carrying out some economic activities. As explained in Chapter 3, one of the consequences of the structural change that took place in Catalonia during the Eighties was that the traditional activities were not economically competitive anymore inside the Park. 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, and the activities dedicated to tourists (e.g. rural pensions, restaurants, production of cheese and honey) became profitable. All these activities required a certain amount of energy. This was an important factor to consider, like one of the users pointed out:

"Tengo una vecina que está con cabras. Esta persona necesita una maquina para ordeñar las cabras, y pues tiene muchos problemas. Si depende de las placas solares, tiene quizás la potencia para ordeñarlas, pero lo que no puede hacer es ordeñarlas regularmente, y te perjudica esto, ¿no? Mi novio va a empezar un negocio de apicultura y necesita un termostato para calentar la miel, que no sea sólida. Bueno, esta es energía térmica, y no lo podemos conectar al panel. Tenemos que pensar cómo hacerlo para que funcione. Como todo está pensado para la corriente eléctrica, cualquier negocio cuesta mucho. Esta chica quiere hacer queso. Para hacer queso necesitas un termostato que esté a treinta grados durante una hora. No puedes tenerlo esto. Son

[10] "*[The reasons that drove us to install solar panels are] purely economic […] with the prices that one has to pay for the electric line, it is impossible, that is, [I chose only] on the basis of an economic factor. Moreover, I like to have solar panels, but they are very expensive and annoying*".

pequeñas cosas, que pero hacen que no puedas llevarlo como una persona normal en una ciudad. Esta es la dificultad. Es verdad que los paneles tienen muchas limitaciones"[11].

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

3. Revaluation of the farmhouses

The possibility of an increase in the value of the households (and therefore a higher rent if leased or price if sold) would have been one of the good reasons for owners to take upon themselves the cost of electrifying their households. According to the SPN technician, revaluation of the farmhouses was one of the reasons that contributed to explaining why the owners preferred the electric grid over PV systems:

"[Los propietarios piden electricidad tradicional,] es evidente, porque esto revaloriza la propiedad"[12]

In fact, PV elements have a limited lifetime (ten years for the batteries, twenty years for the panels and fifteen for the regulating machinery and inverters)[13], making installing them not a long-lasting investment. On the contrary, the electric grid has a virtually infinite time-horizon: once extended to the farmhouses, it increases the value of a farmhouse permanently. The electricity company pays for maintenance and repairs of possible break-downs.

This aspect was very clear to the owners. For example one of the interviewed owners held that one of the main reasons why she opposed PV systems was that they were not definitive.

Also, the Mayor saw this factor as one of the limitations of solar energy:

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[11] "*One of my neighbours has goats. This person needs equipment to milk the goats, and has many problems. If she depends on solar panels, she might have the power to milk them, but what she cannot do is milk them regularly, and this damages her, doesn't it? My boyfriend is going to set up a business of apiculture and needs a thermostat for keeping the honey warm, in order not to let it become solid. Well, this is thermal energy,y and we cannot connect it to the panel. We have to think about how to make it work. Since everything is designed for electricity, all business is very expensive. This girl wants to make cheese. In order to make cheese she needs a thermostat that remains at thirty degrees for one hour. She cannot have it. These are trifles, but it does not allow you to live as a normal person in the city. This is the difficulty. It's true that the panels have many limitations*".

[12] "*[The owners ask for traditional electricity,] it is evident, because it revaluates the property*".

[13] Personal communication of a PV installer working for the company TMF (December 2003).

"Nadie garantiza que cuando todas estas casas tienen que empezar a cambiar las baterías, que son muy costosas y valen dinero (es buena parte de la inversión), tengan las mismas ayuda que han tenido ahora. Inicialmente es muy bonito decir: se les ha pagado el 90% de la inversión. Perfecto, se les ha pagado el 90%, contentísimos todos: estamos en un Parque Natural, hay que apostar por las energías renovables, y todo esto. ¿Pero tendrán este mismo 90% dentro de dos, tres, cuatros, cinco, no sé, los años que le van a durar las baterías? […] [los sistemas solares] son mucho más baratos inicialmente, esto el lo que digo. Dentro de algunos años las baterías hay que cambiarlas… […] No es una garantía de por la vida. No puedes estar permanentemente pendiente de si te dan esto o si no te dan esto. ¿Si mañana no te lo dan y lo tienes que pagar tú de tu bolsillo? ¡Es un coste elevado! Cuando actualmente el contrato con la compañía eléctrica pasa de padre a hijo, y simplemente mientras tú pagues cada mes las tarifas aprobadas por el Ministerio de Industria en Madrid, punto, no tienes otro condicionante"[14].

Obviously, this criterion was important only to owners and not to inhabitants (who were mainly leaseholders).

ENVIRONMENTAL DIMENSION: environmental protection

Environment was important both for the inhabitants and for the owners. For the former it was important not only to live in a healthy place, but also the aesthetical pleasure of enjoying the view of an uncontaminated landscape from their house. In change for this pleasure, they were willing to forgo the comforts that life in cities could offer. Therefore, they were very interested in preserving the environment as much as possible.

Owners also had a strong relationship with the Park. Many of them leaved nearby, some used to spending their spare time in the Park. Some of them did not rent their houses, even though it was expensive to maintain them, because they wanted to have the possibility to use them if they wished.

In both cases, it is likely that what really mattered to them were their property and the area nearby. The most important risk to the inhabitants' farmhouses was forest fire, which might have represented a danger to their houses and the surrounding area, and even to them.

4. Risk of fire

Fire is a real danger in a forested area. One of the inhabitants stated:

[14] "*Nobody guarantees that when all houses have to begin to change the batteries, which are very costly (they cause most of the total expense), they will have the same support that they had now. Initially, it is very nice to say: they have been paid for 90% of the investment. Perfect, they have been paid for 90%, all are very happy: we are in a Natural Park, we have to stake on renewable energies, and all that. But will they have the same 90% in two, three, four, five years, I don't know, the years that the batteries will last? […] [The solar systems] are much cheaper initially, this is what I say. In some years the batteries must be changed… […] It is not a life- lasting guarantee. You cannot permanently depend on whether they give you this or they don't give you this. If tomorrow they do not give it to you, do you have to pay for it by yourself? It is expensive! When actually the contract with the electricity company passes from father to son, and simply if you pay every month the tariff approved by the Ministry of Industry in Madrid, you do not have any other conditioning*".

"Yo creo que la gente se cabrea mucho porque hay una línea de alta tensión que pasa por encima de las masías, pasa por el medio del Parque Natural, que además es super peligroso porque si se caen chispas van a incendiar el bosque. Es lo que pasó en La Garriga. No es Montseny, pero casi: hay chispas en el verano y se incendia. Se quemó poco pero se quemó, y entonces aquí está la incoherencia. Me parece que no está dentro de la zona del Parque Natural protegida, pero está al lado, está a cinco minutos del Tagamanent".[15]

SOCIAL DIMENSION: reduction of disparities with respect to urban population

The feeling of being cast away with respect to the people living in an urban agglomeration is often pretty strong among rural population, and it was mentioned in many of the interviews.

People living in scattered farmhouses inside the Park enjoyed fewer services than people living in cities. In fact, all activities such as administrative offices, hospitals, schools, cinemas and restaurants, etc., were concentrated in cities, and people living inside the Park had to drive a long way to reach them. Public transport was practically non-existent inside the Park. The path to the farmhouses was often in bad conditions. They did not have telephone and often mobile phones did not work well in these zones, making them feeling quite isolated.

To a certain extent, they felt the lack of services as an insufficient acknowledgment by the Public Administration of their role in maintaining the biodiversity and the architectonic patrimony of the Park. The Mayor of Tagamanent explained this point as follows:

"Cuando quieres hacer según que actividad no te lo permite, no puedes colocar ciertas maquinas, tienes que controlarlo mucho, con la cual cosa esto es un poco en desventaja con él que llega a su casa y simplemente da al interruptor, sin preocuparse si las baterías están cargadas, si ha dado suficientemente horas de luz solar, todo esto. […] Es decir, que [la gente dentro del Parque] tiene que tener opción a tener el mismo servicio que otra persona que esté en el núcleo urbano. […] Vivir en estas masías que tienen un largo recorrido, que tienen dificultades de acceso por la pista, por la carretera que van, que no pueden tener un teléfono normal, que tienen que ir con móviles, a veces con poca cobertura, no pueden estar conectados a Internet, y encima le ponemos más limitaciones, de una cosa que está superado [los paneles solares]. En todos sitios se está haciendo la electrificación. […] Para vivir habitualmente y tener las mismas comodidades que pueda tener otra casa en el casco urbano o cerca del casco urbano [es necesario] que pueda tener energía eléctrica, es diferente. Y son diferencias importantes"[16].

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[15] *"I think that people get very angry because there is a high tension line that passes over the farmhouses, it passes in the middle of the Natural Park, which is moreover very dangerous because if sparkles drop, they burn the forest. This is what happened in La Garriga. It is not Montseny, but almost: there are sparkles in the summer and it gets burned. It did not get very much burned but it got burned, and therefore in this issue lies the incoherence. It seems to me that it is not inside the protected area of the Natural Park, but it is nearby, it is five minutes far away from Tagamanent*".

[16] "*[PV electricity] does not allow you to carry out some activities, you can't set up some machinery, you have to control it a lot, and so it represents a disadvantage with respect to those who arrive at home and simply switch the light on, without worrying wether the batteries are charged, whether there were sufficient hours of solar light, and all this. […]. That is, [people inside the Park] should have the possibility to have the same services as people living in urban areas. […] To live in these farmhouses which are very far away, have difficulties of access, can't have a normal telephone, and have to use mobile phones, sometimes with little coverage, can't be connected to Internet... and moreover we put more limitations, of something that is surpassed [that*

Almost all the interviewees had some feeling of discrimination against people living in urban areas. For example, one of the owners strongly stated that electricity was a fundamental good that everyone should have guaranteed, and that it was unfair that they did not.

5. Comfort

The most important feature for Montseny inhabitants was comfort, i.e. the possibility of using electrical appliances whenever needed.

This criterion only applies to the inhabitants and not to the owners, because the lack of comfort affected those who live in the farmhouses[17].

6. Reliability

Reliability of electricity supply was very important to the farmhouse inhabitants (but probably not a lot to the owners that did not live in the farmhouses). All persons interviewed underlined this aspect as crucial.

All interviewees underlined that the reliability of electricity supply was crucial to the farmhouse inhabitants. Users wanted to be sure that they could use electricity when they needed it and that breakdowns would not be frequent.

All users mentioned the frequent breakdowns as the biggest disadvantage of solar energy. For the ones that ran a restaurant or a rural pension (La Vila, El Bellver) this was a major problem because when a PV system broke down they were not able to offer a good service to their clients. One of the users said on this point:

"Es verdad que los paneles tienen muchas limitaciones. Para una familia yo creo que se pueda arreglar, pero para un negocio no puedes estar pendiente que no tienes energía porque esta semana no ha habido sol. No funciona así esta sociedad, no es así. […] La Vila, que es una casa de turismo rural, y como la gente no está acostumbrada a ahorrar energía, y entonces todos llevan su maquineta para afeitar, y están allí con el generador eléctrico todo el día. Y si haces turismo rural, también tener un generador eléctrico sonando allí detrás todo el día tampoco es muy agradable. […] El Xavier, que tiene este restaurante, ahora no tanto, pero antes sí que tenía muchos problemas con las placas solares: a veces se apagaban del todo, se iba la electricidad, y ¡hostia!, tú tienes un restaurante, y quizás un día te vienen a comer cien personas, y no puedes estar allí que se te va la luz"[18]

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is, solar energy]. In all places electrification is being carried out. […] In order to live permanently and have the same comfort that one might have in another house in the urban area o near the urban area having electricity makes a difference. And it is a substantial difference"

[17] Those particular owners who also live in the farmhouses are considered in both categories.

[18] "*It is true that the solar panels have many limitations. For a family I think that it can be made, but for a business, you can't always pay attention on whether you don't have energy because this week there was no sun. This society doesn't work like that. […] La Vila is a house dedicated to rural tourism, and since people are not used to saving energy, everyone brings their electric shaver, and they use electric generators the entire day. And if you do rural tourism, then having an electric generator making noise the entire day is not so pleasant […]. Xavier, who holds this restaurant, used to have a lot of problems with solar panels: sometimes they broke down completely, the electricity was gone, and look!, you have a restaurant, and maybe a day one hundred people come to eat, and it just can't be that the light goes away*".

I considered this criterion only for the inhabitants and not for the owners, because the owners would not have directly experienced the possible breakdowns, since they did not live in the farmhouses.

In Table 4.2 and 4.3 the criteria that were relevant for the owners and inhabitants when choosing among different modalities of rural electrification are summarized.

Table 4.2 Relevant criteria for owners

Dimensions	Objectives	Criteria
Economic	**Income maximization/ Costs minimization**	1. Cost per household
		2. Possibility of founding an enterprise
		3. Revaluation of the farmhouses
Environmental	**Environmental protection**	4. Risk of fire

Table 4.3 Relevant criteria for inhabitants

Dimensions	Objectives	Criteria
Economic	**Income maximization/ Costs minimization**	1. Cost per household
		2. Possibility of founding an enterprise
Environmental	**Environmental protection**	3. Risk of fire
Social	**Reduction of disparities with respect to urban population**	4. Comfort
	Reliability	5. Reliability

5 Impact Matrices

5.1 Servei de Parcs Naturals

5.1.1 Economic criteria

1. Total cost

For the purposes of calculating the costs associated to the photovoltaic option, I decided to perform the calculations on the basis of the average electricity consumption of a Spanish household in 1998, i.e. 192 kWh/month.

Thus, under the necessary worst-case assumptions[1] needed to ensure that the required electricity would be produced even during the winter season, I calculated an installed power of around 2.9 kWp per household (40.6 kWp total).

I then multiplied this figure by the average cost of a PV equipment, as indicated by SEBA (around 18.3 € per installed Wp[2]). It resulted that the total cost would have been around **53,000 € per household** (totalling 743,000 € for 14 households). Also, the share SEBA asked for PV maintenance (around **240 € per year**) was taken into account.

It should be noted, however, that for budget reasons only a severely limited number of modules were then really installed (7.4 kWp total, i.e. 18% of the total required amount calculated here), leading to a much less satisfactory performance of the photovoltaic option than theoretically possible (as proven by the related complaints by the inhabitants – see Section 5.2.3).

Also, I took a twenty-year temporal horizon in order to take into account the replacement costs[3]. The expenses that would have taken place in the future had to be discounted, using equation (1):

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

where DC means discounted cost, **Cb, Cm, Cps** represent respectively the cost of batteries, regulating machinery and inverters, and solar panels. **Cv** stands for the

[1] i.e. irradiation = 1,300kWh/m2/yr and Performance Ratio = 60%.
[2] The price of PV equipment has been decreasing steadily since. Today, the average module retail price can be estimated at around 5 – 6 €/Wp, which represents approximately 50 to 60% of a complete PV system (excluding batteries). (http://www.solarbuzz.com/Moduleprices.htm)
[3] On the basis of the interviews to PV system installers, I estimated the battery and solar modules lifetimes at respectively ten and twenty years. I assumed that regulating machinery and inverters would have become obsolete after around fifteen years and that the structure would have to be changed with module replacement.

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[4].

In order to calculate the discounted cost for a twenty-year time horizon, I had to make some bold assumptions.

First of all, I assumed that the cost of PV components would not change in the following twenty years. This assumption certainly overestimated the price of replacement of PV components, because PV market is developing very fast and the price of PV elements is quickly decreasing.

Secondly, I supposed that SEBA's share and the consumption of an average household would not change in twenty years.

Thirdly, I held solar system efficiency stable (I assumed them to produce the same amount of kWh per kWp).

Fourthly, I did not take into account either the expense for the electrogenerators, which were used in some farmhouses in order to complement solar energy, nor the difference in the cost of energy-saving household appliances with respect to normal ones.

Finally, I did not consider possible changes in figures such as interest rate and inflation, because of two reasons. In the first place, they cannot be easily predictable. In the second place, it can be argued that social actors did not have this kind of information when they made their decision. However, these figures will not probably change so much that the result of the analysis can significantly change.

As interest rate, I took the SWAP rates, which are normally used by financial entities for discounting future expenses. The SWAP rates are formulated by combining the interest rate with some parameters that take into account forecasts on future trends of the economy. They increase with the period of time to discount[5]. This is because they take uncertainty into account, which increases with time. For this reason, it seemed to me appropriate to use SWAP rates instead of simply interest rates in order to take into account the dynamics of the solar energy market. In fact, the cost of PV components is steadily decreasing, and in the future

[4] SEBA's document did not specify the cost of the PV components, but it indicated only the whole cost (around 18.3 € per Wp). Therefore, I estimated the cost of the various components using information found in TMF (2002). According to this report, the battery, the PV modules and the supporting structure constitute respectively 21%, 53% and 18% of the total PV cost, while the regulation, control, data gathering and protection elements represent the remaining 18%. I estimated the cost of the PV components applying these percentages to SEBA's estimate. This procedure gave only a rough approximation, but I considered it to be enough for the purposes of this paper (what was important to me was the difference among alternatives, and small inaccuracies would not make a substantial difference).

[5] 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).

modules and batteries will probably be cheaper than they are now. Applying SWAP rates allows reducing the future costs, making the analysis more realistic.

Calculated in this way, the cost of PV systems for the 14 households included in the analysis would have been approximately **1,193,000 €**. 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 did) would have led to a total cost of 551,000 €, whereas if the temporal horizon had been only 10 years (i.e. without including replacement cost), the total cost would have been 859,000 €. Combining the two latter assumptions, the total cost would have been 355,000 € instead of 1,193,000 €.

As regards traditional electricity, the costs were taken from FECSA and SEBA reports respectively for the original FECSA project and SEBA proposal. They were discounted with SWAP rates, considering a temporal horizon of twenty years. I also took into account the variable cost of electricity, which was obtained by multiplying the average consumption of Spanish households by the price of electricity for 1998[6]. With these assumptions, the total cost of the original FECSA project would have been **731,000 €** whereas the SEBA proposal would have implied a cost of **796,000 €**.

2. Cost for SPN

SPN calculated to have financed up until now around 45% of PV installed within the framework of the Montseny rural electrification plan. If this percentage had not changed, the cost for SPN for rural electrification would have been around **510,000,** maintaining all the assumptions explained above and including the replacement cost. On the contrary, SPN did not finance grid extension, as a way of hindering it.

5.1.2 Environmental criteria

3. Risk of fire.

Opinions on risk of fire diverge significantly according to the interviewee's interest. The Mayor affirmed that there would not be any risk at all, whereas the SPN technician claimed that risk would be high. According to FECSA, the number of fires caused by the electrical line is negligible (FECSA/Endesa, 1999), but this is presumably not a neutral opinion. Users perceived a high or a low risk depending on their sympathy towards electric line and solar systems.

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[6] Boletín Oficial de España, N. 210, 27/12/1997, pages 8161-8168. The price for a contracted power under 15 kW in 1998 was 257 PTAs/kW (1.54 €/kW) per month plus 14.61 PTAs/kWh (0.09€/kWh). I added to these figures 16% VAT and some further taxes (around 5%), plus around 1 € for the rental of the equipment. I assumed that user would contract 4.4 kW of power, as it is usual in private households.

Therefore, I asked the opinion of an expert, which was neutral in the conflict under analysis. According to the technician of the Catalan *Servei de Prevenció d'Incendis Forestals* (Forest Fire Prevention Service) who I interviewed, it is true that interlaced cables reduce risk, but they do not guarantee that electric lines do not cause fires. Moreover, they are much more expensive (the FECSA technician in charge of rural electrification explained during its interview that they are in fact rarely used). The risk of fire depends on the kind of forest, on the state of the cables and on the level of maintenance (it is reduced if vegetation around the line is continuously cut). If asked to define the possible risk of fire of an electric grid in the Tagamanent municipality among “none”, “very low”, “low”, “medium”, “high”, and “very high”, the Forest Fire Prevention Service technician said that it would have been between “medium” and “high”.

Some idea on the risk of fire can be obtained from statistics. Between 1960 and 2002, 10% of all forest fires in Montseny Natural Park were caused by the grid. Tagamanent municipality suffered from 29 fires between 1967 and 2001[7]. Table 5.1 shows the number of forest fires occurred in the Vallès Oriental (the area where Montseny Natural Park is situated) between 1993 and 2002, together with their cause and the forest area they burned.

Table 5.1 Number and cause of fires in the Vallès Oriental between 1993 and 2002

Cause	Number	Damaged hectares	%
Natural causes	10	1,2	0,015
Negligence	102	2.718,1	33,553
Accidents	25	266,5	3,290
Arsons	45	29,0	0,358
Unknown	39	5.085,9	62,781
Relighting	3	0,2	0,003
Total	**224**	**8100**	**100**

Source: Forest Fire Prevention Service ‘s statistics

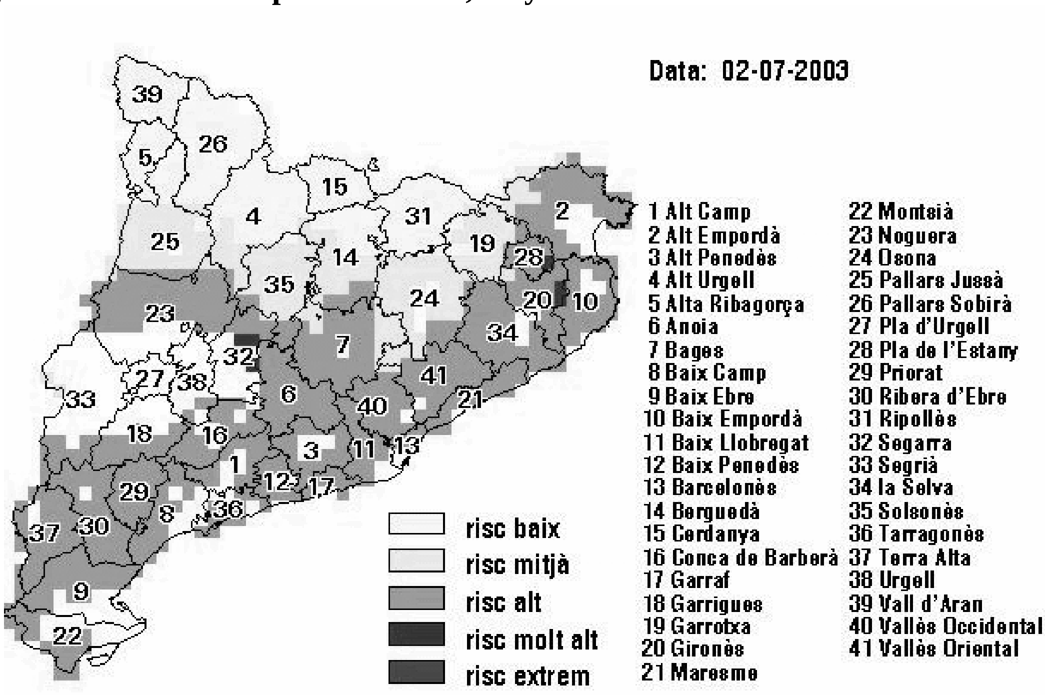
Out of the 224 forest fires that occurred in the Vallès Oriental between 1993 and 2002, nine were caused by electric lines (i.e. 4%).

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 easily flammable the whole year round (Peix and Massip, 1999).

In the fire risk map of Catalonia (see Figure 5.1, prepared by the Department of Environmental Statistics of Catalan government), the Vallès Oriental are represented as an area characterized by a high risk of fires in summer.

[7] Data of the Forest Fire Prevention Service.

Figure 5.1 Fire risk map of Catalonia, July 2003



Source: Catalan Government Department of Environmental Statistics, available in http://mediambient.gencat.net/cat/el_medi/incendis/inici.jsp

The criterion "risk of fire" is difficult to quantify, and for this reason I gave it a qualitative score. In this way, I made the analysis more transparent by not hiding uncertainty with a set of assumptions in order to give a quantification.

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 would have entailed was "**high**", because the entire length of the electric line would have been aerial. SEBA's proposal would have implied a "**low**" risk, because part of the line would have been buried. PV systems would not have caused any forest fire, so that the risk they would have posed was "**none**".

4. Deforestation

Building an electric line through a forest requires deforesting a corridor along the line. According to the Decree 268/1996[8], a corridor of six and two meters along respectively low and medium-tension line must be kept free from vegetation. This means that the FECSA project would have implied a deforestation of **67,000 m^2**, whereas SEBA's proposal only would have required to deforest **57,000 m^2** (actually, this was its main advantage). Obviously, stand-alone PV systems would have implied no deforestation at all.

[8] Diari Oficial de la Generalitat de Catalunya N. 2236, 29/7/1996

5. Risk for birds

Electric lines are among the primary causes of non-natural death for many endangered species. For example, electrocution causes 65% of adult deaths of Bonelli eagles (an endangered species of bird of prey) in Catalonia and it is one of the main causes of the sharp reduction of its presence. In the last 10 years the number of bird deaths from electrocution increased notably, due to the electric lines installed in rural areas (Tintó and Real, 2003). Technological solutions that can reduce the risk are usually rather expensive. Accidents occur in two different ways: through electrocution and through collision (Asistencia Técnicas Clave, S.L., undated).

Risk of collision is inversely proportional to visibility, and is worst in wet areas or along 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 a very dangerous area.

Electrocution 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 cause blackouts. Sometimes, birds fall down from the pole burning and cause forest fires. The risk of electrocution proportionally increases with the dimension of the bird: it is more probable that larger birds can simultaneously touch two conductors or a conductor and a pole. Unfortunately, many endangered species are predators at the top of the food pyramid, and hence are rather large. Pylons in areas with a high bird of prey population, pylons in prominent position and pylons set in open natural vegetation habitats are more likely to produce electrocution accidents (Mañosa, 2001).

According to Fernandez and Azkona (2002) the risk of electrocution increases if an electric grid is located 1) in spacious landscapes where there are no 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 one), so risk is not so high.

This opinion was shared by the ornithologist that I interviewed, who is specialized in damages to avifauna caused by electric grid. According to his opinion, risk that an electric grid would jeopardize Montseny 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 would be some possibility that some birds would be killed by an electric line, but it would not be probable due to the characteristics of the Montseny forest. Moreover, the length of the electric line would not be much extended. On the other side PV systems would not have affected avifauna, and their impact would have been “**none**”.

6. Greenhouse gas emissions

By multiplying the share of each source of energy in Spanish final consumption (Bundesamt für Umwelt, Wald und Landschaft, 1996) by its equivalent CO_2 emissions, I obtained the average CO_2 emissions for one kWh produced in Spain, as it is shown in Table 5.2. I expressed greenhouse emissions in equivalent CO_2, using the Global Warming Potential (GWP) for a temporal horizon of 100 years[9] (Houghton et al., 1994). 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. The result is that for each kWh produced in Spain, approximately 0.5 kg CO_2 equivalent is emitted.

Table 5.2 CO_2 content of electricity in Spain

Energy source	%	CO_2 content (kg eq. CO_2/MJ)	CO2 content (kg eq. CO_2/kWh)[10]	Weighted CO_2 content
Coal	30	0.297	1.069	0.325
Natural gas	10	0.224	0.806	0.078
Hydropower	16	0	0	0
Nuclear	27	0.002	0.006	0.002
Oil	10	0.253	0.910	0.095
Others	6	0	0	0
Total	100	0.776	2.792	**0.500**

Multiplying this number by the Spanish average energy consumption in the domestic sector, I obtained that **96 kg of CO_2 equivalent** would have been emitted with traditional electricity.

As regards PV, Alsema et al. (1998) calculate that for an off-grid PV system, the energy pay-back time[11] was at least 7 years in 1998. Thus, assuming an overall lifetime of twenty years, it results that the CO_2 emissions caused by PV on a larger scale would have been 96 x 7/20 = **34 kg of CO_2 equivalent.**

7. Limitation to enterprises

The choice of the modality for rural electrification might be an important factor in determining the kind of development of the Park. Therefore, SPN wanted to favour the modality that could have allowed some environmentally friendly enterprises but would have limited the ones that could have potentially jeopardized the environment inside the Park.

All interviewed social actors (the SPN technician, the Mayor, the owners and the inhabitants) agreed on the fact that solar energy would have constituted a strong limitation on the economic activities inside the Park.

[9] CO_2=1; CH_4=21; N_2O=310.
[10] 1 kWh=3,6 MJ, Instituto de Diversificación y Ahorro, 2002.
[11] The period that it needs to supply the same amount of energy that was necessary to produce it in terms of electricity.

Therefore, the limitation to enterprises of PV would have been "**high**". On the other side, the limitation of traditional electricity would have been "**none**", because it would have provided a virtually infinite supply of energy.

5.1.3 Social criteria

8. Educational effect

PV systems would have had a "**high**" educational effect, because they would not only have allowed a direct educational work, but they would also have favoured the development of a consciousness on energy saving. In fact:

a) They would have improved the environmental consciousness of Montseny inhabitants and visitors. Being in touch with PV systems might have given people the incentive to get informed about the greenhouse effect and local pollution.
b) By means of hindering the industrial activities that require a lot of energy, they would have shown that it was possible to live inside a Natural Park developing businesses with a low environmental impact.
c) Since they would not have supplied much energy, they would have made people accustomed to sparing energy and eliminating unnecessary consumption, as well as to using low-consumption household equipment.

On the contrary, the educational effect of traditional electricity would have been "**none**".

9. Impact on landscape.

The impact on landscape would have been especially high in mountainous and forested areas. In this case, the area where the trees would have to be cut to avoid risk of fire would have appeared from a long distance as a yellow line zig-zagging in the middle of the green forest. Also, the poles would have had a visual impact, even though the rules inside the Park would have required painting the poles green[12]. The impact on landscape of electric lines could have been minimized burying the line (as suggested for part of the route in SEBA's proposal), but this solution would have made traditional electricity more expensive.

According to SEBA's analysis, FECSA's project would have implied a high visibility near Turó del Tagamanent, a hill that was situated in Tagamanent municipality, due to the fact that it was a very flat area.

SEBA's proposal would have reduced visibility by incorporating three measures: 1) part of the line would have been buried, 2) the itinerary would have been partially changed in order to avoid the flat area and 3) transformers in boxes on the ground would have been used instead of aerial ones.

[12] Art.11 of the *Special Plan.*

PV systems would have had minimal impact on visibility. Therefore, visibility would have been "**high**" in the case of FECSA's project and "**low**" in the case of SEBA's proposal. PV systems would have not been really visible from a distance, making their impact on landscape "**none**".

Table 5.3 indicates the impact matrix for SPN.

Table 5.3 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. Greenhouse gas emissions	kg CO_2 eq.	96	96	34
	7. Limitation to enterprises	Qualitative	None	None	High
Social	8. Educational effect	Qualitative	None	None	High
	9. Impact on landscape	Qualitative	High	Low	None

5.2 Owners and inhabitants

5.2.1 Economic criteria

1. Cost per household

I calculated costs as explained before, and taking into account that users would have covered only 22% of the cost of PV installation and 50% of the cost of grid extension. The results for FECSA's project, SEBA's proposal and PV were respectively **28,000, 31,000** and **21, 000 €** per household. In these figures the variable costs were included (the cost of electricity in the case of grid extension and the SEBA's share of 20 € per month in the case of PV systems).

2. Possibility of founding an enterprise

The preferences regarding energy sources were obviously influenced by the use of the farmhouse. All social actors agreed on the fact that one of the main reasons that could explain the hostility against PV was that it would have hindered the possibility of setting up an enterprise, as explained by one of the Tagamanent inhabitants:

"*[la extensión de la red eléctrica] […] da la posibilidad de realizar actividades que ahora no se pueden realizar: turismo rural… Los propietarios ven en la llegada de la electricidad la posibilidad de transformar aquella casa que ahora no vale (y incluso hay problemas de mantenimiento de estas casas), montar un negocio, un negocio agrícola, un negocio turístico, etcétera. […][El conflicto] coincide con expectativas que no están en función todavía. Es decir que si estos pedían electricidad era para hacer una cosa para proyectos futuros que no han iniciado. […] Es decir, La Codina quiere restaurar la casa y hacer una vivienda para particular y una cierta explotación agrícola. La Figuera también una actividad ganadera más intensiva de la que tiene en esto momento y una vivienda permanente con complemento de turismo rural […]Y La Perera, por ejemplo, reconstrucción y alquiler de la masía, y El Bellit, aunque tiene equipos, que* *se pusieron en su día para cubrir las necesidades del pastor, el propietario tiene expectativas de hacer un equipamiento turístico con restaurante, con habitaciones"*[13] .

Tagamanent Mayor confirmed this idea:

"*Nosotros, todo esto nos hizo reflexionar mucho cuando algún propietario nos dijo: "es que yo quiero poner una maquina y no puedo ponerla. Tengo que tirar con un generador de gasolina", con la cual cosa el precio del kWh es elevadísimo […] [se habla de] actividades simplemente de ganadería. Poner unas maquinas para ordeñar las vacas, las cabras o las ovejas. O la colocación de una bomba de agua. Sí que se puede con paneles solares, funcionan, pero no llegan al rendimiento a que te puede llegar una bomba normal que no sea movida por energía solar: hay poca agua, muy despacito, las demás no tienen tanto problemas". […] [la electricidad tradicional] puede ayudar[a repoblar el Parque], o por lo menos hacer que se puedan hacer nuevas actividades. Es decir, actualmente en un proceso de ganadería donde quieran hacer una transformación de subproductos, que necesiten colocar unas maquinarias, no pueden hacerlo con placas solares, está demostrado […]. Pero si yo tuviera ganadería […], si yo necesitara ordeñar estas vacas, necesitaría una maquina. Manualmente actualmente ya no se hace, higiénicamente ya no es posible. Estas maquinas necesitan energía eléctrica. Si yo necesitara esta leche trasformarla en mi propia finca, necesito unas maquinas, necesito unas cámara frigorífica. Esto no puedo hacerlo con placas solares, por mucho que se diga. […]Actualmente casi todo el mundo tiene actividades turísticas. Y cuando tu montas una actividad turística, si te viene gente, necesitas que las cámaras refrigeradas, las neveras, funcionen perfectamente, necesitas tener agua corriente, con la cual cosa necesitas pompa de agua, porque en estas zonas hay problemas de agua, es un local público, entonces necesitas luces de emergencia. Hay una serie de normativas que cumplir. No quiero decir que no se pueden cumplir con los paneles, pero hay estándares mínimos, que quizás pueden dar problemas*"[14].

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[13] *"[The extension of the electric grid] […] gives the possibility of founding an activity that now they cannot carry out: rural tourism… The owners see in electricity the possibility of transforming their house, which has no value now* (*and there are* even *problems of maintenance* for *these houses*), *of setting* up *a business, an agricultural business, a tourist business, etc. […][The conflict] derives from plans that are not being carried out yet. In other words, if they were asking for electricity it was in order to do something for future projects that they have not begun yet. […] That is, La Codina wants to repair the house and to get a dwelling for privates and some agricultural exploitation. La Figuera as well* wants *a breeding activity more intensive than the one it has at this moment, and a permanent dwelling complemented by rural tourism […] And La Perera, for example,* wants *reparation and renting of the farmhouse, and* at *El Bellit, even though* there is *machinery,* which was installed *in order to cover the shepherd's needs, the owner plans to set up a tourist equipment with a restaurant* and *rooms.*

[14] "*All this made us reflect a lot, when an owner told us "I want to have a piece of machinery and I cannot. I must keep going with a generator that works with gasoline, making the cost very high […] [We are speaking] simply about breeding activities. Putting some machinery in order to milk the cows, the goats or the sheep. Or setting up a water pump. Obviously it can be done with solar panels, it would work, but it does not have the same yield as a normal pump that does not work with solar energy: it provides little water, very slowly, while the others do not have so many problems. […] [traditional electricity] can help [to repopulate the Park], or at least to allow new activities to be run. That is, actually in a breeding process where they want to carry out a transformation process of sub- products, where they need to put some machinery, they cannot do it with solar modules, it is demonstrated […]. If I had some breeding, […] if I needed to milk these cows, I would need machinery. Nowadays, it is not done manually, hygienically it is not possible. This machinery needs electricity. If I needed to transform this milk in my own farmhouse, I would need some machinery, I would need a refrigerating room. I cannot do it with solar modules, no matter what people say. […]. Nowadays almost everyone has a tourist activity. And when you set up a tourist activity, if people come, you need air conditioning and refrigerators to work perfectly, you need running water, and so you need a water pump, because in these zones there are problems with water availability, they are public buildings and so you need emergency lights. There are regulations to follow. I do not want to say that you cannot accomplish this with PV systems, but there are minimum standards, you might have problems*".

Therefore, the possibility of founding a business using traditional electricity would have been ”**high**” because it would have guaranteed a virtually infinite supply of energy. If an enterprise decided to use more energy it would have had only to increase the contracted power. Increasing the power of an electricity installation from 4.4 to 5.6 kW costs approximately 60 €, i.e., around 50 € per kW[15].

However, PV would have only provided a limited, and to a certain extent unpredictable amount of electricity, making the possibility of founding an enterprise based on solar energy “**low**”. In Tagamanent municipality there were a restaurant and a little rural pension, which functioned partly on solar energy. However, both complemented the energy supplied by PV with electricity generators.

3. Revaluation of the farmhouses

The lifetime of PV components is between ten and twenty years, therefore it cannot really be said that installing PV would have been a very effective long-lasting investment. On the contrary, the electric grid would have had a virtually infinite time-horizon, and once extended to the farmhouses, the value of the properties would have increased permanently. In fact, if the grid had been installed, FECSA would have committed itself to maintaining it, without additional expenses for the users.

Since the increase in value of the farmhouses in monetary terms depends on many uncertain factors, I preferred a qualitative evaluation. The revaluation of the farmhouses would have been “**low**” with PV systems and “**high**” with the grid.

5.2.2 Environmental criterion

4. Risk of fire

The scores for this criterion are illustrated above.

5.2.3 Social criteria

5. Comfort

Owners and inhabitants of scattered farmhouses inside the Park felt discriminated against in their energy use because of the lower degree of comfort they enjoyed.

In fact, with conventional electricity, the inhabitants would only have had to turn the switch on to have as much electricity as they were willing to pay for. Electricity in rural areas is much more expensive than in cities - in fact, in an urban context installing traditional electricity in a new house only costs around

[15] Personal communication of a technician in charge of new installations in FECSA (September 2003).

200 € for a typical power level of 4.4 kW[16]. However, once installed, there would have been no differences among users because of their location.

PV electrification, instead, contributed to the feeling of discrimination in Tagamanent because of the restrictions that it imposed in daily life. PV systems implied lower comfort because users had to worry about whether the batteries would be adequately charged or whether they were using too much household equipment at the same time. For example one of the PV users testified:

"Muchas cosas no podemos tenerlas: el microondas, el secador de pelo […]. Yo me programo. Pongo la lavadora sólo de día, nunca de noche. Si veo que ha llovido toda la semana, que ha hecho nubes, que no está muy cargada, ya no pongo la lavadora. Intento no cargar mucho el congelador en el verano……es controlar mucho todo"[17]

As already mentioned, however, this issue was principally caused by the fact that only about 18% of the PV capacity theoretically necessary to guarantee the same amount of electricity required by fourteen typical Spanish households (i.e. 14 x 192 kWh/month) was installed. Had a full 40.6 kWp of PV been installed (as calculated in section 5.1.1), the level of comfort that the owners and inhabitants would have enjoyed would have been comparable to the one possible by means of grid electricity.

Since it was here decided to carry out the comparison between the two scenarios assuming the same level of availability of electricity irrespective of the technological option whereby such electricity was to be provided (see also section 5.1.1), the same score was attributed to all alternatives under this criterion, i.e. "**high**".

6. Reliability

Concern regarding blackouts was one of the factors that contributed to the hostility against PV systems: most Tagamanent inhabitants did not trust solar energy and were convinced that renewable energy was not able to supply enough energy.

Solar energy users stated that sometimes their PV equipment suffered breakdowns (especially in the first period of use, when they were not yet familiar with them and did not use them properly).

The interviewed solar system technicians confirmed that from time to time some of the PV components broke. Therefore, reliability was "**low**" in the case of solar energy.

[16] See previous note.

[17] *"We can't have many things: the microwaves, the hairdryer […]. I get organized. I use the washing machine only during the day, never in the night. If I see that it has been raining the entire week, that it was cloudy, that [the battery] is not charged, I don't use the washing machine. I try not to load the freezer too much in the summer…this means that I have to control everything a lot".*

Electric line could also suffer from blackouts. The SPN technician stated that the probability of an electric line interruption would have been much higher in isolated areas than in urban conglomerations because maintaining the grid and fixing the damages would have been very expensive for electricity companies.

However, having asked the people who have extended the grid to their farmhouse in the area under study, I concluded that the grid problems were very rare in that area, and that their supply security was "**high**".

Tables 5.4 and 5.5 summarize the criteria scores for users and inhabitants.

Table 5.4 Impact matrix for owners

Dimension	**Criteria**	**Unit**	**Score**		
			FECSA	*SEBA*	*PV*
Economic	1. Cost per household	Thousand €	28	31	23
	2. Possibility of founding an enterprise	Qualitative	High	High	Low
	3. Revaluation of the farmhouses	Qualitative	High	High	Low
Environmental	4. Risk of fire	Qualitative	High	Low	None

Table 5.5 Impact matrix for inhabitants

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

6 Results

6.1 The aggregation

The model used here to obtain a ranking is the one proposed by Munda (2005a and 2005b).

Given a finite set of criteria $G=\{g_m\}$, $m=1,2,..., M$, and a finite set of alternatives $A=\{a_n\}$, $n=1, 2,..., N$, it is assumed 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, and that a criterion is preferred if it has a higher score:

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

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 $a_i \boldsymbol{P} a_j$).

The weights are taken as importance coefficient and not trade-offs (see Part I):

$W=\{w_m\}$, $m=1,2,..., M$, with $\sum_{m=1}^{M} w_m = 1$

The information on preference and indifference relations and weights must be used to build a ranking among the alternatives in a complete pre-order (the relation among alternatives must be either of preference or indifference, but not of incomparability).

In order to do that, first of all the alternative are compared pair-wise according to all evaluation criteria.

The result is the so-called *outranking matrix* (Arrow and Raynaud, 1986; Roy, 1996), i. e. a N x N matrix where any generic element of E: e_{jk} , $j \neq k$ is the result of the pair-wise comparison, according to all the *M* criteria, between alternatives *j* and *k*. The pair-wise comparison among alternatives is performed by means of equation (3).

$$e_{jk} = \sum_{m=1}^{M} \left(w_m(P_{jk}) + \frac{1}{2} w_m(I_{jk}) \right) \quad (3)$$

where $w_m(P_{jk})$ and $w_m(I_{jk})$ are the weights of criteria presenting a preference and an indifference relation respectively. It can be noted that

$$e_{jk} + e_{kj} = 1. \quad (4)$$

The maximum likelihood ranking of alternatives is the ranking supported by the maximum number of criteria for each pair-wise comparison, summed over all the pairs of alternatives considered.

The outranking matrix E is formed by all the *N(N–1)* pair-wise comparisons. Being *R* the set of all *N!* possible complete rankings of alternatives, $R=\{r_s\}$, $s=1,2,..., N!$, for each r_s, the corresponding score φ_s is calculated as the summation of e_{jk} over all the $\binom{N}{2}$ pairs *j,k* of alternatives, i.e.

$$\varphi_s = \sum e_{jk} \quad \text{where } j \neq k,\ s = 1,2,...N! \text{ and } e_{jk} \in r_s \qquad (5)$$

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

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

By applying this ranking algorithm, from the impact matrix of SPN (Table 5.3) the outranking matrix described in Table 6.1 is obtained.

Table 6.1 Outranking matrix for SPN

	FECSA	SEBA	PV
FECSA	0	0.4	0.2
SEBA	0.6	0	0.2
PV	0.8	0.8	0

The maximum likelihood ranking of alternatives deriving from this outranking matrix is the one presented in Table 6.2:

Table 6.2 Maximum likelihood ranking of alternatives for SPN

PV	**SEBA**	**FECSA**	**2.2**
PV	FECSA	SEBA	1.9
SEBA	PV	FECSA	1.6
FECSA	PV	SEBA	1.4
SEBA	FECSA	PV	1.1
FECSA	SEBA	PV	0.8

Clearly *PV* is the most preferred option for SPN and the *FECSA* solution is the worst one. In fact, most of the criteria that were considered important for SPN belonged to the environmental dimension and were favourable to PV.

By applying the same ranking algorithm to the impact matrices of the owners and inhabitants (Tables 5.3 and 5.4), the results presented in Table 6.3 and 6.4 are obtained.

Table 6.3 Maximum likelihood ranking of alternatives for owners

FECSA	SEBA	PV	1.5
SEBA	FECSA	PV	1.5
FECSA	PV	SEBA	1.5
SEBA	PV	FECSA	1.5
PV	FECSA	SEBA	1.5
PV	SEBA	FECSA	1.5

Table 6.4 Maximum likelihood ranking of alternatives for inhabitants

FECSA	SEBA	PV	1.5
SEBA	FECSA	PV	1.5
FECSA	PV	SEBA	1.5
SEBA	PV	FECSA	1.5
PV	FECSA	SEBA	1.5
PV	SEBA	FECSA	1.5

For the owners and inhabitants the ranking of policy options is the same, i.e. all three alternatives proved to be equally preferable.

The reason is that the method here proposed does not take into account the intensity of preference (the distance among alternatives) and both for the owners' and inhabitants' matrices the number of criteria in favour of the first one is always equal of the number of criteria in favour of the second one (see Tables 5.4 and 5.5).

In other words, in some ways the advantages of PV (lower cost and lower environmental risk) are compensated for by the disadvantages (smaller possibility of founding an enterprise, reduced revaluation for owners and reliability for inhabitants).

As regards the comparison between the FECSA project and the modifications proposed by SEBA (characterized by a higher cost and a lower environmental impact), the improvement in environmental protection assured by the latter were offset by an increase in costs.

However, during the interviews, owners and inhabitants did not show to be neutral among electric grid and PV. The reason is that, due to budget constraints, the amount of installed power was much lower than the one calculated here as theoretically necessary. Therefore, the electricity provided by their PV systems was scarce. Hence, they would have preferred electric grid, which would have not imposed limitations on the electricity consumption, but only with the condition that part of the significantly higher cost would be subsidized.

The results discussed so far are a consequence of the fact that I gave the same weight to all criteria. This implies giving more importance to the economic dimension (3 criteria out of 4). As regards the inhabitants, this same assumption implies giving more weight to the economic and social dimensions (2 criteria each) than to the environmental one (only 1 criterion). When modifying the weights, the results change, as it is shown in Section 6.2.

As a concluding remark, from the impact matrices shown in Table 5.5 it can be seen that if the analysis had been performed changing the assumptions for the PV scenario so as to reflect the actual installation (i.e. 7.4 kWp instead of 40.6 kWp), the costs for PV would have been even lower whereas comfort would have been lower for PV than for the traditional electrification options. All the other criteria would have remained unchanged.

However, since the method used here does not take into account the intensity of preference, the comparison among the alternatives according to the criterion "Cost" would not have changed. On the contrary, the criterion "Comfort" would have assigned a better performance to the two grid options than to PV, leading to a possibly different ranking than the one shown in Table 6.4.

Instead, the ranking for the owners would not have changed, because the criterion "Comfort" was not considered to be important for them.

6.2 Sensitivity analysis

In the ranking exercise presented in Section 6.1, all criteria receive the same importance since all criteria had the same weight. This implies that, for instance, in the case of SPN the environmental dimension has a bigger weight than other dimensions, because 5 out of the 9 criteria used belong to the environmental dimension.

In this section a sensitivity analysis of the obtained rankings is performed according to the weight given to dimensions. By giving the same weight to all dimensions, the following rankings are obtained.

Table 6.5 Sensitivity analysis for SPN's rankings

PV	**SEBA**	**FECSA**	**2.2**
PV	FECSA	SEBA	1.9
SEBA	PV	FECSA	1.6
FECSA	PV	SEBA	1.4
SEBA	FECSA	PV	1.1
FECSA	SEBA	PV	0.8

Table 6.6 Sensitivity analysis for owners' rankings

PV	**SEBA**	**FECSA**	**2.0**
SEBA	PV	FECSA	1.7
PV	FECSA	SEBA	1.7
FECSA	PV	SEBA	1.3
SEBA	FECSA	PV	1.3
FECSA	SEBA	PV	1.0

Table 6.7 Sensitivity analysis for inhabitants' rankings

PV	**SEBA**	**FECSA**	**1.8**
PV	FECSA	SEBA	1.6
SEBA	PV	FECSA	1.6
FECSA	PV	SEBA	1.4
SEBA	FECSA	PV	1.4
FECSA	SEBA	PV	1.3

The previous results are reinforced for SPN, for whom PV is again the best option, due to the higher number of environmental criteria, in favour of PV.

However, the ranking changes for owners and inhabitants. The reason is that giving the same weight to the three dimensions, the relative weight of the environment increases with respect to the weight distribution adopted in Section 6.1 and therefore PV becomes more preferable and FECSA the worse option.

7 Conclusions

7.1 The underlying debate

This study is a clear example of how a Social Multi-Criteria Evaluation (SMCE) can be a means whereby to explore the real reasons behind a conflict. I began this analysis with a focus only on the energy issue: I intended to identify 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 essential for understanding that the problem of energy was strictly bound to other issues that were not solved yet inside the Park, especially water supply and access.

As a matter of fact, the issue of rural electrification was not only a technical problem, but it was a part of a larger political issue.

In order to explain this point, I find Ravetz's distinction between technical and practical problems helpful (Ravetz, 1971; Strand, 2002). The first ones can be solved using specialized, technical knowledge, whereas the second ones have to do with the objectives and values of part of society, such as the wish for a clean environment, economic growth or a fairer distribution of wealth.

Using this terminology, one can say that the solution of the technical problem (how to electrify the isolated farmhouses in Tagamanent) depended on how to give an answer to the practical problem that was at the root of it: the conflict between different views on the long term political strategy for Montseny Natural Park.

SPN, whose institutional task was to preserve the environment inside the Park, tended to adopt a conservationist view, i.e., to limit human intervention as much as possible, in order to reduce its interference with the natural ecosystems. This attitude can be traced back to the history of SPN, which was created for protecting the Park from building speculation. Another reason for this approach was the theoretical background of wildlife conservationism, which suggests the creation of untouched natural spaces as a way of safeguarding the environment. As a consequence, SPN wanted to limit infrastructures to the minimum. For example, it was against asphalting the paths inside the Park, which would have made life for the inhabitants easier, causing nonetheless an environmental impact and also facilitating an increase in the excursions.

The reason for SPN's position on rural electrification can be understood in this context. Extending the electric grid to the isolated farmhouses would have caused deforestation, risk of fires and would have modified the landscape. Moreover, it might have also stimulated the foundation of enterprises inside the Park. On the contrary, PV systems would have helped hinder the activities that would have needed much energy, and which therefore would presumably have caused a high environmental impact, due to their scale or their nature.

On the contrary, farmhouse owners and inhabitants in the Park mostly thought that policies encouraging the economic activities should be privileged. Some of them ran or wanted to set up an enterprise, mainly in the tourist sector, and they wished to have guaranteed the necessary conditions. As explained by some owners during the interviews, the most important services that they needed were (in this order) water, easy access to the farmhouses and energy (thermal and electrical). Even if they had an infinite supply of energy, they could not create a small tourist structure if clients could not reach their farmhouses or if they did not enjoy a sufficient water supply.

As regards electrification, the most important reason why many owners opposed to solar energy, even though it was cheaper to them, was the possible limitations on the setting up of an enterprise, i.e. the idea that the energy supplied by solar systems would not be enough, or would not be reliable enough.

In conclusion, there was no agreement among the social actors on the future development of the Park. In this sense, there was not an “optimum solution” for this problem. The policy that could be suggested depended on which values were considered most important, whether wildlife conservationism or economic development. Each choice would have privileged the interests of some social actor - e.g. the owners, the inhabitants, Barcelona citizens - and sacrificed the interests of others.

This study showed that the relevant criteria, and hence the preferred alternative, were different for each group of social actors, and therefore three different impact matrices were built. At the end, the most powerful social actor, SPN, imposed its set of evaluation criteria and decided in favour of PV systems without a real participatory process. One of the reasons of the discontent that this decision raised was its “top-down” nature. Including the interests and the expectations of the other social actors in the decision-making process would have increased the legitimacy of the final decision.

Moreover, it should not be forgotten that the installed power was lower than theoretically necessary for ensuring a sufficient supply of electricity during winter months. This was a serious cause of discontent among the inhabitants, and ended up in damaging the very image of PV in general.

It can be reasonably assumed that one of the main reasons behind SPN’s choice of PV instead of grid extension was the fact that in this way the costs could be reduced by installing less power, whereas the costs associated to the grid would have been fixed.

7.2 Social Multi-Criteria Evaluation as a learning tool: social and technical incommensurability

The focus on the social dimension is one of the key differences between SMCE and other policy analysis instruments (such as for example Cost-Benefit Analysis, Environmental Impact Assessment and also the technocratic types of Multi-Criteria Analysis).

In fact, a technocratic analysis would have limited itself to comparing prices and environmental performances of PV systems and the two grid extension options. On the contrary, SMCE requires getting knowledge about the points of view of the social actors and the relationship of the problem with other related issues. This feature allows including in the analysis different kinds of knowledge, deriving both from technical information supplied by the experts and from the experience of local people. The latter is crucial in managing problems characterized by uncertainty, because it may shed light on some important aspects that the experts might not be able to see.

The second innovation of SMCE -but also of all kinds of Multi-Criteria Analyses (MCA)- with respect to other similar instruments is its capacity of dealing with ”technical incommensurability” (Munda, 2004), i.e., the impossibility of expressing all positive and negative impacts of the available alternatives in the same unit of measurement.

Cost-Benefit Analysis translates all impacts into monetary terms, sums them up and associates to each alternative a single number that summarizes all impacts. On the contrary, in MCA, the impact matrix shows each criterion in its own unit of measurement. For example, deforestation is measured using m^2, greenhouse gas emissions by means of kg of equivalent CO_2, cost in thousand €, and so forth.

SMCE increases the transparency in the decision-making process and promotes a social debate, because it makes the consequences of a policy immediately evident to the public. In other words, SMCE is not only a learning tool for the analyst but also for society as a whole, who can use it for getting information on the political decisions.

The consequence is the need for multidisciplinary and interdisciplinarity[1] for formulating the criteria and determining the criteria scores. In this research, I got information by experts in many different disciplines, e.g. an ornithologist on mortality of birds caused by electric lines, an institution dedicated to fire prevention, a specialist in life-cycle analysis.

[1] Multidisciplinarity is necessary to analyze the various impacts of policies that have consequences on the environmental, economic and the social dimensions. Interdisciplinarity implies that disciplines “need” one another, because the findings of a discipline regarding one issue may be used by another discipline as assumptions for its analysis. For example, information given by engineers on the performance of PV systems was used to estimate the economic cost of using solar energy.

7.3 Subjectivity, transparency and scale

The final ranking of the alternatives is strongly dependent on the problem framing in three stages: first of all in the definition of alternatives and criteria, secondly in the distribution of weights, and in the third place in the aggregation procedure.

As regards the first point, decisions on scale, both in temporal and geographical terms, can considerably affect the ranking among alternatives and even reverse the results (Giampietro 1994; Munda, 2004).

For example, I considered only the local social actors. However, it could be argued that for instance also the inhabitants of Barcelona and the surrounding area who use the Park as a place for their weekend outdoor excursions might have some rights on the Park. Also, Montseny Natural Park was declared Biosphere Reserve by UNESCO, and humanity in general or even the future generations might be considered important stakeholders. Obviously, the political choices to be taken are different according to whom is given the right to decide about the future of the Park.

Not only the definition of the social actors, but also the calculation of the criterion scores is affected by the chosen scale, possibly delivering contrasting results. For example, in the case of rural electrification the environmental impact of traditional electricity can be analyzed on a local scale (deforestation, risk of fires, possible damage to birds, etc) but also on a global scale (environmental impact cause by the fossil fuels or the nuclear energy that are used elsewhere to produce traditional electricity). On a local scale, PV systems have no environmental impact, but if one considers the environmental impact associated with their production and disposal (especially of the battery), the evaluation might change.

The same holds for the temporal scale. With a shorter time horizon, PV systems are much cheaper than if the replacement cost is taken into account.

As regards weights, Munda (2004) argues that deriving them directly from participation is technically very difficult, pragmatically not desirable and even ethically unacceptable[2]. Therefore, in SMCE the set of weights is decided by the analyst, reflecting different ethical positions (see Part I). I distributed the same weights to all criteria (with the consequence that the weight of each dimension depended on the number of criteria that belong to it).

[2] In the first place, deriving weights from a participatory process is difficult because it is not easy to formulate a mechanism that translates the opinion of the social actors into weights. In the second place, establishing a set of weights implies deciding about the relative importance of the different groups of social actors. For example, giving more weight to environmental criteria implies favouring the groups of social actors that consider environmental protection more important. Therefore, it is very difficult to reach an agreement among the groups of social actors on the distribution of weights. In the third place, participation might be biased by many factors that would make it controversial to derive weights directly from it: for example, information in participation processes might be manipulated, the social actors might be influenced, some social actors might be excluded, etc.

However, other possible weight distribution would have been correct, too. In this sense, the sensitivity analysis of the weight distribution played a crucial role and demonstrated that if assigning the same weight to each dimension (according to the concept of sustainable development), the final ranking would have changed for inhabitants and owners in favour of PV, as discussed in Section 6.2.

The choice of the aggregating procedure constitutes a third source of unavoidable subjectivity. However, it must be underlined that in reality what really counts is the process and not the raking itself. By showing the consequences of the analyzed alternatives according to all relevant criteria in the impact matrix, SMCE increases the transparency and gives information on the trade-offs.

Subjectivity is unavoidable in any evaluation exercise. As clarified by the post-normal science framework (Funtowicz and Ravetz, 1991 and 1994), science cannot be neutral. Therefore, the best way of dealing with it is increasing the transparency of the analysis as much as possible, i.e. explaining in a detailed way how the decisions on the representation of the problem were made. The objective is to give the chance to others to make different decisions, in order to see how the results would change if the problem were structured in a different way (if criteria were defined differently, if the scores were assigned in another way, and so forth).

7.4 Solar energy or traditional energy?

The result of the SMCE performed for the Tagamanent conflict showed that, under the assumptions made, within the present subsidizing framework, and giving the same weight to all criteria, solar energy is to be preferred by the public administration. Instead, owners and inhabitants would be neutral between PV and the two grid extension options, provided that enough power were installed to satisfy their energy demand. Four main factors must be pointed out.

First of all, ***public incentives can modify the preferences of the users very much***. In the Tagamanent case, even though the PV systems were more expensive (the electricity consumption being equal), they were cheaper for the final users, because the public administration contributed by almost 80% to the total expense, whereas grid extension was subsidized only by 50%. A lesson that can be learned is that the role of the public administration is crucial in promoting renewable energies, because without its intervention, only in rare cases they are economically competitive. The public actor can modify the preferences of the private actors using economic incentives.

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 preferable if the users are planning to stay in the farmhouse for a limited period of time, e.g. if they rent the house. Surprisingly enough, in this case the most environmentally friendly alternative (i.e. PV) also turns out to be the preferred one according to economic criteria.

In the third place, ***the activity carried out in the farmhouses is crucial in deciding the relative preferability 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 a commercial activity complain about the limits imposed by renewable energy, both in terms of their reliability and available supply of electricity.

Finally, ***solar energy is diffused and discontinuous in nature, and for this reason installation prices are high***. For this reason, if one wants to assure a certain level of service by means of off-grid PV, the dimension of the installation should be calculated under worst case assumptions (winter months). Inevitably, if dimensioned for the winter conditions, stand-alone PV is a comparatively wasteful energy solution[3], because it produces a surplus of electricity in summer, which cannot be stored for long in the batteries (and also there is a limit to the maximum capacity of accumulation). The fact that in the Tagamanent case the decision was made to install a limited amount of PV power clearly shows that the cost for PV wasl high and the public administration could not afford to subsidize such a full blown system, which would have been able to provide a sufficient amount of electricity also in winter. However, the prices of PV components are rapidly decreasing, and a similar analysis could probably produce different results if performed in the near future.

As a conclusion, in this case ***PV is the best option because firstly it is preferred by SPN due to environmental and social criteria and secondly owners and inhabitants are neutral among PV and the two grid extension options (if they are provided with a sufficient amount of electricity). The conflict in Tagamanent was therefore due to the fact that, due to budget constraints, not enough power was installed***.

[3] On the contrary, on-grid PV systems avoid energy wastes because they can be dimensioned according to the yearly average irradiation rate (instead of the lower winter rate), allowing users to buy electricity from the grid in winter and selling it back in the summer.

PART III

AN INTEGRATED ASSESSMENT OF BIODIESEL POLICIES IN ITALY

1 Introduction

Biofuels have been an increasingly hot topic on discussion table in the last few years. In 2003 the European Union introduced a Directive suggesting that Member states should increase the share of biofuels in the energy used for transport to 2% in 2005 and 5.75% in 2010. In 2005 the target was not reached and it will not probably be reached in 2010 either (we are in 2006 at approximately at 0.8%), but anyway the Directive showed the great interest that the European Commission places on biofuels as a way to solve many problems at once.

Biofuels are often presented as a totally advisable policy option, which, if adequately supported, can contribute to reducing the problems related with our strong dependency on fossil fuels. In fact, biofuels are seen as a clean, “green” energy, which is renewable in nature and therefore can supply a virtually infinite amount of energy. For this reason, it is often argued that biofuels would overcome the problem of fossil fuel scarcity, which is of increasingly big concern due to the rising oil demand.

Moreover, many claim that since biofuels can be produced locally, they would alleviate energy dependency, which is an issue in Europe (in the EU-15 53% of the energy used is imported) and especially in Italy, with a share of energy dependency of 85%. For this reason, a large-scale biofuel production, by substituting fossil fuels, would make Europe and Italy less vulnerable to oil price fluctuations.

Also, it is often stated that biofuels, by replacing oil products, would allow reducing greenhouse gases emissions. In fact, the carbon emitted by biodiesel in the combustion phase is the one absorbed by the plant during its growth through photosynthesis, resulting in a neutral carbon budget.

Another point that is often raised to promote biofuels is urban pollution. Biofuels are not only seen as a “green” fuel on a global scale (reduction of greenhouse effect) but also on a local scale. They would contribute to reducing traffic contamination, and therefore the numerous illnesses associated with it.

Finally, promoting biofuels is a strategy for rural development. European agriculture is experimenting increasingly strong difficulties because of the liberalization of the international food market. The European subsidies granted in the framework of the Common Agricultural Policy are often criticized because they distort the free market competition, keeping the European food prices artificially low. Also, the CAP is progressively shifting its focus from a system where financing was proportional to production to a system where farmers are financed independently of the amount of food produced. In this context, many suggest that European subsidies may be used for biofuels. In fact, this would not result in unfair competition with extra-European countries and would not incur in food over-production. Biofuels might be a way out of the impasse for European farmers, who are looking for new ways to make their business profitable.

At first sight, it seems that promotion of biofuels is even more than a win-win solution, and it is optimal under many points of view. As a matter of fact, they are promoted not only by the environmentalists, but also by most scientists, as well as by the agricultural sector and car drivers.

However, if one takes a closer look at how the entire biofuel process works, the conclusions appear not so clear anymore. In fact, biofuel production requires the use of fossil fuels, in the form of fertilizers, pesticides, machinery in the agricultural phase, and also for transporting the oil seeds to the processing plant, and the biofuels to the final user. Also, fossil fuels are used in the processing phase in the form of the methanol used for trans-esterification. The advantages in terms of reduction of greenhouse effect and energy dependency are put into perspective, if one takes into account the entire picture and not only the end-of-pipe emissions.

Also, a large-scale production of biofuels might imply a competition for land with food crops, which in turn might result in an increase of food imports.

All these issue are relevant because biofuels are not competitive with fossil fuel-derived products if left to the market. In order to make their price similar to those of gasoline and diesel, they need to be subsidized. In Europe, biofuels are subsidized in three ways: 1) agricultural subsidies, mainly granted within the framework of the Common Agricultural Policy; 2) total or partial de-fiscalization, which is indispensable, because energy taxes account for approximately half of the final price of gasoline and diesel; 3) biofuels obligations, which establish that the fuels sold at the pump must contain a given percentage of biofuels.

These three political measures need financial means, which are paid for by the European Commission (agricultural subsidies), by the Italian government (reduced energy revenues), and by car drivers (increase in the final fuel price). For this reason, an integrated analysis is needed in order to discuss whether investing public resources in biofuels and employing a large extension of agricultural land is the most advisable strategy to solve the problems associated with fossil fuels.

In order to do that, many different issues should be taken into account, not only the energy yield or the economic cost, but also social and environmental factors. Moreover, the analysis should be performed at different scales and under different perspectives. For these objectives, a Social Multi-Criteria Evaluation (SMCE) approach seems to be the most appropriate.

SMCE is a procedure that supports the public decision making process (see Part I). In all Multi Criteria Analyses (MCA), the different impacts of the evaluated alternatives are expressed each in its own unit of measurement, and are not reduced to one only unit of measurement (such as money in Cost-Benefit Analysis).

SMCE is an extension of MCA, where the evaluation criteria are not decided by the analyst alone, but are derived from the objectives and the interests of the involved social actors. It is a useful approach when there is conflict among different interests and values, uncertainty on the possible effects of the alternatives and incommensurability.

SMCE is particularly suitable for the discussion about biofuels for three reasons. First of all, the entire issue is characterised by a high amount of uncertainty about oil price, food demand, technological development, etc. SMCE allows taking uncertainty into account because it clarifies the different assumptions behind the indicators and does not translate all impacts in one only unit of measurement. Secondly, there are many actors at stake, with different values and interests. Since we are discussing about a public decision making problem, i.e., whether it is worthwhile to invest public resources in promoting the biofuel sector, the interests of the different parts of society should be taken into account. Thirdly, different dimensions (environmental, social, economic) are involved in the issue, and the impacts take place at different scales. SMCE can take into account these aspects, by means of different criteria.

This analysis focuses on biodiesel policy only and not on bioethanol. The reason is that biodiesel is by far the most used biofuel in Europe. It is not likely that bioethanol will replace biodiesel in importance in the short run, even though recently some measures to launch it were taken at the European and at Member States levels. The analysis is performed here for Italy, even though the conclusions can be generalized in many aspects to other densely populated European countries.

The work is structured as follows:

- Chapter 2 gives an outlook on the different energy uses of biomass, and in particularly on biofuels
- Chapter 3 presents the methodology used
- Chapter 4 is dedicated to the institutional analysis, and in particular to the laws regulating the biodiesel sector, the recent history of biodiesel in Italy and the involved social actors
- Chapter 5 defines the alternatives that will be evaluated later on

- Chapter 6 shows the criteria and their scores, and gives some preliminary conclusions
- Chapter 7 focuses on the issue of urban pollution, and compares biodiesel with other fuels currently available in the market under this point of view
- Chapter 8 compares biodiesel with an alternative strategy for rural development, i.e., organic agriculture
- Finally, Chapter 9 discusses the results

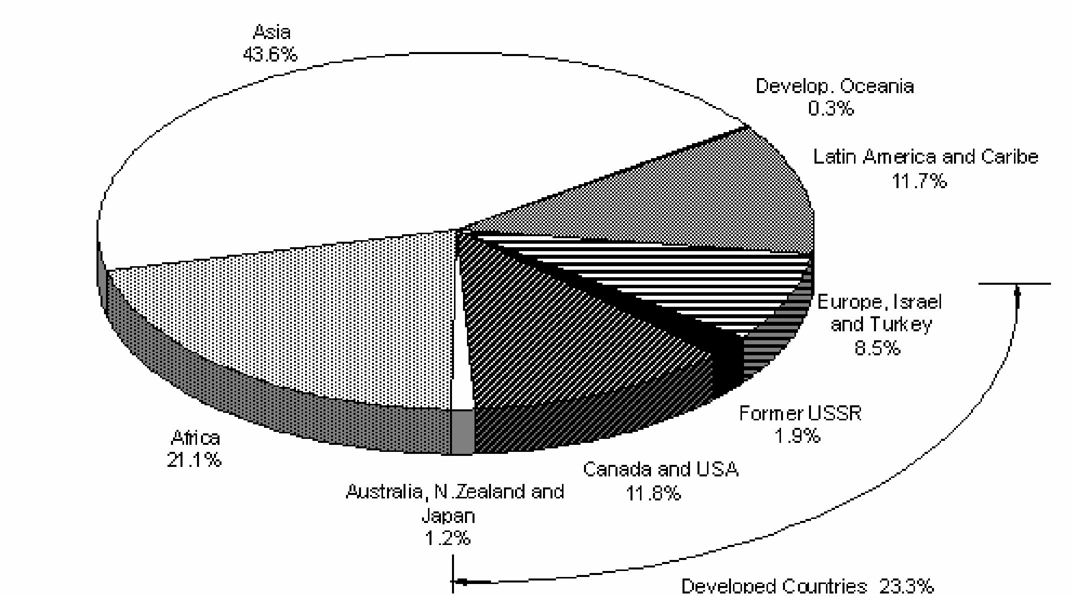
2 Biomass and Biofuels

2.1 Energy use of biomass

2.1.1 Biomass for energy production

Biomass is defined as the organic matter that is produced through a photosynthetic process, including plants, trees and crops, including agricultural and forest residues, as well as the organic fraction of municipal and industrial wastes. In 2003 it provided 10.8%[1] of the world primary energy supply, i.e. around 1,143 Mtoe (IEA, 2005). Most of the biomass employed as energy source is used in Asia and Africa (see Figure 2.1) and is mainly used through direct combustion for domestic heating and cooking.

Figure 2.1 Biomass as a primary energy source in the world



Source: http://www.fae.sk/Dieret/Biomass/biomass.html

Biomass can provide energy as heat, electricity or fuel for transportation. In this sense, it might represent a promising alternative to fossil fuels and nuclear power, because of its lower environmental impact and its wider availability. Many experts are very optimistic on biomass potentiality. For example,

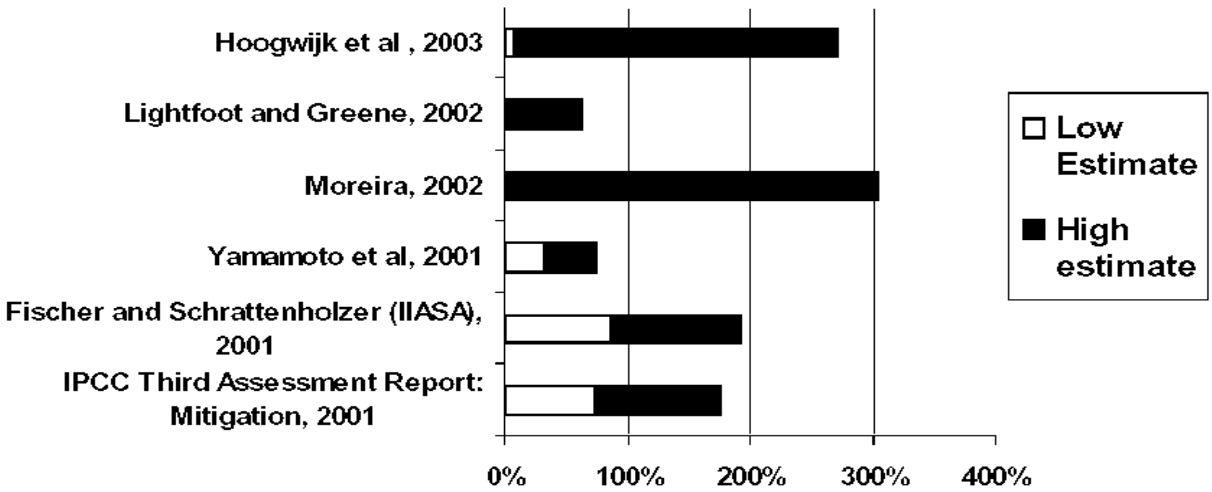
- Hoogwijk et al. (2003) indicate a potential range between 35 and 1,135 EJ per year in 50 years (836 to 27,109 Mtoe). Such high variability depends on the great degree of uncertainty that is related to the issue.
- According to Hall and House (1995), biomass could supply between 9 and 13.5 EJ per year (214 to 322 Mtoe) in 2050.
- Berndes et al. (2003) gather the results of 17 analyses on biofuel potential, which estimate the future contribution of biomass to global energy supply

[1] This figure includes biomass and animal products, municipal and industrial waste.

in a range between 47 EJ and 450 EJ per year for 2050 (1,122 to 10,748 Mtoe).

In TERES II, a study commissioned by the European Union to the English consultancy ESD, in the business-as-usual scenario electricity from biomass will increase in the EU between 1995 and 2020 by 3.7% annually, whereas heat from biomass will increase by 1.8% and ethanol and biodiesel by 10.9%. In Figure 2.2, other very optimistic forecasts are presented[2].

Figure 2.2 Various estimates of the percentage of world transport fuel demand that can be covered by biofuels within 2050



Source: IEA, 2004

Biomass used to produce energy is obtained from different kinds of residues or from earmarked crops. Three kinds of residues can be used: 1) primary residues, i.e. agricultural residues which are generated in the field during the production of food, animal feed or wood; 2) secondary residues generated during food/feed or wood processing, such as bagasse and rice husk; 3) tertiary residues, generated after biomass is used, such as organic municipal solid waste, waste and demolition wood, sludge, etc. (Hoogwijk et al., 2003).

In general terms, it can be said that almost ***any technological option that can be used to recycle wastes should be welcomed because, firstly, it reduces the amount of residues to be discharged, secondly, it reduces the need for primary resources and increases the efficiency of the system***[3]. ***The cultivation of biomass for producing energy is more controversial***, and the objective of this study is to analyse the advantages and disadvantages of such energy policy.

[2] World primary energy consumption in 2003 was 10,723 Mtoe. World energy consumption in the transport sector was 1,895 Mtoe, i.e. 26% of the final energy consumption (IEA, 2005).
[3] However, some residues have alternative uses, such as fertilization, animal feed, raw material for recycling, etc. Therefore, in each case it should be evaluated whether using them for energy production is the best option.

Earmarked cultivations for energy production are mainly sugary plants, cereals, and short-rotation woody crops (such as poplar and willow). The latter are not yet commercially used.

Table 2.1 shows the biomass primary energy supply in Europe. According to these data, the category that provides the largest amount of energy is municipal wastes.

Table 2.1 Biomass primary energy supply in Europe, 2002, thousand toe

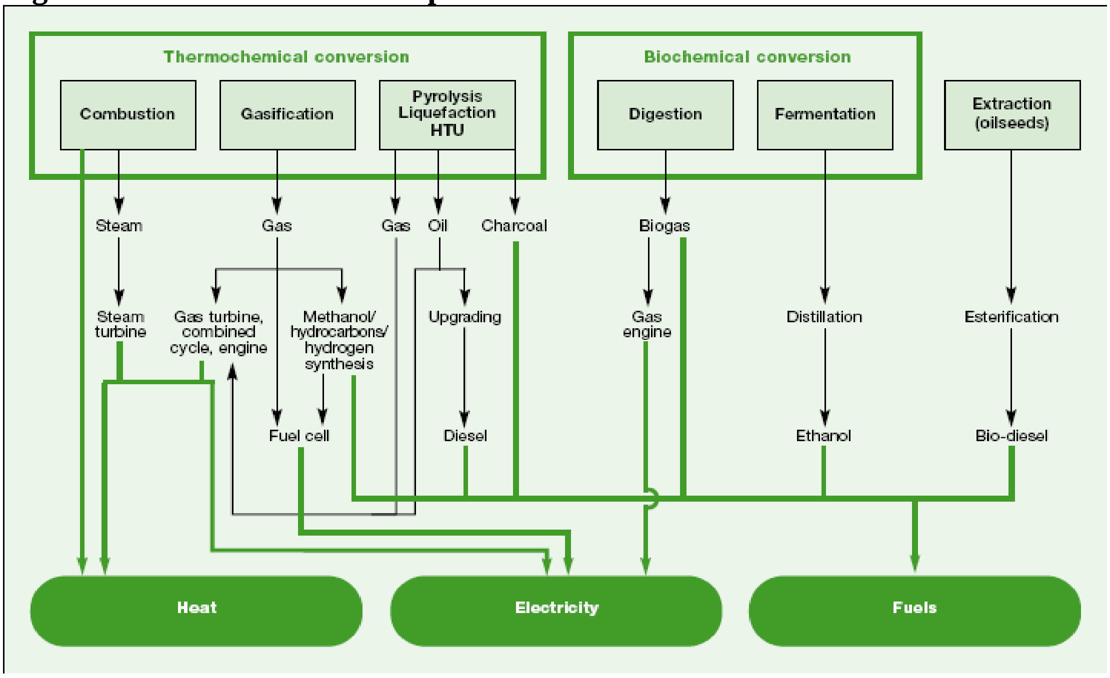
PRODUCT[4]	Municipal wastes-renewables	Municipal wastes-non renewables	Primary solid biomass	Biogas	Liquid biomass
Austria	45	73	3,015	38	14
Belgium	135	193	389	46	0
Denmark	647	154	1,201	80	0
Finland	74	0	6,783	17	0
France	2,043	0	8,573	296	259
Germany	763	700	4,701	1,270	358
Greece	0	0	947	48	0
Ireland	0	0	152	24	0
Italy	426	0	1,566	216	0
Luxembourg	27	0	15	2	0
Netherlands	294	300	634	133	0
Portugal	182	0	2,654	1	0
Spain	195	0	3,811	168	122
Sweden	478	0	7,671	119	0
UK	335	173	800	968	0
European Union-15	**5,643**	**1,593**	**42,913**	**3,427**	**752**

Source: IEA, 2002

Three kinds of processes allow to extract energy from biomass: thermochemical conversion, biochemical conversion and chemical conversion (Figure 2.3). For an overview on the biomass conversion technologies see McKendry (2002), Faaij (2006) and Hamelinck and Faaij (2006).

[4] Primary energy supply= primary production + imports - exports. Municipal wastes include the waste products that are combusted directly to produce heat and/or power (including hospitals). Primary solid biomass includes inputs to charcoal production but not the actual production of charcoal. Biogas is derived principally from the anaerobic fermentation of biomass and solid wastes are combusted to produce heat and/or power. Included in this category are landfill gas and sludge gas (sewage gas and gas from animal slurries) and other biogas. Liquid biomass includes ethanol.

Figure 2.3 Biomass conversion processes[5]



Source: Turkenburg et al., 2000

2.1.2 Thermochemical conversion

Thermochemical conversion can be obtained through combustion, gasification or pyrolysis. The most widespread technology is **direct combustion**, which can be used for domestic heating and cooking. About 2.8 billion people live in rural areas in Southern countries. For them, combustion of wood, crop residues and dung in open fireplaces represents the only available way to obtain energy.

Unluckily, the massive use of biomass for direct combustion in Southern countries has worrying drawbacks (WEC and FAO, 1999; Sagar, 2005). First of all, in many countries the direct combustion of wood is one of the causes of deforestation and is partly responsible for the increasing loss of native forests. Moreover, combustion efficiency is very low, and considerable amounts of biomass must be used. Secondly, use of crop residues and manure may result in deterioration of soil quality and breeding productivity, since they could be used as fertilizers and livestock fodder instead. Thirdly, biomass cooking in traditional stoves generates harmful pollutants, such as particulate matter, carbon monoxide, nitrogen oxides and various carcinogenic organic compounds, which especially affect women and children (Ezzati and Kammen, 2001). Also, stoves may be dangerous for users. Fourthly, collecting and using biomass in a traditional way require a huge amount of time from women and children, which might be spent in other occupations.

Modern technologies have been developed to increase efficiency and reduce pollution, such as pellet burners and wood boilers. They mostly use wood pellets

[5] HTU means "hydrothermal upgrading", and is a methodology for producing liquid fuels from biomass.

that are produced as residues by the wood processing industry. Using pellets as fuel in modern wood boilers or pellet burners reduces the emitted organic compounds very much and increases efficiency because a complete combustion is achieved (Kiällstrand and Olsson, 2004). Another advantage is that pellets are easy to distribute and store (Vinterbäck, 2004). The use of wood pellets increased very quickly in the last ten years and it is especially widespread in Austria, France, Germany and Sweden (Faaij, 2006). They seem to be a promising renewable energy source, especially as a way to recycle wood residues. An entire issue of the journal Biomass and Bioenergy (volume 27, issue 6, December 2004) is dedicated to pellets. A relevant drawback of pellets is the production of ashes (Öhman et al., 2004).

Also, **co-combustion** of biomass in coal-fired power plants allows a reduction in the use of coal and in the related pollution, thus also increasing conversion efficiency (Demirbaş, 2003). The most widely used biomass types are wood wastes, plantation wood, manure, landfill and wastewater treatment gas, urban wood waste, switchgrass (Tillman, 2000). Co-firing constitutes the most effective way to use residues that would otherwise be thrown away and to reduce the greenhouse emissions of coal-fired power plants (Baxter, 2005).

Finally, combustion can be used to generate steam to be used in steam turbines, in order to produce electricity. Using **combined heat and power** (CHP) systems allows producing at the same time electricity and heat, increasing the efficiency and lowering the costs of the system. Denmark, Finland and the Netherlands have implemented large programmes to use CHP for district heating (Korhonen, 2004). Biomass combustion to generate electricity and heat is mostly carried out by the paper and pulp industry, which can use black liquors and waste incineration.

Gasification allows converting biomass to gas and syngas (abbreviation of synthesis gas, a mixture of carbon monoxide and hydrogen). It is carried out oxidising biomass at 800-900 °C. The low calorific value gas produced can be burnt directly or used in gas engines and gas turbines. Syngas can be used for producing chemicals. In this way, biofuels can be obtained, in particular methanol, liquid hydrocarbons or diesel and hydrogen, which have a promising future as fuels for transportation. Also, gasification can provide heat and electricity in combined systems (Pilavachi, 2000; Marbe et al., 2004; Murphy et al., 2004). Other promising uses of gasification are CHP for district heating and co-firing processes of coal-fired power plants. However, the technology is not mature yet and it is not used on a commercial scale.

Pyrolysis is a process whereby biomass is heated to 450-600 ^{o}C in absence of air in order to produce organic vapour (which is then condensed to bio-oil), gases and charcoal. It can be used for heat, power or CHP applications. The advantage of pyrolisis as compared to gasification is that it produces a fuel (the bio-oil) that can be easily stored and transported. Bio-oil constitutes typically around 75% of pyrolysis production. Bio-oil technology is not commercial yet, but this technology is improving quickly and is now approaching the demonstration phase. Some problems, such as the scarce thermal stability and high corrosivity, still need to be solved. According to Brammer et al. (2006), in six out of the analyzed fourteen European countries bio-oil will soon be economically competitive, especially for heat generation.

2.1.3 Biochemical conversion

Biochemical processes can be carried out through digestion and fermentation, and are mainly used to obtain biofuels for transportation.

Anaerobic digestion is a process that generates biogas (basically a mixture of methane and carbon dioxide) by means of bacteria that degrade biomass in absence of oxygen. It is particularly suited for wet biomass, such as sludge, manure, organic wastes. It is commercially used by various countries. The most common application of this technology is waste treatment. Biogas can also be produced using landfill gas, which is rich in methane. The biogas that is obtained from anaerobic digestion can be used in CHP plants. It can also be used as vehicle fuel, if discharged into the gas grid in order to build up a set of biogas service stations. For example, the international car enterprise Volvo developed a bi-fuel car that can be fuelled with either gas or petrol, allowing great flexibility (Murphy et al. 2004).

Fermentation is widely used on a commercial scale in many countries. It allows producing ethanol from sugar crops (sugar cane, sugar beet) and starch crops (maize, cereals) or ligno-cellulosic biomass (wood and grasses). Biomass is converted by enzymes to sugars, which are then converted to ethanol by yeasts. Finally, ethanol is purified by distillation. The residues generated during the process can be used to feed cattle. The bagasse obtained as a by-product from sugar cane fermentation can be used as a fuel for boilers or gasification. If sugar is obtained from ligno-cellulosic biomass, before fermentation the longer-chain polysaccharide molecules must be broken through hydrolysis processes, which are still at a pre-pilot stage. If mixed with petrol at a low percentage (around 8%), ethanol can be used without changing the car engine. It can also be used pure, but in that case it requires special engines, because it is not really compatible with normal petrol engines. The last choice does not appear suitable for private cars, because ethanol distributors are still few, and using engines that can only be used with ethanol would reduce flexibility very much.

2.1.4 Chemical conversion

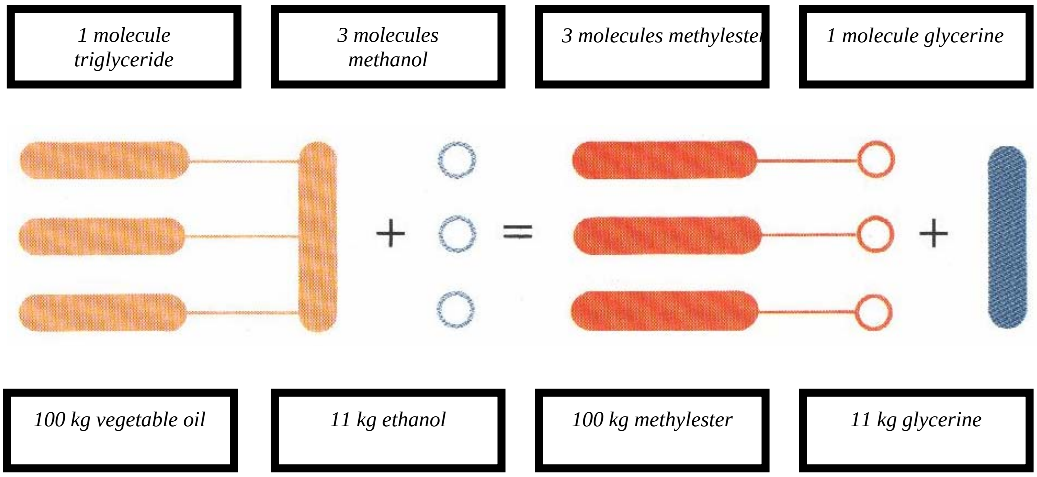
Biofuels can also be produced using oil seeds (e.g. rapeseed, sunflower and soybean). In this case, the product is called **biodiesel**. Vegetable oils cannot be directly used in the diesel engines that are designed to be used with fossil fuels because of 1) their higher viscosity; 2) their higher flash point and 3) their tendency for thermal or oxidative polymerization.

In order to solve these problems, the vegetable oils need to be adapted, with the objective of making their characteristics as similar to the oil-derived fuels as possible. Four techniques were developed: pyrolysis, dilution with conventional diesel, micro-emulsification and trans-esterification.

The most viable and commonly used method is trans-esterification (see Figure 2.4). The process is very simple. First of all, the oil seeds must be dried, baked, ground and pressed. The resulting oil is converted to biodiesel by trans-esterification, which consists in adding an alcohol (generally, methanol, which is the cheapest alcohol) to the vegetable oil, obtaining as a result biodiesel[6] and glycerine. This process was already known in the mid nineteenth century and was used in the Thirties and Forties to produce soap (see Section 4.2). The first biodiesel patent dates back to 1937 (Knothe, 2005). It was referred to as biodiesel produced with palm oil ethyl esters. In 1938 a bus fuelled by palm oil ethyl esters ran between Brussels and Louvain (Mittelbach and Remschmidt, 2004).

Biodiesel can replace petroleum diesel. Unlike vegetable oils, it can be used in diesel engines with only minor adaptations, and if mixed in a low blend with diesel, it does not require any modification.

Figure 2.4 The trans-esterification process



Source: Rocchetta, 1992

The biodiesel process produces as main by-products glycerine and cake meal (see Table 2.2).

[6] The term “biodiesel” was introduced in 1988 in a Chinese paper (Knothe, 2001).

Table 2.2 Biodiesel by products

	kg/ha	%
Biodiesel	1,048	42
Glycerine	115	5
Cake meal	1,331	53
Total	**2,494**	**100**

Source: Bernesson et al., 2004, adapted.

Cake meal is composed of the oil seed residue after oil extraction. It can be used as cattle feed. However, some experts argue that cake meal is also very valuable for soil amendment (Cohen and Mazzola, 2004).

As shown in Figure 2.4, glycerine is produced during the trans-esterification process (0.11 kg of glycerine for each kg of biodiesel). It can be employed in many industrial processes. For example, it can be used by pharmaceutical industries as a solvent and a wet support for tablets, by the alimentary industries for various preparations or to produce plastics and paints. It is also used in agriculture, in the textile and leather industries. Finally, it can be used for preparing soaps, toothpaste, and creams[7].

2.2 Diffusion in Europe

Biofuels represented around 0.8% of European energy consumption for transport in 2004[8]. This percentage is steadily increasing, as shown in Table 2.3[9].

Table 2.3 Percentage of liquid biofuels on total fuel consumption in the transport sector

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Belgium	0	0	0.1	0	0	0	0	0	0	0	0
Czech Republic	0		0	0.4	0.4	0.6	0.3	0.3	0.8	0.6	0.5
Germany	0	0	0	0	0.1	0.1	0.1	0.2	0.3	0.4	0.7
Spain	0	0	0	0	0	0	0	0	0.2	0.2	0.4
France	0	0.1	0.2	0.4	0.5	0.6	0.5	0.6	0.6	0.6	0.6
Austria	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
EU-25	**0**	**0**	**0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**
EU-15	**0**	**0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.3**

Source: Eurostat data-base

About 90% of biofuel is obtained using domestic raw materials, which are cultivated in 1.8 million hectares (total arable land in EU-25 is 97 million

[7] Comitato Termotecnico Italiano, http://www.cti2000.it/biodiesel.htm.
[8] COM(2005) 628 final, 7/12/2005.
[9] It can be noted that data from different sources do not match, due to the high degree of uncertainty. The share of biodiesel in Europe as indicated by the European Biodiesel Board (1.5 Mtoe) is about 0.4 % of the final consumption of the transport sector as indicated by OECD (321 Mtoe). This figure is higher than the one indicated in the Eurostat statistics for all liquid biofuels (Table 2.3). This discrepancy may have at least two causes. First of all, biofuels represent such a small amount in the energy balances that it is not considered worthwhile to invest resources to gather detailed data about them. Secondly, the European Biodiesel Board may be interested in showing that biodiesel production is higher than it really is.

hectares). Biodiesel constitutes 80% of the European biofuels, the rest being bioethanol. Whereas in 2001 high blends or even pure biofuels prevailed, in the last years a shift towards low blends has taken place[10].

Table 2.4 shows some indicators on the production and consumption of biofuels in Europe. It can be noted that they are mainly used in the transport sector (but on the contrary in Italy they are mainly used for heating purposes, see below). The main European producers are Poland, Germany and France. There are no figures available for Italy, presumably due to a lack of data.

Table 2.4 Production and consumption of biofuels in Europe, thousand tonnes, 2003

Indicator	EU25	Czech Republic	Denmark	Germany	Spain	France	Austria	Poland	Slovakia
Primary production	2,606	0	45	650	257	452	21	1,1	2
Imports	10	-	-	-	-	10	-	-	-
Exports	62	-	-	-	-	62	-	-	-
Final energy consumption	2,577	70	0	650	257	400	21	1,179	-
Final energy consumption industry	3	3	-	-	-	-	-	-	-
Final energy consumption transport	2,526	30	0	650	257	400	10	1,179	-
Final energy consumption household and services	48	37	-	-	-	-	11	-	-
Final energy consumption agriculture	48	37	-	-	-	-	11	-	-

Source: after Eurostat data-base

Data on production, manufacturing and use of specific biofuels are difficult to find and subject to a large degree of uncertainty. In fact, biofuels can be produced from a number of crops. It is very difficult to distinguish which part of the European crop production is used for biofuels and which one is used for as food or cattle feed. In the OECD energy balances, a note warns that in the biomass category, "*data under this heading are often based on small sample surveys or other incomplete information. Thus the data give only a broad impression of developments, and are not strictly comparable between countries. In some cases complete categories of vegetal fuel are omitted due to lack of information*". Some statistics are provided by biofuels producers or specialized institutes, and can be found on the internet.

According to some data published in the web page of the Online Distillery Network[11], in 2001 65.5% of the world ethanol production was located in the American continent (mainly in Brazil and USA) and 13.2% in Europe. In Europe, ethanol is mainly not used directly, but transformed into ethyl

[10] COM/2005/628 final, 7/12/2005.
[11] http://www.distill.com.

tertiary butyl ether (ETBE) and mixed with petrol. The European countries with a higher production are France, Spain and Sweden. In
Table 2.1, the production in Europe is shown by country.

Table 2.5 Ethanol in the most important European producers

	ETBE		Ethanol	
	Thousand tonnes	Thousand toe	Thousand tonnes	Thousand toe
France	192.5	123.2	90.5	57.9
Spain	375.5	240.3	176.7	113
Sweden	0	0	50	32
Total	**568**	**363.5**	**317**	**203**

Source: His, 2004

According to the European Biodiesel Board[12], in Europe there are 40 biodiesel plants, mainly located in Germany, Italy, Austria, France and Sweden. Also, 1.4 million ha are used for biofuels. In 2004, almost 2,000,000 tonnes of biodiesel were produced (see Table 2.6). This figure corresponds to about 1.5 Mtoe. In order to have an idea of what this figure means, it may be useful to remember that according to the OECD energy balances, in 2002 the final consumption of energy in Europe was 1,057 Mtoe and the final consumption in the transport sector was 321 Mtoe[13].

Table 2.6 Biodiesel production in Europe, 2004

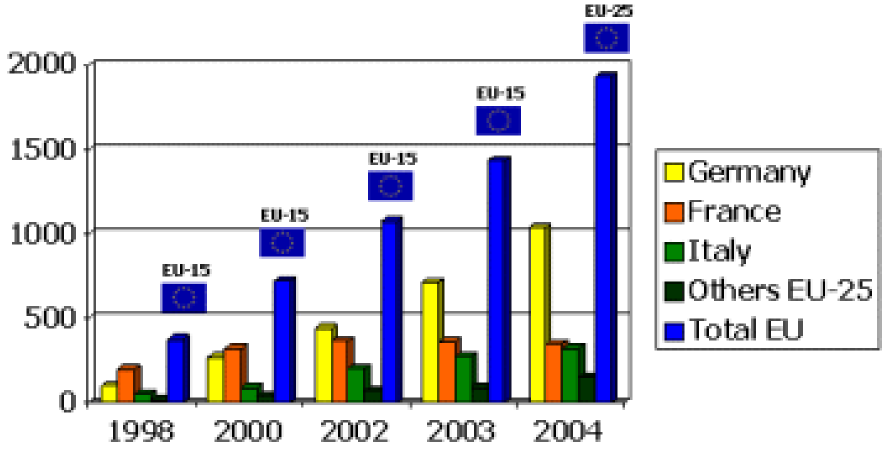
Country	Production (thousand tonnes)
Germany	1,035
France	348
Italy	320
Austria	57
Spain	13
Denmark	70
United Kingdom	9
Sweden	1.4
Czech Republic	60
Slovakia	15
Lithuania	5
Total	**1,933**

Source: European Biodiesel Board, http://www.ebb-eu.org

It is important to note that biodiesel production increased very quickly in the last few years (Figure 2.5). In 2004 it increased by 35% with respect to 2003 (European Biodiesel Board data-base).

[12] http://www.ebb-eu.org.
[13] It can be noted that these data do not match the OECD and Eurostat ones shown before, probably due to the inherent uncertainties.

Figure 2.5 Biodiesel development in Europe between 1998 and 2004



Source: European Biodiesel Board, http://www.ebb-eu.org

2.3 Diffusion in Italy

In Italy most biofuel production consists of biodiesel, whereas the production of bioethanol is still negligible. Biodiesel in Italy increased very quickly in the last years, from 145 thousand tonnes in 2001 to 326 thousand tonnes in 2004[14]. 80% of Italian biodiesel is derived from rapeseed and 20% from sunflower[15].

Most biodiesel is produced using imported oil seeds. Considering a yield of 0.7 tonnes/ha (see Chapter 5), to produce 326 thousand tonnes, around 466 thousand hectares of oil seeds had to be cultivated. However, as it is shown in Table 2.7, in 2004 only 277 thousand hectares were cultivated with sunflower and rapeseed. This figure includes oil used in the food and chemical industry.

Table 2.7 Cultivation of oil seeds in Italy, thousand hectares

	1999	2000	2001	2002	2003	2004	2005
Rapeseed	51	36	26	10	5	3	3
Sunflower	207	216	208	166	151	124	130
Soybean	246	257	233	152	152	150	152
Total	**504**	**509**	**467**	**328**	**308**	**277**	**285**

Source: ISTAT data-base

In fact, only approximately 20% of Italian biodiesel is produced with Italian oil seeds (mostly sunflower). Most Italian biodiesel producers buy the raw material in Germany where, due to higher yields, it is cheaper than in Italy (De Filippis, 2003). Considering a yield of 0.7 tonnes/ha, it can be concluded that in 2004 around 93 thousand hectares were used in Italy for producing biodiesel.

Italy is a net importer of both rapeseed and sunflower. Table 2.8 shows the Italian oil seed international trade, both in monetary terms and in terms of weight. These data refer to the total oil seed trade, thus including import and export not only for

[14] Biodiesel News, Assobiodiesel newsletter, March 2005, http://www.assobiodiesel.it.
[15] Data provided by the Comitato Termotecnico Italiano, CTI, http://www.cti2000.it.

energy use but also for industrial and food uses. It can be noted that the average price for oil seed import is less than half of the export price.

Table 2.8 Italian oil seeds international trade, 2003

	Rapeseed		Sunflower	
	Thousand tonnes	Thousand euros	Thousand tonnes	Thousand euros
Import	15	3,110	173	45,606
Export	2	788	5	3,803
Import-export	13	2,322	168	41,803
Average price import (€ per tonne)	205		263	
Average price export (€ per tonne)	434		782	

Source: OECD, 2005

Another interesting issue to underline is that most biodiesel is used in Italy for heating purposes. Therefore, up until now the car drivers that used biodiesel were a very small minority. In fact, at the moment biodiesel is not sold at the pump, neither pure nor as a blend, but only in bulk. However, as it will be explained in Chapter 4.4 a recent law established that from 1st July 2006 the fuels sold at the pump must contain at least 1% of biofuels (see Section 4.4).

2.4 Is it really worthwhile to support biofuels?

Biofuels are not (yet?) economically competitive with fossil fuels, and thus they need to be supported through some public policies. Some authors argue that biofuels should be supported in the first stage of their development in order to reduce prices, which in turn will increase demand and production. The subsequent market expansion would allow technological progress and scale economies. At a certain point, government incentives would not be needed anymore.

For example, Goldemberg et al. (2004) argue that this was the case in Brazil, where ethanol from sugarcane was strongly supported by the Brazilian Alcohol Program (PROALCOOL), established in 1975 in order to reduce oil imports. PROALCOOL controlled the ethanol price until 1997 and liberalized it afterwards, when it reached economic competitiveness. The programme allowed sugarcane production to increase from 91 million tonnes in 1975 to 320 million tonnes in 2002, and the price to dramatically decrease. Now subsidies are not needed any more, and ethanol is competitive with fossil fuels. In this case, optimism on the role of biomass in future energy supply can be explained with the abundance of land in Brazil with respect to population. However, the Brazilian experience is not directly applicable to Europe, where the population density is much higher.

Nevertheless, also in Europe and in the United States many experts are very optimistic on biomass potential and its future role in reducing oil dependency, as it is mentioned in Section 2.1. Biofuel advocates argue that governments should invest public resources to support biofuels not only because they contribute to reducing greenhouse emissions but also because of the environmental and social advantages they might offer.

Most papers published in the journal *Biomass and Bioenergy* and other journals claim that biofuels are a very promising option for several reasons: 1) they allow reducing greenhouse-effect emissions; 2) they contribute to preserving rural landscape and creating employment in rural areas; 3) they increase energy security and reduce dependency on oil exporting countries; 4) they pollute less on a local scale than fossil fuels. However, for several reasons that will be explored later in this study, a minority of experts disagree on all these points and state that biofuels are not good candidates to substitute fossil fuels (Giampietro et al., 1997; Ulgiati, 2001).

The present study explores the different aspects of this debate, underlining the advantages and disadvantages of biomass cultivation to produce energy.

3 Methodology

3.1 Social Multi Criteria Evaluation

This work is based on the Social Multi-Criteria Evaluation (SMCE) approach (see Part I), as defined by Munda (2004), even though the methodology was adapted for the problem under analysis.

SMCE is a kind of multi-criteria analysis that combines the technical evaluation of different options according to various assessment criteria with the analysis of the social actors' conflicting values and interests.

Two main ideas are at the basis of SMCE: *technical incommensurability* (i.e. in a complex environment one cannot express all impacts of a policy using one only unit of measurement, or, in other words, an inter/multidisciplinary analysis is needed) and *social incommensurability* (i.e. the social actors have different and legitimately conflicting values and interests, which must be taken into account when evaluating a policy or a project).

Even though many studies have been published on *Biomass and Bioenergy* and other journals on the characteristics and the feasibility of biodiesel, they all focus on one or another aspect of biodiesel, e.g. land requirement, costs, technical characteristics or emissions. For this reason, many claim that, for example, biodiesel is environmentally friendly because it allows sparing some greenhouse emissions. However, these analyses do not investigate sufficiently other environmental impacts that a large-scale biodiesel production would imply, i.e. the ones associated with intensive agricultural techniques (use of fertilizers, reduction of agricultural biodiversity, use of GMOs, etc.).

The novelty of the analysis presented here is on the contrary the attempt to give a wide picture of the consequences of the policy measures in favour of biodiesel. In order to do that, many different criteria were used, each with its unit of measurement, which represent the impacts of a possible large-scale biodiesel production in different dimensions.

Social incommensurability implies that in a complex environment the properties of a system cannot be described using only one perspective (Giampietro and Mayumi, 2000). As a consequence, the evaluation of a policy cannot be carried out by means of a technocratic analysis made by the analyst alone. On the contrary, it should be based on the objectives, values and interests of the involved social actors and each option should be considered good or bad according to their objectives. In this analysis, part of the evaluation criteria were derived from the objectives of the social actors involved. This feature contributes to widening the analysis and taking into account many different issues.

3.2 The scope of this study

The objective of this study was to discuss whether a large-scale biodiesel production in Italy is advisable.

The focus was on biodiesel production from earmarked cultivations, for two reasons. Firstly, even though bioethanol is the most widely produced biofuel in the world, its production represents only 20% of the European share and is negligible in Italy. Secondly, according to Giampietro and Ulgiati (2005), the net to gross energy ratio is 1.16 for biodiesel and only 0.58 for bioethanol (the ethanol production process consumes more energy than it provides). It might be noticed that they calculate this number considering a corn-based bioethanol process, whereas the sugar beet allows obtaining a much higher yield. However, sugar beet causes a very high soil erosion rate, making it a not-so advisable option on a large scale. Second generation biofuels, such as the ones obtained from ligno-cellulosic processes could possible increase significantly the bioethanol yield but they are still under development. According to the Biomass Action Plan[1], second generation biofuels will not be economically suitable until after 2010.

SMCE seemed to be appropriate to explore the biodiesel policy debate for three reasons.

First of all, the issue involves different scales (local, national, European, worldwide) and different dimensions (at least the energy, environmental, economic and social ones). Therefore, it needs to be analyzed with a methodology that allows taking into account a wide range of assessment criteria, which refer to different scales and dimensions.

Secondly, the issue is influenced by a number of very uncertain factors, such as oil price, demand for food and world population, technological development, and many others. This uncertainty should be recognized and not hidden behind a list of assumptions. SMCE allows taking into account uncertainty by using not only quantitative but also qualitative criteria, which can be used when quantitative information is not available.

Thirdly, biodiesel policy is a matter of public policy where many actors come into play (biodiesel producers, rural population, farmers, car users, governments, urban population, etc.). They have different values and interests that may come into conflict. In a situation characterized by complexity, no optimal solution exists, or, in other words, any choice may be better from one point of view and worse from another. SMCE can offer a framework wherein to gather information on the various consequences of the alternative options in different dimensions and for different social actors, in order to favour the social debate.

[1] COM/2005/628 final, 7/12/2005.

3.3 Two differences with respect to the “orthodox” SMCE procedure

I did not follow here all steps that are usually carried out in a SMCE (see Part I). There are two main differences.

First of all, I did not carry out a participatory process, as it is normally done in SMCE to look for information on the social actors, define alternatives, choose criteria and give them a score. In fact, most SMCE (de Marchi et al., 2000; Martí 2001; Gamboa, 2003) were performed to analyze a local conflict or a project. On the contrary, this work was intended to analyze a policy on a national scale.

Therefore, it would have been difficult to involve in interviews, workshops and focus groups the representatives of the relevant social groups, such as for example the European Commission (DG Energy and Transport and Agriculture and DG Rural Development), the Italian government (Ministries of Agriculture and Forestry, of the Environment, of Finance, of Transport), the three Italian farmer and agricultural entrepreneur associations, the car drivers, the biodiesel producers, the main Italian environmentalist NGOs, the experts on energy issues, etc. In order to do that, a great availability of resources would have been needed and, above all, the different parts should have been willing to collaborate, explain their points of view and find an agreement.

I obtained information on the position of the social actors through newspaper articles and documents found on the internet. I am however convinced that the results are a good approximation of a real participatory process and represent well the opinions and the interests of the different social actors.

Also, I felt that the criteria derived from the social actors’ objectives were not enough to represent the different trade-offs involved in the problem under analysis. In fact, some important issues that are important for society as a whole, such as land requirement and food sovereignty, do not necessarily reflect the objectives of the social actors involved in the biodiesel debate. However, they cannot be ignored when dealing with a policy that would have such a strong impact on the agricultural sector.

The second difference is that I did not build a ranking system for the alternatives, but simply discussed their pros and cons on the basis of the observation of the impact matrix. The main advantage of not aggregating the criterion scores is the increase in transparency. In fact, when creating a ranking among alternatives, some crucial decisions on weighting factors must be made, which can hide some pre-conceived judgments. On the other hand, the main disadvantage is the lack of practical suggestions for the policy-maker on what to do. However, in this case the trade-offs were sufficiently clear (e.g. land use *versus* CO_2 savings) not to require further aggregation. The political debate should focus precisely on these trade-offs when deciding whether it is really worthwhile to support a large-scale biodiesel sector in Italy.

3.4 The phases of the research

I structured the research following the main steps of a SMCE (see Part I):

1) Institutional analysis
2) Definition of the alternatives
3) Choice of the criteria
4) Attribution of the criterion scores and construction of the multi-criteria impact matrix

As explained in Section 3.3, I did not perform the last steps (the aggregation of the criteria and the sensitivity analysis).

A SMCE always starts with an ***institutional analysis***, which gathers information on the institutional context, the involved social actors and their interests and values, the pattern of interaction among them, the relevant laws. Also, at this stage, a chronology of the facts that led to the present situation is essential.

Chapter 4 presents the results of the institutional analysis on the biodiesel issue. First of all, I performed a research to find information on the history of biodiesel development from its start at the beginning of the 20th century (sources were scientific papers and documents found on the internet). Then I used official documents and statistics of the European Union to give an overview on the situation of biofuels in Europe: the latest legislative acts, the situation in the Member States and the international trade. On a smaller scale, I also sketched the history of the “biofuel fever” in Italy, mainly on the basis of documents found on the internet and produced by environmentalists, journalists, car magazines, farmer associations, etc. The history of biodiesel allowed me to define the involved social actors together with their objectives. Also, I learnt about the arguments of biodiesel promoters (obtained through declaration and documents), which are listed in Section 4.6.

The second step is the ***definition of alternatives*** (Chapter 5). For the reasons explained above, I did not build the alternatives by means of a participatory process, as is normally done in a SMCE. I took the target established by the European Directive 2003/30/EC on biofuels and tried to forecast what could happen if it were achieved in Italy. In order to perform the analysis, I made some assumptions on the energy output/input ratio, the oil seed mix, the use of by-products. I always made the most optimistic assumptions in order to demonstrate that if even in this way the disadvantages of a large scale biodiesel production are not acceptable, then it can be safely claimed that biodiesel should not be promoted with public financing and laws.

The next step is the ***choice of the criteria*** (Chapter 6) that were used to evaluate the alternatives. I derived part of the criteria from the social actors’ objectives, as defined in Chapter 4. Other criteria reflected some more general issues, such as land requirement and energy dependency.

Once the criteria were chosen, I gave them a ***score***, which expressed the ***performance of each alternative according to each criterion***. The result was a genuine multi-criteria work, where variegate knowledge about agriculture, environmental impacts, energy systems, etc. was used. In order to do that I carried out a wide literature review to gather information regarding the different aspects of the biodiesel process. The results are presented in the ***impact matrix*** shown in Section 6.5.

After that, I explored more in depth two issues which are related with biofuels, i.e. urban pollution and rural development.

It is often claimed that biodiesel can give a contribution in reducing urban pollution. However, there might be other options that are more effective to that end. In Chapter 7 I used data found in the scientific literature to ***compare biodiesel with other fuels currently available on the market*** (petrol, natural gas and LPG) and ***other options that might be more widespread in the future*** (battery electric vehicles, hybrid electric vehicles and hydrogen vehicles).

Finally, Chapter 8 explores ***a possible alternative to biodiesel: organic agriculture***. The point is that if the objective is to incentive rural development, organic agriculture may offer a better solution, since it provides society with bigger benefits and does not present the huge drawbacks of large-scale oil seed cultivation. In order to develop this argument, I gathered information on the main characteristics of organic agriculture, and compared it to biodiesel production.

4 Institutional Analysis

4.1 Taking the social dimension into account

Most papers dealing with the potentiality of biofuels focus on some single specific or technical aspect. Dozens of papers published in recent years in *Biomass and Bioenergy* and other journals analyze the potentiality of biofuels in terms of energy yield and land availability (Berndes et al.; 2003 Wolf et al.; 2003, Hoogwijk et al., 2003).

Others assess the life cycle, and in particular the energy requirement of biodiesel production and the output/input yield (Bernesson et al. 2004; Janulis P., 2004; Kallivroussis et al, 2002; Venturi and Venturi, 2003; Cardone et al., 2003; Gärtner, 2005).

Many studies focus on the technical characteristics of the fuel and on exhaust emissions (Altin et al. 2001; Graboski and McCormick, 1998; Kalligeros et al., 2003; Labeckas and Slavinskas, 2005; Mc Cormick and Aleman, 2005; Puhans, 2005; Turrio-Baldassarri et al., 2004).

Also, a smaller but non-negligible number of papers deal with the economic aspects of a possible expansion of the biofuel sector in Europe (Haas, 2006; Dorado et al., 2006; Ahoussoussi and Wetzstein, 1997).

However, the social aspects of biofuels are mostly neglected. At most, local opposition against biomass facilities (Upretia and van den Horst, 2004) is analyzed. Also, papers can be found arguing that if biofuels are not really taking off it is because education and communication are lacking.

Nevertheless, the social dimension is a very important aspect to take into account. Political decisions are deeply influenced by the power games among the actors. Stronger groups can lobby to impose on the others the decisions that are most favourable to their own interests, but not necessarily to the interests of society as a whole. Also, social aspects can determine the success or failure of a policy. For this reason, when evaluating a possible policy it is essential to also analyze how it would affect the involved social actors and how the latter might influence the decision process.

In this work the social dimension of the biofuels issue was explored using institutional analysis. In particular, I focussed on the history of biofuels (Section 4.2); the European institutional context, including the legislative framework and the main instruments used to promote biofuels both at the European level and in the Member States (Section 4.3); the history of biofuels in Italy (Section 4.4); the main groups of actors and their objectives (Section 4.5); the main arguments in favour of biodiesel that are used by the different social groups (Section 4.6).

4.2 Biodiesel history

Trans-esterification of vegetable oils was already used in the middle of the nineteenth century[1]. The process was probably invented to produce glycerine for soap. Biodiesel was a by-product of this process.

During the 1990 Paris Exposition, Rudolph Diesel presented five of his new efficient engines (invented in 1893). One of them ran on peanut oil and nobody noticed the difference. In one presentation at the Institution of Mechanical Engineers, cited by Knothe (2005), Diesel explained that the request came from the French Government, who was interested in making its colonies independent of energy imports.

Diesel thought that the engine he invented could have been fuelled with vegetable oils. His idea was that it would have allowed people to break free from dependency on fossil fuels, and consequently from the large industries and the supplying countries. Also, using plant-derived fuels would give an incentive to agriculture and support local development[2].

He stated that "*[vegetable] oils may perhaps become in course of time of the same importance as some natural mineral oils and the tar products are now. Twelve years ago, the latter were not more developed than the fat oils are today, and yet how important they have since become. One cannot predict what part these oils will play in the Colonies in the future. In any case, they make it certain that motor-power can still be produced from the heat of the sun, which is always available for agricultural purposes, even when all our natural stores of solid and liquid fuels are exhausted*"[3].

Also, Henry Ford's cars, including the famous model T (1908), were designed to use ethanol. Ford set up a hemp-based ethanol mill and made a partnership with the enterprise Standard Oil to sell his ethanol at its pumps. During the 1920's ethanol constituted 25% of the fuel sold at Standard Oil pumps in the area of Ford's ethanol mill (Midwest).

Until the Forties, most European governments with African colonies showed an interest in vegetable oils, especially palm oil, as a way to ensure energy independency to their colonies. Also a number of technical papers showed an interest in the academic environment (Knothe, 2005).

However, in the Thirties fossil fuels became increasingly cheaper and more widespread, and consequently biofuels became less attractive. Biofuels could not support an energy-intensive economy, because they would have required too much land, besides being much more expensive than oil.

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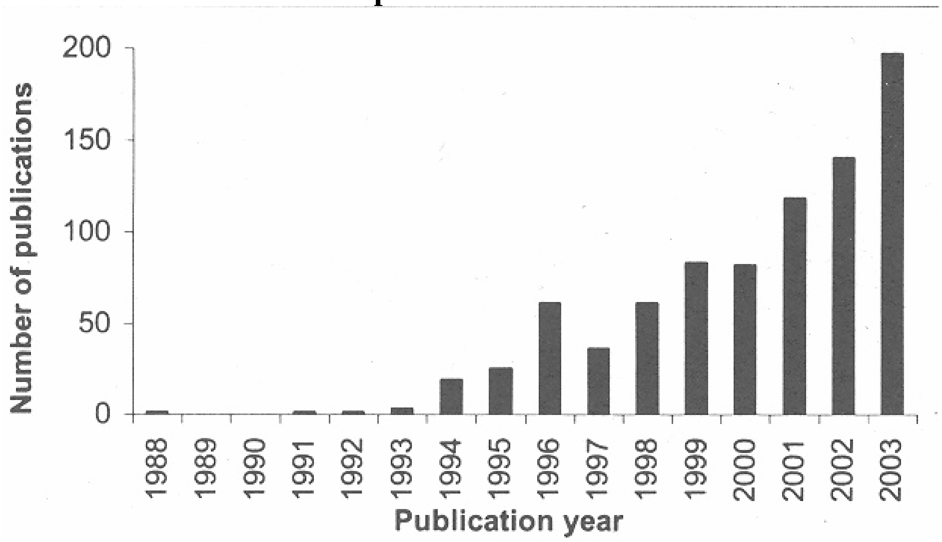
[1] http://www.ybiofuels.org/bio_fuels/history_biofuels.html.
[2] http://www.planetfuels.co.uk/history/index.php.
[3] Diesel R., 1912, *The diesel oil engine*, Engineering 93: 395- 406, cited by Knothe, 2005.

Two further reasons contribute to explaining the reduction of interest in biofuels. Firstly, car industries modified the diesel engine in order to use a cheap by-product of the petrol refinery process, which was called diesel to associate it to the newly-invented efficient engine. Secondly, a campaign was set up by the entrepreneurs in the newspapers to discredit hemp, the most important source of biomass for energy purposes. In 1937 the Marijuana Tax Act (marijuana was the Mexican name for hemp) imposed a levy of approximately one dollar per ounce and a very complicated bureaucratic process to everyone dealing with hemp. Also, it established very tough penalties to those who did not respect the new rules (2000 dollars and five years imprisonment). The result was a downfall of the hemp industry. In 1940 Ford's ethanol plant was closed[4].

As a consequence of these factors, the diesel engine was used with petroleum-based diesel and biofuels were almost forgotten until the late Seventies (even though during the Second World War both the Nazis and the Allies utilized vegetable oils as emergency fuels or to substitute fossil fuel imports, see Knothe, 2005).

The two oil crises raised renewed interest in vegetable oils, because they appeared as a promising alternative to fossil fuels. At the beginning of the Eighties, various scientific publications and discussions in international conferences dealt with biofuels. Various research teams dedicated themselves to studying the biofuels characteristics and improving efficiency of their use. From the Nineties the number of scientific papers dedicated to biofuels has increased steadily, as shown in Figure 4.1.

Figure 4.1 Number of scientific publications on biodiesel



Source: Knothe, 2005

As it was underlined above, energy security and energy independency were therefore the main reasons for interest in biofuels both at the beginning of the century and in the late Seventies and Eighties. However, later on, the need to look

4 http://www.ybiofuels.org/bio_fuels/history_biofuels.html

for an alternative to the increasingly worrying environmental and health problems associated to the use of fossil fuels contributed to the success of biofuels.

For example, the USA Clean Air Act Amendment of 1990 and the Energy Policy Act of 1992 establish the use of alternative fuels with low environmental impact in regulated truck and bus fleets. Also the Energy Policy Act Amendment (1998) gives credits for biodiesel use (also mixed with fossil fuels) and is one of the most important reasons for the notable increase in biodiesel use in the USA (Knothe, 2001).

4.3 Biodiesel in Europe

4.3.1 The European laws

Reducing the use of fossil fuels is one of the European political priorities, because a) they are responsible for the bulk of anthropogenic greenhouse emissions; b) they cause a worrying impact on the environment and human health; c) they make Europe very much dependent on few oil-exporting countries.

With the Kyoto protocol Europe committed itself to reducing its CO_2 emissions by 8% with respect to 1990 levels within 2010. Also, the White Paper on Renewable Energy (COM/97/599 final), establishes the target to double the share of renewable energy from 5.4% in 1997 to 12% in 2010.

According to the Commission, biomass is crucial for achieving the Kyoto and the White Paper objectives. The Biomass Action Plan says:

"*Europe needs to break its dependence on fossil fuels. Biomass is one of the main alternatives*"[5].

Among the renewable sources, a specific strategy is dedicated only to biomass: the Biomass Action Plan. In order to support biomass, the European Union gives incentives to research on the issue. Projects supported by the European Commission on biofuels in general and on biodiesel alone between 1993 and 2005 were respectively 35 and 25 (details can be found on the Cordis web site[6]).

Also, the European Commission is setting up a legislative framework to promote the large scale production of biofuels. Three European Directives play an important role: the first one regards the authorized percentage of biofuels in fuel blends, the second one is on biofuel promotion, and the third one is on biofuel taxation.

1) The **European Directive 98/70/EC** (amended by **Directive 2003/17/EC** of 3rd March 2003) on motor fuel quality authorized for sale at the pump fuels that contain no more than 5% of ethanol, 15% of ethyl tertiary butyl ether (ETBE), a

[5] COM/2005/628 final.
[6] http://www.cordis.lu/en/home.html.

bioethanol derivative, and 5% of vegetal oil methyl esters (VOME), i.e biodiesel. If the biofuel content is higher, the customer should be advised.

2) The **European Directive 2003/30/EC** established that 2% and 5.75% of the fuels used in the transport sector should be obtained from biofuels within respectively 2005 and 2010 (art. 3, 1 b and c). In order to reach these targets, the European Directive allowed the Member States to reduce or eliminate the taxes on biofuels. These targets are not compulsory, but in any case the Member States must notify the European Commission on the measures taken in order to reach them with a mandatory yearly report.

The target established for 2005 was not reached. The Commission launched infringement proceedings against seven Member States (including Italy, see Section 4.4), for adopting too low targets (which were not reached either). The target established for 2010 is also quite ambitious and presumably will also not be reached within the period indicated. In fact, the present share of biofuels is 0.8% of the energy used for transport (See Section 2.2). If the target established by the Member States for 2005 had been reached, biofuels would have constituted only 1.4% of the energy used for transport.

3) Finally, the **European Directive 2003/96/EC** restructured the Community framework for the taxation of energy products and electricity. It allowed the Member States to totally or partially exempt biofuels from excise tax. Taxation on biofuels is established by each Member State.

Two recent Communications [7] from the European Commission set up the European strategy for supporting biofuels and reopened the public debate on them.

The **Biomass Action Plan** (December 2005) aimed at promoting energy production for heating, electricity and transport from wood, wastes and agricultural crops. Two main pathways were defined: a) market-based incentives and b) removal of the barriers that hamper their development. The objectives are manifold: 1) increasing the share of renewable energy (5%) and reducing the energy imports from 48 to 42%; 2) decreasing greenhouse emissions by 209 million tonnes CO_{2eq} per year; 3) increasing employment by 250-300,000 jobs; 4) reducing oil prices through a reduction in demand. Promotion of biomass is planned to be reached increasing both demand and supply, as well as supporting research to overcome technical barriers.

The direct costs of the planned measures were estimated to be €9 billion per year (€6 billion for biofuels and €3 billion for electricity generation, where biomass in heating is often cost-competitive and does not need to be supported). Also, according to the Biomass Action Plan, biodiesel would become economically competitive with oil if the latter were sold at 75€ per barrel, whereas for

[7] COM(2005) 628 final.

bioethanol oil would have to reach 95 €. In reality, we are approaching the first estimate, but biodiesel is still not competitive with traditional fuels.

As regards biofuels, with the *Biomass Action Plan*, the Commission committed itself to writing a report in 2006 in view of a possible revision of the biofuels directive. This report will address the following issues: 1) national targets for the market share of biofuels; 2) biofuel obligations on fuel suppliers; 3) a certification scheme that will ensure minimum sustainability standards for energy farming. Other measures that will be taken into consideration are, firstly, the possibility of including vehicles using high biofuels blends in the future legislative proposals to encourage clean vehicles and, secondly, a possible modification of the fuel quality directive, which states that biofuels can only be mixed at a maximum of 5% with conventional fuels (Directive 2003/17/EC). Also, research on biomass uses will be supported, as it is especially emphasized in the Seventh Framework Programme (FP7).

Also, it is interesting to note that the *Biomass Action Plan* favours bioethanol, even though there are more diesel vehicles than petrol[8]. The reason is that, according to the Commission, Europe has greater capacity to produce bioethanol than biodiesel, using less land and with more room to reduce costs through economies of scale.

The second Communication, **An EU Strategy for Biofuels** (February 2006), defined seven policy axes to reach the objectives established with the *Biomass Action Plans*:
1) stimulating demand for biofuels (through national targets, biofuel obligations and promotion of vehicles using high blends of biofuels);
2) capturing environmental benefits (making biofuels count towards CO_2 emission reduction targets and proposing not-well-specified measures to increase the sustainability of biofuel production, as well as making agreements with car manufacturers to build cleaner cars);
3) developing the production and distribution of biofuels, especially in rural areas of central and eastern Europe, which are assisted by the Structural and Cohesion Funds (according to the Commission, staking on biofuels in these regions would be especially advantageous because they have low labour costs and high resource availability);
4) expanding feedstock supplies through informative campaigns for farmers. Also, biofuels will be included in the future Forestry Action Plan and the use of organic wastes for producing biofuels will be promoted;
5) enhancing trade opportunities, through the ongoing bilateral and multilateral trade negotiations with ethanol-producing countries. Moreover an amendment of standard EN 14214[9] is proposed, in order to facilitate the use of a wider range of vegetable oils;
6) supporting developing countries, developing a coherent Biofuels Assistance Package for developing countries and assisting the development of national biofuel platforms and regional biofuel action plans;

[8] http//www.anfia.it.
[9] The technical requirements for biodiesel are established in the European Standard EN 14214.

7) supporting research and development, through the 7th Framework Programme (2007-13), which gives special relevance to biofuel development. High priority will be given to a) "bio-refinery" (using all parts of the plant) and b) second-generation biofuels (ligno-cellulosic processing, which is still not at a commercial stage). Also, the development of the industry-led Biofuel Technology Platform[10] will be encouraged, in order to involve many European stakeholders.

The **European Biofuels Technology Platform** is an initiative that aims to create a large-scale European biofuel industry. To prepare it, the Biofuels Research Advisory Council[11] was constituted, which includes representatives of the most important European biofuel stakeholders (the agricultural and forestry sectors, food industry, biofuels industry, oil companies and fuel distributors, car manufacturers and research institutes). The Council prepared a document called "Biofuels in the European Union - A Vision for 2030 and beyond"[12], which defined a long–term strategy to promote biofuels both in the European Union and outside. A public consultation process was also launched about the document in order to take into account the point of view of all interested social actors[13].

The increasing interest of the European Union in biomass and in particular biofuels was confirmed in the **European Council held on 23rd-24th March 2006**[14]. In this occasion, it was established that by 2015 the share of renewable energy should be increased to 15%, and the proportion of biofuels in the transport sector to 8%. It can be underlined that among the different kinds of renewable energy, a quantitative target was established only for biofuels. Table 4.1 lists the most important European laws about biofuels.

[10] Other platforms relevant for the development of biofuels are the Plants for the Future, Forestry-based Sector and Sustainable Chemistry.
[11] http://forum.europa.eu.int/Public/irc/rtd/biofrac/home.
[12] http://ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf.
[13] http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_bm/article_4012_en.htm.
[14] Council of the European Union, 2006.

Table 4.1 Main European laws affecting the biofuels sector

Year	Law	Contents	Notes
2003	DIRECTIVE 2003/17/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 3 March 2003 amending Directive 98/70/EC relating to the **quality of petrol and diesel fuels**	Maximum percentage at the pump: • 5% ethanol • 15% ETBE • 5% biodiesel If the biofuel contents are higher, the customer should be advised	At these percentages, there is no difference for the engine
2003	DIRECTIVE 2003/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 8 May 2003 on the **promotion of the use of biofuels** or other renewable fuels for transport	Share of biofuels in the total energy use for transport: • 2% by 2005 • 5.75% by 2010 The Member States must present a yearly report on biofuels promoting strategies and their results	The present share is 0.8%. The reports are available at http://europa.eu.int/comm/energy/res/legislation/biofuels_ members_states_en.htm
2003	COUNCIL DIRECTIVE 2003/96/EC of 27 October 2003 restructuring the Community framework for the **taxation of energy products and electricity**	The Member States are allowed to totally or partially exempt biofuels from excise tax	Many European Countries have approved of tax exemptions as a way to support biofuels expansion
2005	COMMUNICATION FROM THE COMMISSION COM/2005/628 final of 7 December 2005. **Biomass action plan**	The European Commission commits itself to actively promote the energy use of biomass, both increasing demand and supply	Bioethanol is privileged against biodiesel. The Commission considers that in Europe there is room for a considerable increase in domestic production of raw materials and in imports, especially from the countries affected by the sugar reform
2006	COMMUNICATION FROM THE COMMISSION COM/2006/34 final of 8 February 2006. An **EU Strategy for Biofuels**	Seven policy axes are established to support biofuels	European raw materials will be complemented by imports from foreign countries, where energy farming will be promoted
2006	BRUSSELS EUROPEAN COUNCIL 23/24 MARCH 2006. Presidency Conclusions 7775/06	Two targets are defined for 2015: • Renewable energy: 15% of total energy use • Biofuels: 8% of the energy used for transport	Among renewable energies, a quantitative target is established only for biofuels, which receive special emphasis

4.3.2 The measures in the Member States

European Member States are using two main instruments to promote biofuels: 1) tax-exemptions and 2) biofuels obligations (the obligation to mix a certain minimum percentage of biofuels to the petrol and diesel sold at the pump). The measures in favour of biofuels are described in detail in the reports that the

Member States are required to present each year within the framework of Directive 2003/30/EC[15].

Following the Directive on energy taxation (European Directive 2003/96/EC), many European states introduced tax reductions or exemptions, as shown in Table 4.2[16].

Table 4.2 Tax regulations on biofuels in the European countries

Country	Tax regulations
Austria	Complete tax exemption for pure biofuels, or blend up to 5% (ethanol, ETBE) and 2% (biodiesel). Higher percentages are taxed as traditional fuels
Belgium	No tax exemption
Denmark	No tax exemption
Finland	No tax exemption
France	0.38 €/L exemption for bioethanol/ETBE-petrol blends up to 219,000 t/y and 0.35 €/L for biodiesel-diesel blends up to 317,000 t/y
Germany	Complete tax exemption for pure or mixed biodiesel for any amount
Greece	No tax exemption
Ireland	No tax exemption
Italy	Complete tax exemption for biodiesel blends up to 200.000 t/y
Spain	Complete tax exemption only for pilot projects
The Netherlands	No tax exemption
Portugal	Complete tax exemption only for pilot projects
United Kindom	0.32 €/L for bioethanol and 0.42 €/L for biodiesel
Sweden	Total exemption up to 40,000 m^3

France, Austria, Slovenia and Italy introduced biofuels obligations, whereas the Czech Republic and the Netherlands will do the same in 2007. The UK and Germany recently declared that they will introduce them.

Table 4.3 shows each Member State’s target and the progress towards its achievement. It can be noted that the planned increase for 2005 (which was however not respected) is much lower than the one defined for 2005 by the Directive, i.e. 2%.

[15] The yearly reports of the Member States are available at: http://europa.eu.int/comm/energy/res/legislation/biofuels_members_states_en.htm.
[16] Comitato Termotecnico Italiano http://www.cti2000.it/biodiesel.htm.

Table 4.3 The progress in biofuels penetration in the markets of European Member States

Member State	Market share 2003	National indicative target for 2005	Targeted increase, 2003-2005
AT	0.06%	2.5%	+2.44%
BE	0	2%	+2%
CY	0	1%	+1%
CZ	1.12%	3.7% (2006)	+ 1.72% (assuming linear path)
DK	0	0%	+0%
EE	0	2%	+2%
FI	0.1%	0.1%	+0%
FR	0.68%	2%	+1.32%
DE	1.18%	2%	+0.82%
GR	0	0.7%	+0.7%
HU	0	0.4-0.6%	+0.4-0.6%
IE	0	0.06%	+0.06%
IT	0.5%	1%	+0,5%
LA	0.21%	2%	+1.79%
LI	0 (assumed)	2%	+2%
LU	0 (assumed)	not yet reported, assume 0	not yet reported
MT	0.02%	0.3%	+0.28%
NL	0.03%	2% (2006)	+0% (promotional measures will come into force from January 2006)
PL	0.49%	0.5%	+0.01%
PT	0	2%	+2%
SK	0.14%	2%	+1.86%
SI	0 (assumed)	0.65%	+0.65%
ES	0.76%	2%	+1.24%
SV	1.32%	3%	+1.68%
UK	0.03%	0.3%	+0.27%
EU25	**0.6%**	**1.4%**	**+0.8%**

Source: COM/2005/628 final

4.3.3 Trade with extra-European countries

In the *Biomass Action Plan* (Annex 11) it is calculated that in order to achieve the 5.75% target (18.6 million toe biofuels), about 17 million hectares would be needed. This amount is very large if compared to the total European tillable land (97 million hectares).

Therefore the European Commission intends to complement the European raw materials with imports. In fact, if biofuels were produced with only imported crops, the European agricultural sector would not take advantage of the expansion of the biofuel sector. If biofuels were produced exclusively with domestic raw material, almost one fifth of the European agricultural land would have to be used for energy farming.

Both in the *Biomass Action Plan* and in the *EU Strategy for Biofuels* it is stressed that Europe will promote the production of raw material for biofuels in extra-European countries, especially the ones affected by the sugar reform. A possible instrument might be the development of a coherent assistance package for developing countries and of favourable trade conditions.

In particular, in the second Communication it is stressed that:

"Biomass productivity is highest in tropical environments and the production costs of biofuels, notably ethanol, are comparatively low in a number of developing countries. […] Developing countries such as Malaysia, Indonesia and the Philippines, that currently produce biodiesel for their domestic markets, could well develop export potential"[17]

Also the same document explains that Malaysia, which is the world's biggest producer of palm oil, is developing a biodiesel industry, as are Indonesia and the Philippines. The first two countries will also supply palm oil to new plants in Singapore, from where biodiesel will be exported.

At present the EU is the main producer and consumer of biodiesel and there is no significant foreign trade for it (on the contrary, bioethanol is imported mainly from Brazil, Guatemala, the USA, Ukraine and Egypt). However, in the future Southern Asian countries like Malaysia, Indonesia and Philippines could become a biodiesel provider for Europe, while Brazil might export large quantities of sugar-cane ethanol and other biomass fuels.

The European strategy on biodiesel might jeopardize agrarian biodiversity and also tropical forests. In fact, if the European demand were increased by means of targets and biofuels obligation, some Southern countries might be stimulated to create large oil seed monocultures, by replacing food cultivation and forests.

In this way, these countries would be more and more dependent on the international markets for food supply. Also, a strong oil seed demand might represent a threat to forests worldwide. For example, between 1985 and 2000 in Malaysia palm plantations caused 87% of the total deforestation and further 6 million hectares will be deforested to make room for palm trees. The same might apply to sugarcane plantations in Brazil. The European Directive, and in general all biodiesel promoting policies, do not only imply a competition for arable land but might also incentive plantations of palm trees, whose oil is cheaper than any other source (Mombiot, 2005). Palm plantations are responsible for most

[17] COM/2006/34 final.

deforestation in South Eastern Asia and represent a real threat to the remaining native forests. Also they are responsible for a high soil erosion rate.

Even the *EU Strategy for Biofuels* itself recognizes that energy farming might have an impact on eco-sensitive areas, such as rainforests, in terms of reduced soil fertility, water availability and quality, and pesticide use, as well as social effects like potential dislocation of local communities and competition between biofuels and food production.

In conclusion, the European biofuel policy aims to a certain extent to reduce greenhouse emissions within its border at the expense of serious environmental impacts in Southern countries.

4.3.4 The Common Agricultural Policy (CAP)

The European Union invests in the Common Agricultural Policy (CAP) around €50 billion per year, which represents almost half of its budget. The reason for such an expenditure is that the European Union attributes a much higher value to agriculture than mere economic income (which only accounts for a small share of the GDP). Rural areas constitute 90% of the European territory and host around 50% of the European population, making it very important to protect and support the agricultural sector.

Gómez-Limón and Atance (2004) identified, through some Spanish focus groups, a set of objectives that citizens attribute to agricultural policies. They include a) maintenance of family agricultural holdings, villages and traditional agricultural products, as well as enhancement of the quality of rural life; b) environmental protection and conservation of agricultural landscape and natural areas and c) low price for consumers, sufficient income for farmers, competitiveness of European products, national food self-sufficiency and production of safe and healthy food.

Without subsidies, European agriculture would not be profitable and rural zones would probably be abandoned. In fact, the high production costs would force farmers to put high prices on their products, with the result that they would be too expensive with respect to the imported ones.

However, increasing pressure is exercised (for opposite reasons) both by neo-liberals and by a part of the left-wing and social movements towards progressively reducing the agricultural subsidies. The former claim that subsidies distort the correct market functioning and produce unfair competition. The latter argue that European agricultural subsidies are unfavourable to Southern countries' farmers and make their products less competitive, so that they are forced to reduce their price.

Bioenergy might be a solution to this conflict. Since the European Union intends to protect the rural landscape and population, yet incentives on food production might have adverse effects, part of the European agricultural subventions might be used for the production of energy crops. For example, Hondraki-Birbili and Lucas

(1997) identify bioenergy as an alternative to the conventional European Agricultural Policy for Greek rural areas, whose environmental, economic and social costs are too high (even though they conclude that if one considers only local costs and benefits and not the national and international ones, it does not result to be the best option).

The Common Agricultural Policy was instituted in 1957 as a cornerstone of the European Union. It was aimed at increasing production in a context of food scarcity and creating employment in rural areas, which were severely damaged by the Second World War. In order to allow European Agriculture to be profitable, the farmers were granted a large amount of subsidies. The two main mechanisms were purchase of agricultural products (to increase demand) and tax reductions (to reduce the competitive disadvantages versus the products of the rest of the world). This policy created a big increase in production, which in turn led to over-production and to a decrease in prices.

In order to reduce the surplus problem, in 1992 the MacSharry reform shifted the CAP focus from the support on prices towards compensatory payments to farmers, not necessarily linked to production. One of these measures was the establishment of the voluntary set-aside schemes, which financed farmers in order for them not to cultivate their lands. Set-aside land was allowed to be cultivated for energy purposes, which represented an incentive to energy farming.

This strategy was reinforced with the 2003 reform, which came into effect in 2005. With the “single-farmer payment” system, the new CAP mostly subsidizes European farmers independently of the volume of production. Also, environmental protection and food quality is at a premium.

As regards energy production, the new CAP rules introduced a specific incentive for energy farming, which amounts to 45 €/ ha. This incentive is granted only to farmers with a contract with processing enterprises. The maximum extension of land which will be given subsidies is 1.5 million hectares, which will be shared among the Member States with a “grandfathering” principle. However, now the land cultivated for energy purposes is around 800,000 hectares, and therefore also the countries that at present have low or no production will be granted CAP incentives (De Filippis, 2003). The reform maintained the possibility of cultivating energy crops in the set-aside land.

4.3.5 Research

In order to reach this objective, special support is given to research. According to the *EU Strategy on Biofuels*, research and technological development will allow biofuels costs to decrease by 30% beyond 2010.

The Seventh Framework Programme (2007–2013) will give priority to research on biofuels. In particular, two programmes concern biofuels: 1) The *Cooperation Specific Programme*, which will focus mainly on two objectives: to reduce the cost of fuels by technological developments and to improve biomass production systems. In particular, research will focus on second generation biofuels (ligno-cellulosic processing), which still need to be developed and brought to a commercial stage; 2) the *Intelligent Energy–Europe* programme (part of the *Competitiveness and Innovation Framework Programme*), which will support the dissemination of techniques that have been proven successful through research.

It is interesting to note that the Commission intends to give high priority to research on life sciences and biotechnologies (including presumably GMOs) as a way to improve yield. Also, much interest is put on the concept of "biorefineries", which aim at the integral use of the biomass for a variety of purposes.

4.3.6 Biodiesel producers

In Europe, the European Biodiesel Board[18] groups the twenty-six major European biodiesel producers[19]. It is based in Brussels and lobbies at the European level. According to its statistics, the total European capacity is around 2.2 million tonnes per year, mainly concentrated in Germany, France and Italy. The production in 2004 in Europe was 1.9 million tonnes.

Another important actor at the European level is Fediol[20], a federation of oil and protein meal industry founded in 1957. It represents the interests of the European seed and bean crushers, meal producers, and vegetable oil producers/processors. The oil they produce is used as raw material for the food/feed industry, oleochemical industry and to a lesser extent also for biodiesel. Due to a process of mergers and acquisitions that began ten years ago, in Europe more than 75% of the oil and proteinmeal capacity comes from four international enterprises[21], which carry out the different processing phases (crushing, refining, and transformation into products). The rest of the production comes from a number of small producers. According to Fediol data, 150 plants with 20,000 employees operate in the EU.

[18] http://www.ebb-eu.org.
[19] NOVAOL AUSTRIA GmbH; BIODIESEL KARNTEN GmbH; BIODIESEL RAFFINERIE; AUSTRIAN BIODIESEL BOARD (Austria); FEDIOL (EU); Neste Oil (Finland); DIESTER INDUSTRIE; NOVAOL FRANCE (France); OELMUEHLE HAMBURG AG; OELMUEHLE LEER CONNEMANN GmbH & Co. KG; CAMPA BIODIESEL GmbH & Co. KG; CARGILL GmbH; MITTELDEUTSCHE UMESTERUNGS WERKE GmbH & Co. KG; NATURAL ENERGY WEST GmbH; PETROTEC GmbH; VERBAND DEUTSCHER; BIODIESELHERSTELLER e.V. (Germany); Elinoil Hellenic Petroleum Company S.A. (Greece); FOX PETROLI S.p.a; NOVAOL ITALY (Italy); IBEROL NUTASA (Portugal); BIONET EUROPA; BIONOR Transformación S.A.; EHN (Spain); SVENSKA EKOBRANSLE AB (Sweden); Argent Energy; BioFuels Corporation PLC (UK).
[20] http://www.fediol.be.
[21] They are (in order of importance): A.D.M., CARGILL, BUNGE and SAIPOL

4.4 Biodiesel in Italy

4.4.1 The Italian Laws

In Italy, the first law that allowed biodiesel (pure or mixed with traditional fuels) to be free from taxes was published in 1995[22] and established that 125,000 tonnes of biodiesel each year would be not burdened with energy taxes. This amount had to be confirmed year by year by the Ministry of Finance with the Financial Law. The law applied both to pure biodiesel and to biodiesel blends.

However, the **Decision 2002/265/EC** of the European Council authorized Italy to apply the tax exemption only to biodiesel mixed at 5% and 25%, whereas pure biodiesel would be burdened with energy taxes.

This amount was increased to 300,000 tonnes per year by the 2001 Financial Law (art. 21)[23], which also established that pure biodiesel consumption would be promoted in public fleets especially in urban areas with much traffic. After four years, this amount was decreased again to 200,000 tonnes per year by the **2005 Financial Law**[24].

The modalities for the tax exemption for biodiesel were defined in the **Decree n.256 of 2003**[25]. In particular, biodiesel can be mixed with diesel up to a share of 25%. If the share is 5% or less it can be sold both in the distributing network and outside the network. If it is between 5 and 25% it can be sold only to users outside the network.

The **2006 Financial Law**[26] confirmed the amount of de-taxed biodiesel at 200,000 tonnes per year and introduced some modifications. In fact, out of the 200,000 tonnes, 20,000 must be under contracts between farmers and biofuel producers. In this way, biofuels are prevented from being produced only with imported raw materials, and the Italian agricultural sector is benefited.

Also, with the **Legislative Decree**[27] that implements the European Directive 2003/30/EC, Italy committed itself to obtaining from biofuels only 2.5% of the energy use in the transport sector. It is a much lower target with respect to the Directive’s one (5.75%). In fact, the Italian government was conscious to be very distant from the Directive’s target, and that reaching it in few years would have implied a big effort.

[22] Decreto Legislativo 504/95.
[23] Legge 388/2000.
[24] Legge 311/2004.
[25] Decreto 256/2003.
[26] Legge 266/2005.
[27] Decreto Legislativo 128/2005.

However, in early 2006 a **Decree Law**[28] established a biofuel obligation of 1% (in terms of low calorific value), which will increase by 1% each year until reaching 5% in 2010, which is very close to the European target of 5.75%. The law refers to biofuels produced in Italy through agreements and collaboration between Italian farmers and biofuel enterprises.

It must also be noted that the target is very ambitious and also in contradiction with the target established by the **2005 Financial Law**, i.e. 200,000 tonnes. In fact, the latter amount corresponds to approximately 0.4% of the total energy used for transport[29]. It should be remembered that the total production of biofuels will probably not exceed the amount of tax-exempted biofuels very much, because if biofuels are burdened with energy taxes they become too expensive and not competitive with fossil fuels.

Also, it is interesting to note that the same decree law establishes that the bioethanol sector, which is still almost non-existent in Italy, must be promoted (art.2 quater).

Table 4.4 synthesizes the most important contents of the Italian legislative framework on biofuels.

[28] Decreto-legge 2/2006.
[29] The total energy used in the transport sector in 2003 was 43 million toe. No more recent data are available. Source: Eurostat data base.

Table 4.4 Main Italian laws affecting the biofuels sector

Year	Law	Contents	Notes
2002	Decisione 2002/265/CE. Decisione del Consiglio del 25 marzo 2002 che autorizza l'Italia ad applicare aliquote di accisa differenziate ad alcuni carburanti contenenti biodiesel a norma dell'articolo 8, paragrafo 4, della direttiva 92/81/CEE. Gazzetta ufficiale n. L 092 del 09/04/2002	Tax exemption are applied only to biodiesel blends at 5% and 25%	Pure biodiesel is burdened with energy taxes and is therefore much more expensive than diesel. This law excluded pure biodiesel from the market
2004	Legge 30 Dicembre 2004 n. 311, Disposizioni per la formazione del bilancio annuale e pluriennale dello Stato (legge finanziaria 2005), G. U. n. 306, 31 Dicembre 2004, Supplemento Ordinario n. 192, art. 521	Tax exemption for 200.000 tonnes/ year	The amount of de-taxed biofuels is reduced by two third parts with respect to previous years
2005	Decreto Legislativo 30 Maggio 2005 n.128, Attuazione della direttiva 2003/30/CE relativa alla promozione dell'uso dei biocarburanti o di altri carburanti rinnovabili nei trasporti, G. U. n. 160, 12 Luglio 2005	Target: • 1% by the end of 2005 • 2.5 % by the end of 2010	The target is much lower than the European Directive that the law implements (2% by 2005 and 5.75% by 2010)
2005	Legge 23 dicembre 2005, n. 266 "Disposizioni per la formazione del bilancio annuale e pluriennale dello Stato (legge finanziaria 2006)" pubblicata nella *Gazzetta Ufficiale* n. 302 del 29 dicembre 2005- Supplemento ordinario n. 211	Tax exemption for 200,000 tonnes is confirmed	Part of the amount of biodiesel that will be tax-exempted must be produced with Italian raw materials
2006	Decreto-legge 10 gennaio 2006, n. 2, coordinato con la legge di conversione 11 marzo 2006, n. 81 (in questo stesso supplemento ordinario alla Gazzetta Ufficiale alla pag. 5), recante: «Interventi urgenti per i settori dell'agricoltura, dell' agroindustria, della pesca, nonché in materia di fiscalità d'impresa	The fuel enterprises are obliged to mix at least 1% biofuels in their product. This percentage will increase by 1% each year until reaching 5% in 2010	The target is very ambitious, provided that the 200,000 tonnes biodiesel that are tax exempted each year constitute 0.4% of the total energy demand for transport

The Italian government also supports biofuels through **PROBIO, Programma Nazionale Biocombustibili** (National Programme on Biofuels), which was instituted in 2000 in order to promote and finance the development of biofuels in Italy, in collaboration with the regional authorities. PROBIO was granted with 2 million Euro financing in 2006[30].

4.4.2 2000-01: The Fo family's campaign

In Italy a big campaign in favour of biodiesel was organized by Nobel Prize for Literature winner, dramatist and actor **Dario Fo**[31], his wife **Franca Rame** and son **Jacopo Fo**, who are also actors and comedians. On 26th June 2000 they gave a press conference in Cervia (Northern Italy) to present biodiesel (alongside methanol, methane and LPG) as a solution for urban pollution. They claimed that replacing fossil fuels with biofuels would reduce urban pollution by 90%. They invited personalities and citizens to sign a document that asked politicians to seriously promote biofuels. Also, they organized protesting acts (pickets to block the traffic in various Italian cities) to draw the attention of citizens and politicians to the issue.

Jacopo Fo has been particularly active in biofuels promotion. In the web page of his commune **Alcatraz**[32] many articles and pieces of information on this topic can be found[33]. On 27th November 2000 Alcatraz opened the first Italian biodiesel pump near Perugia, in central Italy.

In 2001 Jacopo Fo organized a petition to ask the European Parliament and the Italian Ministry of the Environment to modify the European Provision 501PC0813 (proposed by the Italian government on 23rd April 2001 and approved with the Decision 2002/265/CE, see Section 4.4.1), which allows tax reduction only on biodiesel blends but not on pure biodiesel. The consequence is that pure biodiesel is burdened with energy taxes and becomes much more expensive than diesel. The law thus hampers biodiesel production and also excludes small producers, which do not have the authorizations and technologies to mix biodiesel and diesel and are forced to sell their production to refineries. This new rule, together with the 2005 Italian Financial Law, which allows not more than 200,000 tonnes biodiesel to be free from taxes every year (see Section 4.41), caused the closure of Alcatraz's pump three years after its opening.

The idea that Jacopo Fo tries to promote is that biofuels could be used *instead* of fossil fuels in all cars. If this is not done, it must be because the Italian government does not take adequate action. According to him, the culprits are the

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30 http://www.governo.it/backoffice/allegati/27734-2984.pdf.

31 See http://nobelprize.org/literature/laureates/1997/press.html.

32 Alcatraz (http://www.alcatraz.it) is an association founded by Jacopo Fo, which organizes various activities to improve people's welfare and sustainability, especially related to fair trade, personal relations and private people's environmental impact. The group also founded an internet journal, Cacao (http://www.cacaonline.it), which is used to disseminate information to increase the environmental consciousness and give some practical tips for saving resources in daily life.

33 http://www.cacaonline.it/indice/olio-di-colza.htm.

fossil fuel producers, who lobby against biofuels because they do not want to loose their monopoly.

According to Fo, replacing fossil fuels with biodiesel has many advantages: 1) biodiesel is renewable; 2) it is cheaper (but he does not take into account that the reason is that diesel is burdened with energy taxes, which make up more than half of its price); 3) it allows reducing energy dependency; 4) it pollutes less than diesel on a local scale and it does not generate greenhouse emissions; 5) it is better than biodiesel for the cars' engines because it is cleaner, it does not obstruct the filters and does not leave incrustations and residues; 6) the efficiency is 3% higher with respect to diesel; 7) it is less dangerous than diesel because it does not catch fire easily; 8) it is biodegradable and non-toxic and if by accident it is spilt to the environment it does not produce environmental disasters; 9) rapeseed is very fruitful and easy to cultivate; 10) biodiesel cultivation allows using marginal and set-aside land; 10) it reduces the costs for waste disposal (used frying oil can be used to produce oil). We will test the soundness of these statements in the rest of this study.

4.4.3 2005: The biodiesel fever

Between 2001 and 2002 the interest in biodiesel increased in Italy, as documented in a service of a journalist program called Report[34], then it decreased until 2005, when it called media's attention again. No doubt that the sharply increasing oil prices can explain this renewed interest at least in part.

The debate on biofuels reached a wide public on 12th March 2005, when one of the three Italian public televisions, Rai Tre, in the 7 p.m. daily newscast showed that some **car drivers** were fuelling their cars with rapeseed oil, which could be bought more cheaply than petrol or diesel (the latter are burdened with energy taxes). Rapeseed oil was sold as cheap and low quality oil for cooking in some supermarkets. The newscast showed a car driver from Trento (in Northern Italy) fuelling his car with a bottle of rapeseed oil bought in the supermarket. The newscast also explained that rapeseed oil sales increased by ten in Trento.

The use of rapeseed oil instead of diesel took place especially in Northern Italy, where Lidl supermarkets (which sell rapeseed oil) are more diffused. The supermarkets were not prepared for such a huge and abrupt increase in the demand and at a certain point it was very difficult to find rapeseed oil[35].

The 1 p.m. Rai Tre newscast of 13th March 2005 confirmed that more and more car users were using rapeseed oil instead of diesel and also added that those who did so were to be considered tax evaders, because they did not pay the energy taxes that the oil-derived diesel was burdened with. Using rapeseed oil instead of diesel was cheaper but it was considered fiscal fraud and therefore liable to

[34] The transcription of the service can be read at http://www.report.rai.it/2liv.asp?c=n&q=8.
[35] http://www.ecoage.org/info/biodiesel-olio-di-colza.php.

prosecution. On 16th March, Rai 3 dedicated a TV current affairs programme called "Primo Piano" to rapeseed oil inviting Jacopo Fo and others guests[36].

The newscasts raised a big debate in Italy. Many newspapers and web pages began to publish articles on the "biodiesel fever". For example, *La Repubblica*, one of the most important Italian newspapers, prepared a dossier with various articles, which is still available on the internet[37]. The dossier had enthusiastic words for biodiesel. For example, an article published on 16th March 2005 and included in the dossier claims that biodiesel presents "enormous advantages for the environment and the wallet". It sounds as follows:

"*If castor oil was the symbol of a dictatorship, another oil, i.e. rapeseed oil, will likely be an emblem of a popular revolution not against a political monopoly, but against an economic monopoly: the one exerted by the big oil companies, which hamper the diffusion of alternative, cheaper and more ecological fuels, such as biodiesel*".

In this article it is argued that rapeseed oil can be used in any diesel engine as a substitute for diesel, without causing any problem and allowing great savings.

The internet contributed to spreading the rumour very quickly and very widely. Hundreds of articles in web pages on biodiesel appeared, as well as many forums where car drivers exchanged suggestions on where to buy rapeseed oil, how to use it and how much to pay for it. In the forum of Quattroruote alone (an Italian magazine dedicated to cars) more than twelve thousand messages were submitted.

On 20th March 2005, a text incorrectly attributed to Beppe Grillo, a very popular Italian showman, appeared in various web pages with the title "Rapeseed oil seriously damages the Ministry of Finance"[38]. Beppe Grillo declared in his blog that he never wrote this text and that he was strongly against biodiesel[39]. In any case, the text spurred Italian citizens to use in their diesel engine vegetable oils sold in the supermarkets, even though it was illegal because it implied fiscal evasion. In this way, the text argued, they could save money and benefit the environment, without damaging their car engines. This text was sent as a chain letter by mail and reached many persons.

Confagricoltura, **Coldiretti** and **Confederazione Italiana Agricoltori** (CIA), the three Italian agricultural entrepreneur and farmer associations, availed themselves of the opportunity created by the wide debate on biofuels. Their idea was that biofuels might be a big opportunity for Italian agriculture, if adequately supported. They all declared in various occasions that biofuels would be a solution for the increasing oil prices, urban pollution and the crisis of the

[36] http://www.tg3.rai.it/SITOTG/TG3_pagina_es/0,9480,990-id_rubrica-,00.html.
[37] http://www.repubblica.it/2005/c/motori/marzo05/colza1/colza1.html.
[38] http://www.ecquologia.it/sito/pag877.map?action=single&field.joined.id=44197&field.joined.singleid=44198.
[39] http://www.beppegrillo.it/2005/05/olio_di_colza_q.html.

agricultural sector. On 23rd February 2005 they signed a voluntary agreement with Assodistil and Itabia. The former is the association of Italian alcohol and brandy distillers. The latter is an association that promotes biomass use, formed by various different enterprises. The agreement promoted collaboration between farmers and bioethanol producers, with the objective of producing 100,000,000 L bioethanol per year (the amount established with the 2005 Financial Law). The bioethanol will be obtained from sugar beet and cereals produced in Italy[40].

Coldiretti claimed that biofuels (mixed at 5% with oil-derived fuels) could supply more than 6 million cars for twenty thousand km per year using 250,000 hectares cultivated with rapeseed, sunflower and sugar beet[41], constituting a great opportunity both for the environment and for the rural sector.

Confagricoltura assumed a similar position. According to Confagricoltura's president, biofuels constitute an increasingly interesting alternative to fossil fuels in a period characterized by high oil prices. Also, they stated in different occasions that Italian agricultural enterprises are willing to collaborate with the industry and transport sector to launch the biodiesel sector[42]. Confagricoltura promoted the foundation in June 2005 of AGRO-ENERGIA, an association of agricultural enterprises interested in renewable resources and energy saving[43].

CIA also claimed that biofuels are a good opportunity both for environment and for Italian farmers. When the Italian government approved the decree that implemented the European Directive 2003/30/EC on biofuels promotion (see Section 4.4.1), CIA commented that the target was too low and the effort was still not enough. In July 2005 CIA signed a collaboration protocol with Legambiente (one of the most important Italian environmentalist NGOs) to promote sustainability in agriculture, including the production of renewable energy. In January 2006, it promoted a conference on agriculture and renewable energy near Padova (northern Italy).

In June 2005 a conference called "The role of agriculture between mitigation and adaptation" was organized in Rome by the Climate Alliance association. The three Italian agricultural associations participated, together with the Italian Minister of Agriculture and Forest and Itabia, and debated, among other issues, on the potentiality of biofuels to reduce the greenhouse effect[44].

In 2005, Jacopo Fo published a book on rapeseed oil, where he argued that vegetable oils can be used instead of diesel with a number of advantages (Fo, 2005). Fo's book is sold through Alcatraz's web page, and it was also enclosed

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[40] http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2005/02/23_03.
[41] http://www.coldiretti.it/docindex/cncd/informazioni/115_02.htm; http://www.coldiretti.it/docindex/cncd/informazioni/184.htm; http://www.coldiretti.it/docindex/cncd/informazioni/245_05.htm; http://www.coldiretti.it/docindex/cncd/informazioni/352_05.htm.
[42] http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2005/03/14_00; http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2005/03/22_00.
[43] http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2005/05/26_00.
[44] http://www.climatealliance.it/public/ingrandimento_news.php?ID=62.

with an issue of “L’Unità” (the Italian social democratic newspaper) of 17th May 2006. It reached a wide audience and contributed to creating the idea in the public that biodiesel may be a real solution to the problems created by fossil fuels.

It is interesting to note that the media contributed to creating a big misunderstanding speaking in many cases indifferently of biodiesel and rapeseed oil or not underlying the difference with enough clarity. In fact, with some modifications to the car engine, biodiesel (obtained making an alcohol react with a vegetable oil) can be used as a substitute for diesel, and if mixed with diesel at a low percentage it can be used in any diesel engine. On the contrary, pure rapeseed oil has a different viscosity and cannot be used in normal diesel engines without seriously damaging them.

Diario, a widespread and left-wing Italian magazine, published in September 2005 a report on biofuels[45], which showed that biofuels were already produced in Italy in 1993. In that year, a biodiesel producing enterprise called Estereco was founded in central Italy (near Perugia, in Umbria), with an investment of 10 billion Liras (approximately 5 million Euro), of which 3 billion Liras were provided by the European Community. Estereco was part of a European network that set up two similar enterprises in Germany and France.

Estereco never went past the experimental phase. Eng. Vincenti, interviewed by the author of Diario’s report, claims that the reason was the lack of political and economic support. According to him, the reason was an intensive lobbying initiative against biodiesel, carried out since 1993 by Agip and Eni, the main Italian oil product enterprises. He states that they succeeded in obtaining that de-taxation would only be applied to a limited amount of biodiesel, and only when sold in blend with diesel.

Also, according to Eng. Vincenti, FIAT, the main Italian car enterprise, is also responsible for Estereco’s failure. In fact, it refused to homologate Estereco’s biodiesel arguing that it would have damaged the car engines. The same is affirmed by Eng. Mario Brighigna, one of the founders of Estereco. In an interview carried out by Diarios’s reporter, he remembered that Estereco asked FIAT to build a bus that could be fuelled with biodiesel, but FIAT never did it.

4.4.4 2005: the indignation against the reduction of amount of de-taxed biodiesel and the low target

Despite the enthusiasm that wide sectors of citizens showed towards biofuels, the 2005 Financial Law reduced the amount of de-taxed biodiesel from 300,000 to 200,000 tonnes per year (see Section 4.4.1). Also, the Legislative Decree[46] that implements the European Directive 2003/30/EC established a much lower target than the Directive, i.e. 2.5%.

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[45] Portanova M., 2 2005, http://www.diario.it/index.php?page=cn05101405.
[46] Decreto Legislativo n. 128/2005.

Obviously, these measures caused the indignation of **Assobiodiesel**[47]. Coldiretti and Confagricoltura also strongly protested against the law. In various public declarations they claimed that in a context of increasing oil prices, the Italian government should exempt from taxes all biodiesel produced and not only a certain amount, and should decisively support the biodiesel sector through transport policies. In this way, citizens would use biodiesel instead of vegetable oils, which cause problems to the car engines, and would not evade taxes. Also, they underlined that the strong interest in vegetable oils comes from the increasing oil prices. They claimed that biofuels are extremely advantageous from an environmental point of view. According to Coldiretti, the amount of tax-exempted biofuels should increase to 800,000 tonnes within 2010 in order to respect the 5.75% target suggested by the European Directive. In order to reach this objective, around one million hectares should be cultivated with rapeseed and sunflower for energy purposes.

Confagricoltura signed at the beginning of 2006 an agreement with the Ministry of Environment, Assobiodiesel, Assocostieri (the National Association of Mineral Oil Coastal Deposits) and the Centre for Research on Biomass of Perugia in order to promote biofuels. The objective is to favour the collaboration between the industrial and the agricultural sectors through research, education and communication strategies[48].

In November 2005, Coldiretti's president, Paolo Bedoni, in occasion of the Montreal United Nations Climate Change Conference (COP 11) claimed that agriculture could give a decisive contribution towards the achievement of the Kyoto targets through the use of biofuels. Also, Bedoni announced Coldiretti's intention of promoting a petition to ask for a law of popular initiative for allowing to produce one million tonnes of biofuels[49]. The petition obtained 60,000 signatures in six months.

On 13th December 2005 the European Commission decided to take Italy (together with Luxemburg and Portugal) to the Court of Justice because they did not submit the 2004 national report on biofuel supporting strategies, as required by the Biofuels Directive. Also, a letter was sent to Italy for failure to adequately motivate its target, which is less than half of the Directive's. The Commission sent to Italy also a letter of formal notice because it had not yet submitted the national report for 2005[50].

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47 http://www.assobiodiesel.it/FTP/area_stampa/comunicatiStampa/BIODIESELNEWS%2001_05.pdf.

48 http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2006/01/27_02.

49 http://www.kwmotori.kataweb.it/kwmotori/kwm.jsp?idContent=1330690&idCategory=902.

50 European Press Release IP/05/1577. http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/05/1577&format=HTML&aged=1&language=EN&guiLanguage=en.

4.4.5 2006: the biofuel obligation

The position of the Italian government changed in the beginning of 2006, probably in part as a consequence of the pressure of both the agricultural associations and the European Commission. A law dated March 2006 [51] established that all fuel producers must mix at least 1% of biofuels to their fuels. This percentage will increase by one per cent per year until reaching 5% in 2010.

Obviously, Coldiretti and Confagricoltura welcomed the law as a very positive development. The presidents of the three Italian agricultural associations wrote a letter to the Minister of Agriculture to ask for a rapid implementation of the law and an expedite organization of a negotiating table of farmers and biodiesel producers. Also, they asked the oil producers association (Unione petrolifera) to define the amounts of bioethanol and biodiesel required to reach the 1% target. Finally, they asked for an increase in the amount of de-taxed biodiesel, which they consider to be far too low [52]. Vecchioni, the president of Confagricoltura, commented the law as follows:

"*An important development for our farmers, who will be able to easily stake on crops such as rapeseed, sunflower, soy, corn, beet, which could be used for energy purposes, as an alternative to the traditional ones*"[53].

In April 2006 a new increase in oil price took place. The agricultural associations took the opportunity to claim that biofuels can be a solution against that[54].

4.5 The social actors

4.5.1 Objectives of this section

This section presents the social actors involved in the biodiesel policies in Italy. It describes the role they play, their objectives, as well as their position on biodiesel. Also, it discusses whether and to what extent their objectives are affected by the political decisions on biofuels. From their objectives, Chapter 6 will derive part of the criteria which will be used to evaluate the different options.

The choice of the actors was made based on the information presented in Section 4.4 on the history of biofuels in Italy.

[51] Decreto Legge 2006/2, art.2, .http://www.governo.it/GovernoInforma/Dossier/legge_agricoltura/TESTO%20COORDINATO.pdf.

[52] http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2006/04/01_00

[53] http://www.sussidiario.it/notizie/ultimora/messages/10061.shtml. See also http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2006/03/01_03

[54] http://www.coldiretti.it/docindex/cncd/informazioni/268_06.html.

4.5.2 The environmentalists and the Green Party

<u>Description</u>

We have already shown the Fo family's point of view. However, they are not the only environmentalists who are promoting biofuels. In fact, the environmentalist NGOs are strongly in favour of the use of biomass as an alternative to fossil fuels. Most include biodiesel in their campaigns in favour of renewable energy and climate protection, which is usually one of the most stressed topics.

For example, the Italian division of WWF produced a document[55] to promote biodiesel, presenting the latter as a sort of magic wand to solve the climate change problem. Obviously, the document does not mention the negative consequences in terms of land requirement and substitution of food crops, reduction of agrarian biodiversity, etc.

The greenhouse effect is one of the environmentalists' main concerns. As evidence of that, one needs only remember that all main environmentalist NGOs set up a climate protection campaign in order to push the governments to implement energy saving policies and to spur the citizens to reduce their energy use. Biofuels promoters claim that bioenergy might contribute to reducing Italian greenhouse emissions.

Also, the Italian Green Party is in favour of biofuels. Some local branches organized campaigns, petitions, and seminars to promote them. For example the Green Party of Rieti (a province located in central Italy) together with Coldiretti, set up a project to launch biodiesel[56], which included the use of biodiesel as a fuel in some public means of transportation and for heating in some public buildings, as well as an increase of earmarked dedicated cultivation in the province and information campaigns.

In this work, environmentalists are seen as representatives of the citizens' concern regarding the environment and their own health.

Reduction of urban pollution is important mainly for the people living in cities, whether they are environmentalists or not. The urban population is interested in reducing local pollution in urbanized areas, which is mainly caused by the intensive use of fossil fuels for transportation. Urban pollution is increasingly perceived as one of the most worrying problems of life in cities, because it is responsible for many health problems, ranging from breathing diseases to cancer. It also causes damages to monuments, buildings and urban vegetation.

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[55] http://www.wwf.it/lavoro/campagne/clima/energiabiomassa.asp. The arguments are: 1) CO2 reduction; 2) soil quality improvement, due to carbon accumulation, and consequent reduction of need for irrigation; 3) possibility of recycling frying oil (500,000 t/year), organic residues and slush produced in the oil refinery industrial process, as well as municipal organic wastes; 4) consequent reduction of energetic expense in recycling. However, the same document warns that biodiesel cultivations should avoid intensive agriculture, characterized by an extensive use of herbicides and phytopharmacology, as well as genetically modified seeds.

[56] http://www.verdinrete.it/rieti/iniziative/biodiesel/confstampa.htm.

For example, according to a recent survey carried out by Eurostat (European Commission, 2005[57]), at least one third of the European citizens is worried about air pollution. This share is higher in Southern Europe and in big cities. As evidence of that, 85% of the citizens of Naples, 90% of those of Rome and 92% of those of Turin consider air pollution a serious problem. Therefore, biofuels would be really appreciated if they could contribute to reducing local contamination.

The reduction of the greenhouse effect is an objective shared by the Italian government and the European Commission, due to the commitments made with the Kyoto Protocol. Italy is lagging behind with respect to the Kyoto Protocol agreement and might be subject to a sanction: the required reduction is 6% with respect to 1990, but until now Italian greenhouse emissions have increased by 11.4% (UNFCC, 2005).

Objectives

By definition, the environmentalists' objective is to improve environmental protection, which implies, among other issues, a **reduction of greenhouse emissions** and **urban pollution**.

4.5.3 Car drivers

Description

Many car drivers were interested in biofuels when the rumour was spread that rapeseed oil could replace diesel. In 2005 they contributed to raising a big debate. The attention of car drivers to biodiesel is strictly related to oil prices. When oil becomes more expensive, car drivers are increasingly interested in the possibility of using alternative fuels, as it happened in spring 2005. Therefore, it can be said that car drivers are interested in biofuels if they allow them to reduce their expenditure for energy.

Objectives

For car drivers, the most important goal is to obtain **cheap fuel** for their cars

4.5.4 Farmers

Description

As explained in Section 2.4, 20% of the oil seeds used to produce biodiesel in Italy are imported. The production of oil seeds in Italy decreased very sharply in the last years due to the rules established in the Common Agricultural Policy (CAP) framework for the years 2000-2004. The progressive reduction of incentives to oil seeds caused a crisis in the sector. Another reason is the competition with maize, for which the CAP granted a much higher incentive.

As a consequence, Italy became more dependent on oil seed imports. The amount of land used for producing oil seeds decreased in four years from 504 thousand hectares in 1999 to 277 thousand hectares in 2004, as it is shown in Table 2.7.

[57] European Commission, 2005, http://ec.europa.eu/public_opinion/flash/fl_156_en.pdf.

Land dedicated to soybean, sunflower and rapeseed decreased respectively by 39%, 40% and 94%.

However, the production of oil seeds increased again slightly in 2005 due to the new payment scheme introduced by the 2003 reform, and it is expected to continue rising. Oil seeds entrepreneurs expect a recovery of the production especially in northern Italy (where soybean can be used in rotation with maize) and in central Italy (where the big extension of land that is actually unused due to disinvestment of wheat, may be used to cultivate sunflower)[58].

In this context, incentives granted to biodiesel production, both directly and indirectly (through de-taxation) may play an important role and represent a good opportunity for the oil seed sector to recover.

This possibility is particularly desirable for farmers because European agriculture is less and less competitive with that of Southern countries. Biofuels might be a profitable alternative to food production, especially in view of the possible end of the subsidies to agricultural exports agreed upon in the last WTO meeting in Hong Kong in December 2005. As explained in Section 4.4, the three agricultural associations (Coldiretti, Confagricoltura and Confederazione Italiana Agricoltori) see biofuels as a good opportunity to re-launch Italian agriculture.

Objectives
Italian farmers' main objective is to increase their income, and more in general, **rural development**. In order to do that, they need their sector to be supported by the government and the European Union.

4.5.5 Biodiesel producers

Description
In Italy nine enterprises produce biodiesel[59]. They are united in the association Assobiodiesel, which is the interlocutor in the negotiations with the Public Administration and other authorities.

Objectives
The objective of biodiesel enterprises is to **increase their income** (and therefore their production) as much as possible. In order to reach this objective, they ask the government to increase the amount of biodiesel to be exempted from taxes (see for example the articles published in the Assobiodiesel newsletter, which is available on its web site[60]). Since biodiesel is more expensive than fossil fuels, this is a necessary condition for its competitiveness.

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[58] http://www.sementi.it/informazione/assemblea_2005/oleaginose.htm.
[59] COMLUBE (www.comlube.it); DP LUBRIFICANTI; FOX PETROLI (www.foxpetroli.com); GDR BIOCARBURANTI (www.biodiesel.it); ITAL BI-OIL (www.italbioil.com); MYTHEN; NOVAOL (www.novaol.it); OIL.BI; RED OIL (www.redoil.it).
[60] http://www.assobiodiesel.it.

The objective of this study is to verify whether the request made by the biodiesel producers should be accepted by the Italian government, or in other words, whether supporting the biodiesel sector would be advantageous for society as a whole. Therefore, the objectives of the biodiesel producers are not included among the social objectives to reach. An argument might be that they are too small a minority for influencing a policy, which has such wide-ranging consequences.

A list of the actors with their main objectives is presented in Table 4.5.

Table 4.5 Social actors involved in Italy in the biofuels policies

Social actor	Representing association	Objectives
Environmentalists	The Green Party, WWF, Alcatraz and others	Reduction of the greenhouse emissions
		Reduction of urban pollution
Car drivers	-	Cheap fuel
Farmers	Coldiretti, Confagricoltura, Confederazione Italiana Agricoltori	Rural development
Biodiesel producers	Assobiodiesel	Increase of their income

4.6 The arguments of the biodiesel promoters

In this section, I analyze the arguments of those who advocate for biodiesel promotion, before proceeding to check their soundness in the next chapters.

First of all, the main arguments that make biofuels attractive for the European Commission can be found in the following declaration made by Mariann Fischer Boel, Commissioner for Agriculture and Rural Development, on the occasion of the publication of the *EU Strategy for Biofuels* (February 2006)

"There has never been a better moment to push the case for biofuels. Crude oil prices remain high. We face stringent targets under the Kyoto Protocol. And the recent controversy over imports of Russian gas has underlined the importance of increasing Europe's energy self-sufficiency. Raw materials for biofuel production also provide a potential new outlet for Europe's farmers, who have been freed by CAP reform to become true entrepreneurs"[61]

The main objectives that biofuels would allow to reach are therefore:
1) **economic savings** due to the increasing oil prices;
2) **reduction of greenhouse emissions**;
3) **energy self-sufficiency** and **energy security**;
4) **rural development**.

As an example of the environmentalists' ideas on biodiesel, I took a report recently published by the Italian division of the environmentalist NGO WWF:

61 http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/06/135&type=HTML&aged=0&language=EN&guiLanguage=en.

"*[biodiesel] can be used for transport or heating, allowing a significant reduction of the polluting emissions with respect to the oil-derived diesel. However, the most interesting aspect is that it is a renewable product, because of its agricultural origin, so we can consider it as a particular form of use of solar energy. The possible realization of an integrated cycle of biodiesel production and earmarked crops represents an interesting prospective for the necessary re-conversion of our energy and productive system towards environmental sustainability*"[62]

Environmentalists generally consider biodiesel to be environmentally friendly both at the local scale (**reduction of pollution**) and at a global scale (**reduction of greenhouse emissions**). Biodiesel is a renewable source of energy and since it can replace oil products, it might give a contribution towards sustainability.

Another example of the environmentalist' arguments about biodiesel can be found in a quotation from Jacopo Fo, which dates back to the beginning of his campaign in favour of biodiesel (2000):

"The technological premises to eliminate the pollution derived from the use of fossil fuels from tomorrow do exist. The diesel engine could be fuelled with rapeseed oil and the petrol ones with methane, LPG or methanol. These fuels are available, they are cheaper than oil-derived fuels and do not cause efficiency losses […]. If there were the awareness and the political will, measures could be immediately taken, which would be able to substantially modify the pollution caused by cars and heating, abolishing immediately the use of oil-derived fuels. All diesel cars circulating at the moment in Italy could be converted to rapeseed oil or some other kind of biodiesel at a negligible cost"[63].

In this quotation we can find again one of the arguments that are often used by environmentalists: biodiesel would help reducing **urban pollution**. Jacopo Fo even claims that biodiesel does not cause pollution at all. More arguments that are used by him can be found in Section 4.4.3.

Also, he is trying to spread the idea that the replacement of fossil fuels with biofuels is only a matter of political will, and not of availability. Various environmentalists think that there is a sort of conspiracy between the big oil enterprises and the car producers to lobby both against the European Commission and the Italian government in order to hamper the policies that could promote biodiesel (see for example the report published in Diario, Section 4.4).

The following declaration by Federico Vecchioni, president of Confagricoltura, dated February 2006, includes the most important arguments that are often used by agricultural entrepreneurs.

"The increasing oil price, the energy crisis of gas in Russia, the reduction of the greenhouse effect represent the most important factors that are pushing various

[62] http://www.wwf.it/lavoro/campagne/clima/energiabiomassa.asp.
[63] http://www.cacaonline.it/auto/index.htm.

countries to diversify the energy need. Italian agriculture can provide a substantial contribution to the development of "green" energy. If we used 30% of the agricultural land to produce energy crops (rapeseed, corn, etc.), we would cover 6% of the national oil need. We therefore need to launch a green energy market. Replacing oil with agricultural raw materials implies to multiply by 50 the occupational effect" (7th February 2006)[64].

He used the same arguments as the European Commissioner for Agriculture and Rural Development, plus the issue of **job creation**. According to Vecchioni, a large-scale biofuels sector would have a positive outcome on Italian employment.

It is interesting to notice that he proposes to use 30% of the Italian agricultural land to reduce the use of oil by 6%. It is clear that the objectives related to the reduction of the dependency on oil, the greenhouse effect, the energy self-sufficiency and security are smaller in importance. In fact, one could question whether a reduction as small as 6% would by itself justify the occupation of 30% of the Italian agricultural land. The main objectives are instead job creation and rural development. Italian agricultural entrepreneurs see biofuels as a chance for them.

Finally, the president of Coldiretti, Paolo Bedoni, uses similar arguments to promote biodiesel:

"*From the Common Agricultural Policy reform comes a clear orientation of the agricultural activity towards food and environmental safety, which also means to put value on those natural resources that are available on the territory for the production of renewable energy. For this reason, Coldiretti is strongly engaged in initiatives to individuate in the fields those sources of alternative energy that allow us to escape from the recurrent crises due to the increasing oil price, and also to reach the objectives established with the Kyoto Protocol"*[65].

In the rest of this analysis these expectations about biofuels are analyzed, in order to verify if they can be reached. I go back to them in the conclusions.

For the time being, let me only underline that **according to the discourse of the European Commission, the environmentalists and the agricultural entrepreneurs, biodiesel seems to allow all social actors involved in the issue to reach their objectives** (Table 4.5): **reduction of the greenhouse emissions and of urban pollution; savings in the energy expenses and rural development**. Also biodiesel would allow to create employment and to increase energy security.

All in all, biofuels seem to be a sort of magic wand, which solves many different problems at once. But is it really so?

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[64] http://www.confagricoltura.it/viewers/newsviewer.aspx?pagepath=comunicati/2006/02/07_01.
[65] http://www.coldiretti.it/docindex/cncd/informazioni/184.htm.

5 The Alternative Policy Options

5.1 Objective of this analysis

The amount of biodiesel to be produced is a genuine political decision and does not really depend on market trends. In fact, biofuels are only competitive with fossil fuels if they are not subjected to tax payment. Therefore, biodiesel production coincides almost exactly with the quantity that the annual financial act exempts from taxes. For example, in Italy in 2004 300,000 tonnes of biodiesel were tax exempted, and the production was 326,000 tonnes[1].

As explained in Section 4.4, Italy decided with the 2004 Italian Financial Law that between 2005 and 2010 200,000 tonnes of biodiesel would be tax exempted each year[2]. However, this amount is largely insufficient if the target set by the European Directive 2003/30/EC is to be reached. In fact, it represents only around 0.4% of the total energy used for transport.

The Italian government is conscious of the distance from the Directive's target, and that reaching it in few years would imply a big effort. For this reason, it set a much more modest target. In the Legislative Decree[3] that implements the European Directive, Italy commits itself to obtaining from biofuels only 2.5% of the energy use in the transport sector.

Should the Italian government be advised to increase this target? Should it try to respect the European Directive and reach the 5.75% target? Is this a good strategy for Italy? This study assesses the consequences of this choice from different points of view, considering various dimensions and scales.

In this context, the Italian government has a double role. On the one side, it is the actor that has the power to decide how much biodiesel will be produced. In this sense, it acts as a representative of and a mediator among the interests of all the involved social actors. On the other side, it is also one of the social actors that have some interests at stake (see Section 4.4), which will be affected by the final decision.

5.2 The energy demand for transport

In order to calculate how much biomass would be needed to fulfil the requirement of the Directive, the first step was to estimate how much energy the transport sector will demand in 2010. The transport sector represented around 33% of the total energy consumption in 2003. This share increased in the last decades: in 1970 it was 20%, in 1980 25% and in 1990 30% (IEA, 2002). Figure 5.1 compares energy use in the transport sector to overall energy use.

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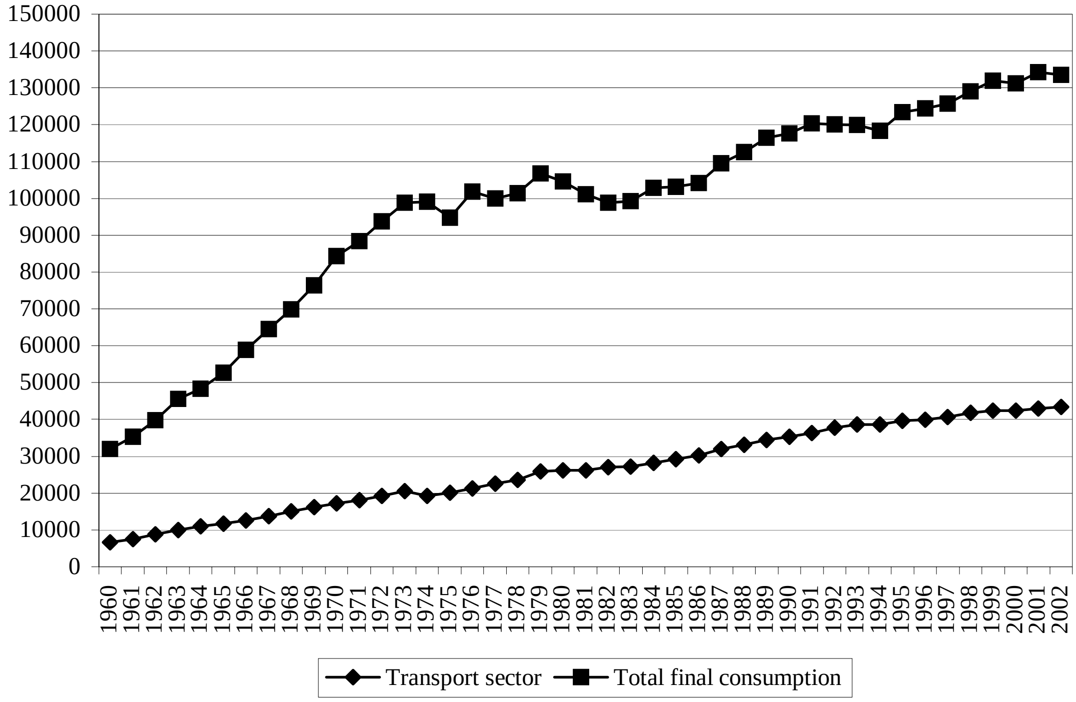
[1] European Biodiesel Board: http//www.ebb-eu.org.
[2] Legge 311/2004.
[3] Decreto Legislativo 128/2005.

Figure 5.1 Total and transport final energy consumption in Italy in the last forty years, thousand toe



Source: IEA, 2002

The future energy demand for transport can be estimated through a linear correlation. Since the energy use for transport presents an increasing and steady trend, a linear correlation is a good approximation and can provide seemingly reliable forecasts.

In order not to take into account the effect of population growth (which will be small in the next years in Italy but was higher in the past), I took per capita data. Figure 5.2, Figure 5.3 and Figure 5.4 show the results for estimates that are made using time series of the last forty years (from 1962 to 2002), twenty and ten years. The continuous lines represent the real data, whereas the dotted ones indicate the estimates. The results of the three linear correlations for 2010 are 0.909, 0.908 and 0.828 toe per capita per year.

The figure calculated using data from the last ten years is lower than the others. In fact, in the Sixties energy use increased very quickly, because of the low oil prices and the strong economic growth. Total energy use in the Italian transport sector increased from 6.689 thousand toe in 1960 to 20.541 thousand toe in 1973 (when the first oil crisis took place). The increase was smaller during the two oil crises but then the low oil prices produced a sharp increase in the Eighties until the Iraqi invasion of Kuwait (1990).

These favourable circumstances (economic growth and low oil prices) are not forecasted to repeat themselves in the next years. On the contrary, experts agree on a probable future oil price increase, due to growing scarcity and rising demand in Asian countries. It is probable that high oil prices will drive an increase in energy efficiency and a reduction of demand, as it happened during the two oil crises in the late Seventies and early Eighties. Therefore, a forecast obtained using the time series of the last ten years is more likely to be realistic.

Moreover, in this study the most favourable assumptions for biofuels are made (low energy demand, high energy yield, high incentives, etc.), in order to demonstrate that if even in this way they did not appear to be a promising option, then they should not be seen as a solution to the energy problem.

Figure 5.2 Estimation of per capita transport energy demand (forty years), thousand toe per capita

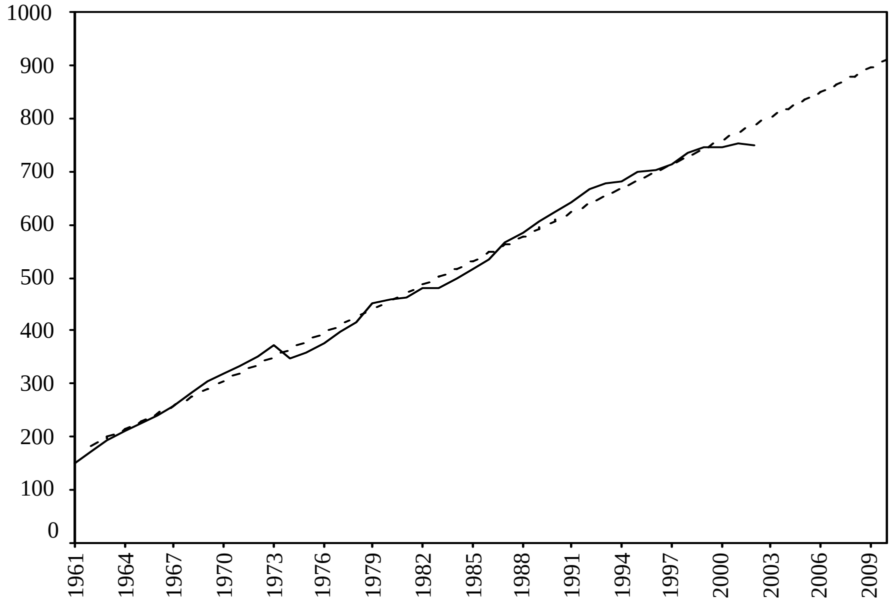


Figure 5.3 Estimation of per capita transport energy demand (twenty years), thousand toe per capita

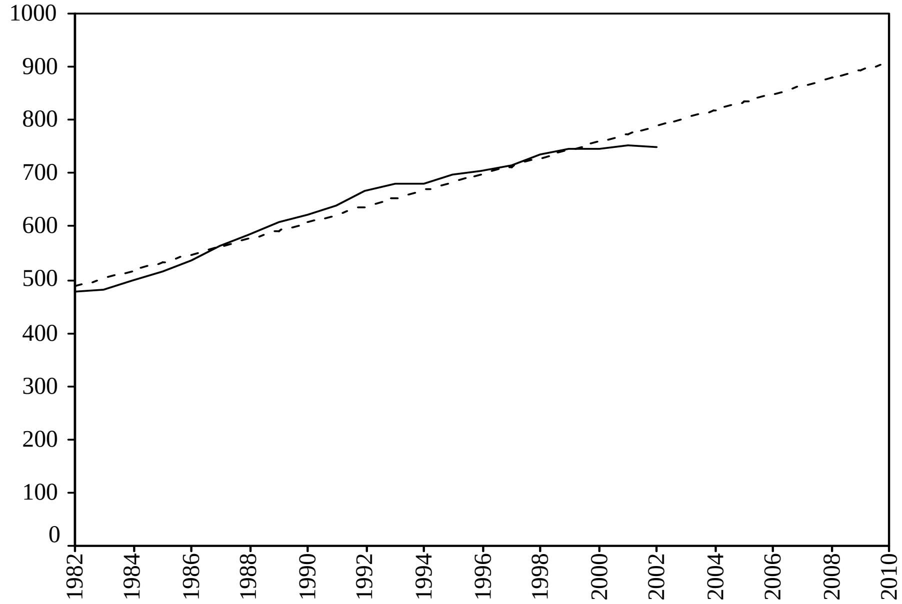
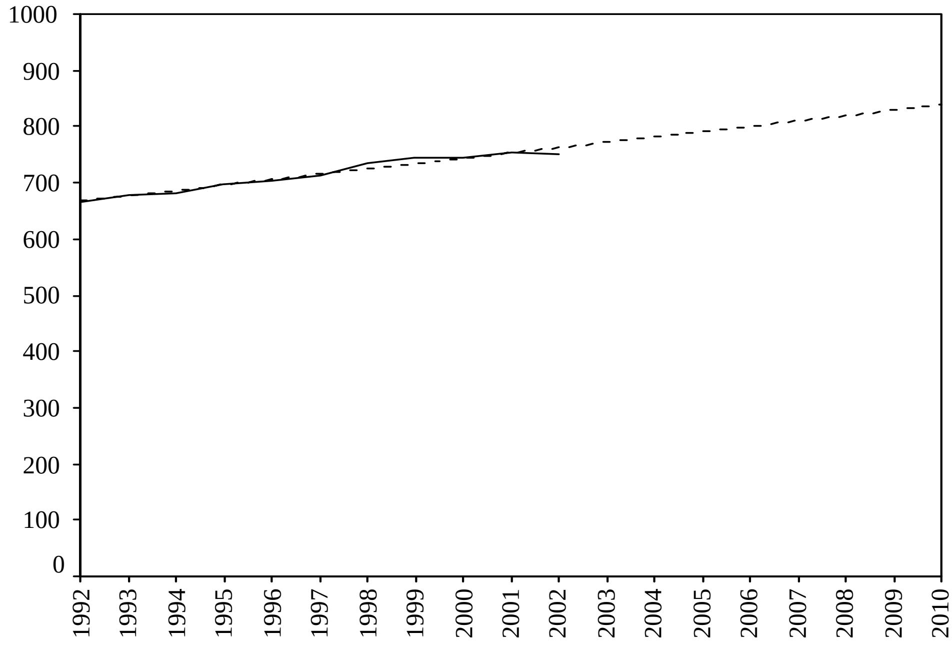


Figure 5.4 Estimation of per capita transport energy demand (ten years), thousand toe per capita



Obviously, it should be remembered that the future energy demand is subject to a high degree of uncertainty, since it depends, among others things, on oil price and economic growth. These two factors are very variable and difficult to forecast, because they strongly depend on political and economic factors. However, in order to discuss the viability of biofuels as a solution to the energy problem, not much precision is needed. What is important is the order of magnitude of the variables.

The Demography Department of the Italian Institute of Statistics forecasts that in 2010 the population will be 58.5 million people. Therefore, taking the lowest estimate of future energy demand in the transport sector, the energy use for transport will be **49.1 million toe** for the entire Italian population. As a consequence, in order to reach the Directive's target (5.75%), **2.8 million toe** should be obtained annually from biofuels. There is thus a **contradiction with the 2005 Financial Law, which establishes that only 200.000 tonnes biodiesel per year will be tax exempted**.

If the Directive's target were achieved and biodiesel were mixed at 20% with diesel, around **61% of the diesel would be mixed with biodiesel**. Diesel itself constitutes around 47% of total fossil fuel use in Italy (IEA, 2002).

The target of 2.8 million toe is equivalent to **2.6 million tonnes diesel** and **3.2 million tonnes biodiesel** (the calorific value of biodiesel is slightly lower)[4]. Considering an oil content of rapeseed and sunflower of respectively 36% and 41%[5], it results that around 8.5 million tonnes of oil seeds would have to be used.

5.3 The alternatives

At this point, some hypotheses must be made, in order to facilitate the calculations. The first one regards the energy sources that would be used to produce the 2.8 million toe established by the European Directive. On the one side, I assumed that the European target would be met only by means of **biodiesel and not ethanol**. In fact, in Italy ethanol production is still negligible. It seems not likely that a strong ethanol sector will come up out of nothing in few years. On the contrary, the biodiesel sector is already active and well launched, making it wiser to place one's bets on it.

There is another reason for this assumption. Biodiesel is a substitute for diesel, which is a denser and heavier fraction of oil, whereas ethanol can replace petrol, which is a lighter fraction. Diesel is more abundant than petrol: the cracking process of crude oil produces a fraction of around 21.5% of diesel and only 13.5% of petrol (USES, 1980). Therefore, since oil will probably be increasingly scarce and expensive, in the future car engines running on diesel will probably be cheaper and/or more encouraged than those running on petrol, in order to avoid wastes. For this reason, it seems to be a better strategy to stake on a product that can be mixed with a more abundant oil product, such as diesel.

[4] The lower calorific value of biodiesel is 37-38 MJ/kg (here the average is assumed, i.e 37.5 MJ/kg), i.e. 0.9 toe/t (1 toe = 41.870 MJ). Source: Comitato Termotecnico Italiano (http://cti2000.it/virt/cti2000/Headbio.htm). Jarach (1985) suggests to take 1.1 toe/t as the diesel's lower calorific value.

[5] Venturi and Venturi (2003) indicate an oil content of 35-40% in rapeseed, 40-48% in sunflower. Comitato Termotecnico Italiano (http://cti2000.it/virt/cti2000/Headbio.htm) considers respectively 38% and 40%. Bona et al. (1999) use a value of 32% and 40%. I took an average among these values: 36% and 41%.

I also assumed that if the Directive recommendation were not accepted, the 5.75% demand of energy use for transport would be satisfied **only with diesel** and not with petrol.

Also, whereas in the USA biodiesel is mainly produced from soybean, in Italy (and in Europe in general) biodiesel is principally obtained from **rapeseed and sunflower** (see Section 2.3). At present, 80% of the biodiesel produced in Italy is obtained from rapeseed and the rest from sunflower[6]. I assumed that the oil seed mix would be the same, so that the required 3.2 million tonnes biodiesel would be produced with **7 million tonnes rapeseed** and **1.5 million tonnes sunflower**. As shown in Section 2.4, Italy is a net importer of both rapeseed and sunflower. One possibility would therefore be to increase imports in order to have enough raw materials to reach the Directive's objective.

It is difficult to forecast from which country such a large amount of oil seeds would be imported. Table 5.1 shows the origin and the destination of the Italian sunflower external trade. Almost one third of sunflower import comes from Romania, and one fourth from Russia. Ukraine provides 17% of the total Italian sunflower import. Three fourths of the total sunflower seeds come from these three countries.

Table 5.1 Italian sunflower external trade, 2003

Country	Import (tonnes)	%	Export (tonnes)	%
Romania	53,840	31.08	46	0.94
Russian Federation	43,430	25.07	-	-
Ukraine	30,166	17.41	-	-
Uruguay	28,237	16.30	-	-
Croatia	5,936	3.43	6	-
Argentina	3,500	2.02	-	-
Hungary	2,947	1.70.	57	1.16
Moldova, Republic of	1,925	1.11	39	0.81
Austria	1,137	0.66	72	1.49
France	657	0.38	1,007	20.70
China	277	0.16	-	-
USA	268	0.15	-	-
Netherlands	257	0.15	1,017	20.91
Spain	166	0.10	89	1.84
Canada	145	0.08	-	-
Germany	118	0.07	1,350	27.75
UK	17	0.01	1,029	21.16
Others	211	0.12	152	3.12
Total	**173,234**	**100**	**4,862**	**100**

Source: OECD data-base, 2005

[6] Comitato Termotecnico Italiano, http://cti2000.it/virt/cti2000/Headbio.htm.

Table 5.2 shows the Italian rapeseed external trade. It can be noted that Austria, Hungary and to a smaller extent Germany provide almost the entire amount of Italian rapeseed imports.

Table 5.2 Italian rapeseed external trade, 2003

Country	Import (tonnes)	%	Export (tonnes)	%
Austria	6,243	41.20	0.1	0.01
Hungary	5,629	37.14	-	-
Germany	2,619	17.28	436	24.01
Lithuania	250	1.65	24	1.32
Netherlands	228	1.50	467	25.72
Romania	121	0.80	-	-
Canada	47	0.31	-	-
Belgium	17	0.11	-	-
Denmark	-	-	297	16.37
France	-	-	572	31.47
Poland	-	-	20	1.10
Total	**15,153**	**100**	**1,816**	**100**

Source: OECD data-base, 2005

Table 5.2 shows that Italy mostly imports oil seeds from Eastern Europe and former USSR countries, as well as from Austria and Germany. A plausible scenario is that **Italy would import the needed oil seeds from Eastern Europe**. It is a credible option because trade is easier inside the European Union. Also these economies are still largely based on agriculture. For this reason, it sounds plausible that if European oil seeds demand increases they will find it profitable to dedicate part of their agricultural production to rapeseed and sunflower for export.

Italy might find it profitable to import from Eastern Europe because the transport and the labour costs would possibly be lower than if the oil seeds were imported from the United States or Canada. In Table 5.3 the fifteen most important rapeseed and sunflower exporters are presented, which represent respectively 86% and 91% of the world sunflower and rapeseed exports. It can be noted that some Eastern European countries are already among the most important world oil seeds exporters.

Table 5.3 Most important sunflower and rapeseed net exporters (million tonnes)

Sunflower seeds		Rapeseed	
Country	**Exports- imports**	**Country**	**Exports- imports**
Ukraine	866,292	**Canada**	3,000,127
Hungary	475,204	**France**	1,706,064
Romania	342,394	**Australia**	624,893
Bulgaria	290,205	**USA**	169,448
Russian Federation	284,744	**United Kingdom**	136,399
Argentina	226,180	**Lithuania**	98,346
Uruguay	216,337	**Hungary**	59,299
Canada	81,963	**India**	43,509
Slovakia	79,105	**Czech Republic**	37,422
China	67,420	**Russian Federation**	25,846
Moldova, Republic of	54,352	**Ukraine**	25,209
USA	27,022	**Croatia**	15,619
Czech Republic	13,578	**Latvia**	9,859
Botswana	6,194	**Estonia**	5,797
Egypt	5,809	**Bulgaria**	5,553

Source: FAO data-base

Importing oil seeds would avoid competition with food production on Italian agricultural land. This is particularly advantageous because Italy is a densely populated country where land is scarce. However, this strategy would imply that part of the added value of the biodiesel production chain would remain in foreign countries. In this way, the Italian agricultural sector would not benefit from the increase in biodiesel consumption and an additional income would only be obtained by the processing and distributing enterprises.

Another possibility would be to cultivate the oil seeds in Italy. Considering yields of 1.85 and 2.25 tonnes/ha[7] respectively for rapeseed and sunflower, the land requirement would be **4.5 million hectares**.

However, one of the by-products of oil seed pressing is a cake meal which is rich in proteins and can be used for cattle feeding (see Section 2.1). Therefore some land that is presently used for fodder production might be converted to oil seed cultivation.

It can be noted that hypothesizing that all the produced cake meal would be used as cattle feed is a very optimistic assumption because it is not obvious that the stockbreeder would find it convenient to replace the cattle feed they normally use with the cake meal and that the latter would have all nutrients that cattle need in the right proportions. Also, the energy and economic cost of gathering, transporting and distributing the cake meal were not taken into account.

[7] Istat data- base, *Dati Congiunturali sulle Coltivazioni*, year 2004.

As will be explained in more detail in Chapter 6, if the target of the Directive were met, approximately 4 million tonnes biodiesel would be produced, which corresponds to a land use of around 0.8 million hectares. Therefore, the total land requirement to reach the 5.75% target would be **3.7 million hectares**.

One of the arguments of biodiesel promoters is that energy farming may be carried out in marginal, degraded and set-aside land. However, Italian land is already densely occupied. The total territory is 30.1 million hectares, out of which 14.4 are occupied by agriculture and pastures[8] and 6.9 by forests (4 in mountain areas). Mountains cover 35% of the surface (10.6 million hectares)[9]. Mountains, forests, pastures and agricultural land occupy altogether 27.9 million hectares. The remaining 2.2 million hectares are partly occupied by cities and roads. Some land is not tillable because it is not fertile, such as for example sandy or rocky areas and highlands. Therefore, ***there is not enough land in Italy to cultivate the entire amount of oil seeds that would be needed to meet the European Directive***.

However, an article recently published in the magazine Newsweek claims that in Italy there are 6 million hectares of abandoned land in the countryside due to the structural change towards the tertiary sector economy, low birth rate and the urbanization process. According to one of the pioneers of Italian environmentalism, Giorgio Nebbia, in Italy there are at least 3 million hectares of marginal and abandoned land that could be used for energy farming (Nebbia, 1990). These figures are probably exaggerated, since they do not match the Istat data on Italian land use that were shown above. Also it should be remembered that if degraded lands were cultivated, more fertilizers, pesticides and water would have to be used to compensate for their low fertility. Notwithstanding that, it can be imagined that some portion of the 2.2 million hectares that are free from pastures, mountains, agriculture and forests, might be used to cultivate sunflower and rapeseed for energy production.

Another option may be to cultivate oil seeds in set-aside land, i.e. land that is withdrawn from production in the framework of the European Common Agricultural Policy (see Section 4.3). However, the set-aside land would only allow meeting a small share of the energy demand. In fact in 2004 it was 232,200 hectares[10] (EU Directorate-General for Agriculture and Rural Development, 2005), which, if cultivated with sunflower, would have allowed to produce about 166 thousand tonnes of biodiesel.

Therefore, even if all marginal, abandoned and set-aside lands in Italy were used for energy farming they would not be enough to meet the Directive's requirement of 3.2 million tonnes biodiesel.

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[8] Ibid.

[9] Istat, 2002.

[10] In 1999 the Italian set aside land was 169 thousand hectares and in 1994 it was 250 thousand hectares (European Energy Crops Internetwork, http://www.eeci.net/archive/biobase/B10552.html).

Since, as already specified in Chapter 3, I decided to make the most favourable assumptions for biodiesel, I assumed that **0.5 million hectares of marginal, abandoned and set-aside land could be dedicated to energy farming** (more than twice the land that is now under a set-aside framework). In any case, even so, 3.2 million hectares of existing crops would have to be replaced. Table 5.4 shows the Italian agricultural land use.

Fodder plants and cereals (especially wheat) occupy together 74% of the Italian agricultural land. 14% is used mainly for olive trees and vineyard, i.e. crops which provide a high added value and which it is not conceivable to replace. Therefore, it is likely that if oil seeds were to be cultivated in Italy, they would have to replace fodder plants and/or cereals.

Table 5.4 Land used for agriculture in Italy, 2004

	Land (thousand ha)	%	Production (thousand tonnes)	Yield (t per ha)
Cereals	4,276	30	23,596	5.5
-*Wheat*	2,354	17	8,777	3.7
Leguminous	71	0	140	2.0
Tubers	74	1	1,885	25.5
Open air vegetables	473	3	14,101	29.8
Greenhouse vegetables	34	0.2	1,585	46.1
Fruit trees	445	3	6,200	13.9
Olive trees	1,135	8	4,678	4.1
Vineyard	787	6	8,973	11.4
Citruses	168	1	3,531	21.0
Temporal fodder plants	2,019	14	59,654	29.6
Perennial fodder plants	4,205	30	19,321	4.6
Industrial cultivations	498	4	23,166	46.5
- *Rapeseed*	3	0	5	1.8
- *Sunflower*	124	1	278	2.2
TOTAL	14,185	100	166,829	

Source: Istat data-base

Since wheat is the most common cereal and constitutes more than half of the Italian cereal production, I assumed that oil seeds would replace *wheat*.

For perennial fodder plants (grasses and pastures), which occupy 30% of the Italian agricultural land, normally the less fertile and less easily tillable areas are used. In fact, productive land is normally used for more profitable crops. Therefore, it is reasonable to assume that oil seeds would replace *temporal fodder plants* (legumes, barley, maize, alfalfa, sorghum, etc.), which are normally cultivated with intensive agricultural techniques.

It is very difficult to forecast how much cereal production and how much fodder production would be substituted. For this reason, I hypothesized that **1.3 million hectares of wheat** and **1.3 million hectares of temporal fodder plants** would be substituted. This is obviously an arbitrary assumption, but the conclusions of the analysis would not change significantly if the proportion between wheat and temporal fodder were modified.

Finally, Table 5.5 lists the three alternatives that were evaluated in this analysis.

Table 5.5 Alternatives

Name	Description	Quantity (Million tonnes)	Quantity of oil seeds required (million tonnes)	Origin of the raw material
Diesel	The target of the Directive is not reached. The 5.75% of the energy use for transport is provided by (imported diesel and not by biodiesel)	2.6	-	Oil exporting countries
Biodiesel-imported	Biodiesel is produced in Italy with oil seeds imported from Eastern Europe	3.2	8.5	Eastern Europe
Biodiesel-domestic	Biodiesel is produced in Italy with oil seeds cultivated within the national borders	3.2	8.5	Italy

In order to carry out the analysis some further assumptions had to be made.

First of all, I assumed that the **entire production would be obtained from earmarked crops**. In fact, if the biodiesel sector were to be launched, it would need a large amount of raw materials, in the order of magnitude of several million tonnes. It would be difficult or impossible to satisfy this demand only with used oil and waste materials. The Italian Consortium of Used Oil collected in 2003 around 200 thousand tonnes oil[11]. Only part of the collected oil can be used for biodiesel production[12], and the possible contribution to biodiesel would be very small even if the amount of collected oil increased considerably.

The second assumption was that the government would decide to stake on the biodiesel sector and allow **all biodiesel production to be totally exempted from taxes**. In fact, as explained above, without this condition biodiesel would not be competitive with traditional fossil fuels, and it would not be worthwhile to produce it.

Thirdly, I assumed that the **biodiesel produced in Italy would be used for transportation**, which is the main aim of the European Directive 2003/30/CE. Actually, unlike what happens in foreign countries, 95% of the Italian biodiesel is currently used for heating purposes[13]. This means that only approximately 16.3 thousand tonnes of biodiesel were used in 2004 for transport.

[11] Consorzio Obbligatorio di Oli Usati (Obligatory Consortium Used Oils), http/www.coou.it.

[12] There are three possible destinations of the collected used oil, that is, regeneration (which eliminates carbon residues and metallic oxides in order to allow re-use), combustion (which allows obtaining energy from not re-usable oil) and thermo-destruction (which eliminates oil contaminated with PCB, and therefore not suitable for the other two processes).

[13] Comitato Termotecnico Italiano http://cti2000.it/virt/cti2000/Headbio.htm.

This quantity is negligible if compared to the amount suggested by the Directive. Therefore, the fourth assumption is that all oil seed cultivation required by the Directive would be **newly introduced in the Italian agricultural system**.

Fifthly, I assumed that oil seeds used for biodiesel production would be cultivated with **intensive agricultural methods**, which imply use of fertilizers, pesticides and machinery. In fact, without this condition, the yield would be very low, and both the costs and the land requirement would become even higher.

The three alternatives defined here were evaluated under the criteria that are defined in Chapter 6.

6 Evaluation

6.1 Objectives and criteria

In a Social Multi-Criteria Evaluation the criteria are derived from the objectives of the social actors. However, the criteria are not directly chosen by the social actors themselves, but are a sort of translation of their objectives (see Chapter 3 and also Part I).

In fact, letting the social actors directly choose the criteria might have some counter-indications (see Munda, 2004). Firstly, there might be double accounting, omissions and scientific inaccuracy. For example, social actors might claim that they wish a reduction of urban air pollution, but they might not be aware of the relative danger of the different kinds of emissions. Also, the interests of some might be neglected in the discussion, because they are not organized, they live far away or they have not been born yet. In this case, the analysts might add some criteria to represent a general interest or the interests of some unrepresented social groups.

Once again, I would like to underline that due to time and budget constraints, I identified the social actors' objectives through articles, documents and declarations found on the internet, in newspapers and magazines. Also, I carried out by myself the translation from objectives to criteria, without setting up a real participatory process, such as it would be required for a comprehensive Social Multi-Criteria Evaluation (see Chapter 3). This procedure inevitably increased the arbitrariness of the analysis and leaves room for further analysis.

In any case, arbitrariness and subjectivity are unavoidable in any evaluation exercise, even though to different degrees (Funtowicz and Ravetz, 1991; Giampietro et al, 2006). The best way to deal with them is to increase the transparency on the procedures, assumptions and calculations as much as possible, in order to leave room for the scientific community and the society to exert further control on the consistency and the soundness of the analysis. In this way, anyone is potentially able to change some assumptions when they disagree on the way they are made (Munda, 2004).

6.2 Definition of the criteria used in this analysis

Criteria are indicators that are used to evaluate to what extent each alternative contributes to accomplishing the objective(s) of each group of social actors.

Beside the criteria derived from the interests of the three groups of social actors discussed in Chapter 4 (i.e. environmentalists, farmers and car drivers), other criteria were used to evaluate the three alternatives. In fact, other consequences of a large scale biodiesel production may be important for some other social actor or even for the citizens as a whole. The fact that they are not often mentioned in the debates on biofuels does not make them less important.

In fact, when analyzing a political decision, which has to be made in a complex environment and will influence a number of different persons, it might not be sufficient to take into consideration only the objectives pursued by the organized social actors, such as for example those represented by Confagricoltura and Coldiretti. On the contrary, the interests of other non-organized social actors should also be considered, as well as those of persons living far away and of future generations. Also, one actor can belong to more than one social groups (for example, one could be a car driver and farmer at the same time) or their interests can be affected by problems that are not underlined by a specific social group, such as for example the increase in food imports. This is especially true when performing a policy analysis at a national scale, where many different issues come into play. For this reason, in this work some criteria were added to the ones reflecting the interests of some specific social group.

The social actors and criteria considered in this study are summarized in Table 6.1 below. The criteria which do not measure the objectives of the social actors defined in Chapter 4 have a grey background. In the following part of this section the criteria which were used to evaluate the alternatives are presented, and the reasons for their selection are explained.

Table 6.1 Social actors, their objectives and criteria

Social actor	**Representing association**	**Objectives**	**Criteria**	**Unit**	**Desired direction**
(Consumers, Italian government, NGOs)	-	No competition with food crops	1. Land requirement	Million hectares	↓
Environmentalists	The Green Party, WWF, Alcatraz and others	Reduction of the greenhouse emissions	2. CO_2 savings	Million tonnes CO_{2eq}	↑
		Reduction of urban pollution	3. Urban pollution	%	↓
(Consumers, Italian government, NGOs)	-	Food sovereignty	4. Food imports	Million tonnes	↓
(European Commission, Italian government, citizen in general)	-	Increasing energy security	5. Energy dependency	Million tonnes of oil equivalent	↑
(Environmentalists, farmers and rural population)	-	Reducing the use of fertilizers in agriculture	6. Fertilizer requirement	Thousand tonnes	↓
(Environmentalists, farmers and rural population)	-	Reducing the use of water in agriculture	7.Water requirement	Million m^3 per year	↓
(Government)	-	Increasing the energy revenues	8. Energy taxes	Million euros	↑
Farmers	Coldiretti, Confagricoltura, Confederazione Italiana Agricoltori	Rural development	9. Rural development	Qualitative	↑
Car drivers	-	Cheap fuel	10. Fuel price	Euros/ Litre	↓

6.2.1 Land requirement

Land requirement is one of the main concerns of biofuel opponents (see for example Ulgiati, 2001; Giampietro and Ulgiati, 2005). The point here is that using part of the Italian territory for energy farming would subtract land from food cultivation or other purposes. Many papers have been written on biofuel land requirement, as well as on the possible competition for land between biofuel production and food cultivation (see Section 2.1). For example, Wolf et al. (2003) calculate how much land could be used for energy farming considering the land demand for food production. Hoogwijk et al. (2003) assess the global potential of bioenergy on the basis of the potentially available land, once the demand for food has been satisfied. Berndes et al. (2003) notice that most feasibility studies on biomass focus on land requirement and possible competition among different land uses.

The issue is crucial for Italy, since it is a densely populated country (191 people per km^2, vs. the European average of 118[1]) and it is occupied by mountains and forests for 45% of its territory (see Section 5.3). Also, it should be remembered that Italy is already a net importer of all categories of food (meat, cereals, vegetables and leguminous crops, milk and dairy products, eggs, honey, other edible products of animal origin), except fruit and wine (see Table 6.2). In other words, the Italian territory is already not enough to fulfil the demand for food of its population. Cultivating oil seeds would worsen the situation.

In order to evaluate these issues, I used the criterion "**land requirement**". The unit of measurement is ***hectares***.

6.2.2 CO_2 savings

Italian government committed itself to reduce its greenhouse emissions by 6% with respect to 1990 (but in reality they have been increasing by 11.4%). For this reason, biodiesel would be much appreciated if it could allow Italy to get closer to the Kyoto target. In order to evaluate the different alternatives from the point of view of greenhouse emissions, I calculated how much CO_2 the different options would allow to save. I used the criterion "**CO_2 savings**", which was assessed in terms of ***tonnes***.

6.2.3 Urban pollution

Urban pollution raises increasing concern not only among environmentalists but also among citizens, because it is widely recognized as co-responsible of many illnesses such as asthma, allergies, lung cancer and respiratory diseases (see Chapter 7). The criterion "**urban pollution"** allowed me to assess whether the most significant pollutants emitted by cars would be reduced by replacing diesel with a biodiesel blend. It was evaluated in ***percentage terms***.

6.2.4 Food imports

The high land requirement is a negative feature of energy farming because its consequence is an increase in food imports.

This aspect is particularly worrying in Italy, which is at present a net importer of all kind of alimentary products, with the exception of fruits and wine, as shown in Table 6.2.

[1] Eurostat data-base.

Table 6.2 Italian external trade of food, 2004

	Imports (million euros)	Exports (million euros)	Net imports (million euros)	Imports (million tonnes)	Exports (million tonnes)	Net imports (million tonnes)
Meat and entrails	3,518	1,16	2,349	1.4	0.5	0.9
Fruits	1,717	2,01	-294	1.9	2.4	-0.5
Cereals	1,639	39	1,246	9.9	1.0	8.9
Vegetables and legumes, roots	1,039	80	233	1.8	0.9	0.9
Milk and dairy products, eggs, honey, other edible products of animal origin	2,875	1,30	1,571	3.1	0.4	2.7
Wine	255	2,86	-2,610	0.1	1.4	-1.3
Olive oil, soy oil, peanuts oil, palm oil, sunflower oil, coconut oil, rapeseed oil	1,814	1,09	719	1.5	0.4	1.1

Source: Istat data-base

An increasing number of consumers tend to think that local food is characterized by higher quality. In most cases, the food sold on the international market is produced with intensive agriculture, gathered when it is still unripe, then conserved and transported in refrigerators. These procedures cause a loss of nutrients.

Increasing food imports reduces food sovereignty, which is a topic of the campaigns of some NGOs, such as for example Altragricoltura[2] and ACEA (Association for Alternative and Ethical Consumption)[3]. The Italian Committee for Alimentary Sovereignty was constituted in 2002, in occasion of the Forum for the Alimentary Sovereignty held in Rome in June 2002.

Another reason to prefer local food is to preserve agrarian biodiversity and landscape.

Finally, food imports have an impact on the Italian trade balance, which has been deteriorating in the last years and was in deficit in 2004 and 2005 (for the first time since 1992[4]), see Table 6.3. In this context, increasing food net imports might worsen the situation, since food represents approximately 4% of the total Italian import in monetary terms.

Table 6.3 Italian trade balance (M€)

	2001	2002	2003	2004
Exports	272,990	269,064	264,616	280,692
Imports	263,757	261,226	262,998	282,205
Net exports	9,233	7,838	1,618	-1,513

Source: Istat data base

[2] http://www.altragricoltura.org/forocontadino/idoc-sovranalimentare.htm.
[3] http://www.consumietici.it/acea/html/2/alimenta.htm.
[4] Istat data-base.

For all these reasons the high land requirement and the consequent increase in food imports might be a reason for concern for different categories of citizens, even though it is not often mentioned in the debates about biofuels.

First of all, it is important for *consumers*, because imported food might be characterized by a lower quality. Secondly, it is important for the *Italian government* as representative of the interests of the Italian citizens in general. The reasons are the vulnerability with respect to the fluctuations of the international food market and the deterioration of the trade balance.

In order to include these issues in the evaluation, I used the criterion "**food imports**" (measured in ***tonnes***), which takes into account how much food Italy would need to import if oil seeds replace food products.

6.2.5 Energy dependency

Another issue that is often mentioned when speaking about biofuels is energy dependency (see for example the quotation of the Commissioner for Agriculture and Rural Development in Section 4.6).

At present, energy security is a big issue in *Europe*, especially after the threats of Iran and the gas crisis that took place in late December 2005, which was due to conflicts between Ukraine and Russia on the price of natural gas. There is no need to say that control of the energy sources is a very important driving force of the industrialized countries' external policy, including the Iraqi wars.

In particular, energy dependency is very strong in Italy, which has very small reserves of fossil fuels and abandoned nuclear energy in 1987 after the Chernobyl disaster. The Italian energy dependency (the share of net import on primary energy consumption) was 85% in 2003, and it has been steadily increasing in the last ten years (see Table 6.4). As a benchmark, the energy dependency of Europe15 as a whole was 53% in 2003. Italy imports 99% of the solid fuels it uses, 94% of the crude oil and petrol products, and 82% of the gas[5].

Table 6.4 Italian energy dependency, million toe

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Primary production	30	29	30	30	30	29	27	26	26	27
Total imports	147	152	154	156	163	164	175	170	175	180
Total exports	21	18	19	21	23	21	22	23	22	24
Primary energy consumption	156	164	165	165	170	173	180	173	179	183
Net imports	126	135	134	134	140	144	153	148	153	155
Energy dependency (%)	81	82	82	82	82	83	85	85	85	85

Source: Eurostat data-base

[5] Eurostat data-base.

The increasing oil price is a threat to price stability, and for this reason, reducing energy dependency is in the interest of *Italian citizens*.

I assessed the criterion "**energy dependency**" in terms of ***tonnes of oil equivalent***.

6.2.6 Fertilizer requirement

Another relevant issue is whether large scale biodiesel production would imply an increase in the use of fertilizers and pesticides with respect to the present situation. The use of fertilizers and pesticides damages the environment because they modify soil composition, jeopardize biodiversity, contaminate water and air, and also increase cancer incidence (ANPA, 2001). The nitrogen and phosphorus in fertilizers trickle down to the underground water-table and cause eutrophication. The increase in available nutrients favours certain plant species over others (such as for example algae in aquatic environments). As a consequence, the ecosystem's resilience is compromised.

The European Commission has long been interested in reducing the use of fertilizers. The first Directive that regulates the issue dates back to the Seventies (Directive 76/116/EEC). The Regulation No. 2003/2003[6] integrates the rules contained in nine Directives that have been published since then on fertilizers. Also, the more recent Directive 91/676/EEC sets rules in order to protect water from contamination produced by nitrates used in agriculture. In Italy the Law 748/84 introduced for the first time a regulation on the use of fertilizers, followed by many other laws and legislative and ministerial decrees.

The issue is important for *environmentalists*, as representatives of those who worry for environmental sustainability. It is also important for *farmers* and *rural population* in general, because they are potentially affected by the health problems associated with the use of fertilizers

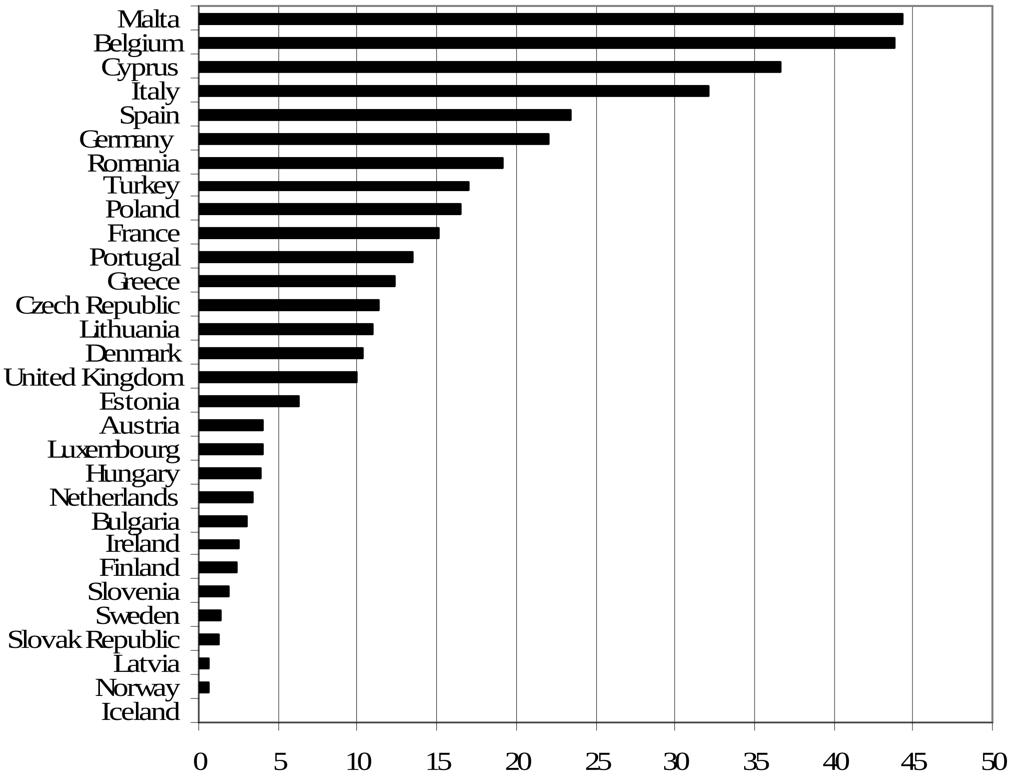
In order to take these issues into account, I calculated how much fertilizers would be used for biodiesel production using the criterion "**fertilizer requirement"**, which was assessed in terms of eutrophication potential (***tonnes*** $PO_4^{3-}{}_{eq}$).

6.2.7 Water requirement

Water use in agriculture is also a serious problem, especially in Italy, which is a densely populated country with a low rate of precipitation. The Italian Water Exploitation Index, which measures the ration between water use and availability, is the fourth highest among the member states of the European Union, as it is shown in Figure 6.1[7].

[6] Regulation (EC) No. 2003/2003.
[7] EEA, 2003.

Figure 6.1 Water exploitation index (%), 2001



Source: EEA, 2003

The point here is whether replacing part of the present crops with oil seed crops would cause a variation in the use of water. The criterion I used to evaluate this issue is "**water requirement**" (measured in ***tonnes***).

The issue is important for *farmers* and for *rural population* for two reasons: first of all, irrigation implies costs. Secondly, and more importantly, water is a finite resource, and as such it should be managed carefully.

6.2.8 Energy taxes

An important issue for the *Italian government* is the variation of the energy revenues that would derive from biofuel de-taxation. Energy revenues in 2005 represented 9.4% of the total Italian revenues. Reducing energy taxes might therefore create difficulties to the Italian budget, especially considering the commitments made in the Maastricht Treaty of maintaining the deficit under 3% of GDP. It should be remembered that the 2004 Financial Law[8] reduced by one third the amount of de-taxed biodiesel not because of a reasoned assessment of biodiesel advantages and disadvantages but because of the financial difficulties that the Italian government was experimenting in that time.

[8] Legge 306/2004.

Table 6.5 shows the Italian budget between 2001 and 2005. The energy taxes represented in the last five years between 8.1 and 9.4% of the total Italian revenues. Reducing energy taxes might make it difficult to keep the deficit under 3% of GDP. In this moment Italian deficit is the second highest in the European Union (more than 4%).

Table 6.5 Italian Budget, million €

	2001	**2002**	**2003**	**2004**	**2005**
a) Revenues	368,113	386,948	392,243	391,532	409,586
- Taxes	*308,826*	*325,269*	*321,925*	*323,508*	*337,455*
- - Energy taxes	*29,091*	*27,156*	*26,460*	*26,047*	*28,694*
- - - Energy taxes (oil and petrol by-products)	*23,443*	*21,389*	*21,053*	*20,549*	*22,739*
- - - Energy taxes (gas methane and LPG)	*4,349*	*4,470*	*4,332*	*4,331*	*4,721*
- - -Energy taxes (electricity)	*1,299*	*1,297*	*1,075*	*1,167*	*1,234*
Share of energy taxes on total revenues (%)	*9.4*	*8.3*	*8.2*	*8.1*	*8.5*
b) Loans creation and credits refunds	241,104	222,278	277,743	262,954	235,775
Total (a + b)	609,218	609,225	669,986	654,486	645,361
c) Expenditures	424,015	434,386	445,793	452,826	465,749
d) Debt refund	185,202	174,839	224,192	201,659	179,611
Total (c + d)	609,218	609,225	669,986	654,486	645,361

Source: CNEL data base

In order to evaluate this point, I used the criterion "**energy taxes**", which was measured in ***euros***.

It is worthwhile to underline that whereas the Italian government faces problems if energy taxes are reduced, Italian citizen mostly whish a reduction in energy taxes, which represent more than half of the price of fuels.

6.2.9 Rural development

For *farmers*, the main objective "**rural development**", i.e. increasing the competitiveness of the agricultural sector and the quality of life in rural areas. Since it is very difficult to assess this criterion in quantitative terms, I preferred to perform a ***qualitative*** evaluation.

6.2.10 Fuel price

For the car user community, the most important issue is the fuel price at the pump. In fact, the "biofuels fever" exploded in Italy when the oil price started increasing very much. To assess whether biofuels would help Italian car drivers to save money, I used the criterion "**fuel price**". The unit of measurement was ***euros per litre***.

6.3 Calculation of the criteria scores

6.3.1 Land requirement

In order to calculate how much land would be used for energy farming, I assumed that: 1) 80% of the required oil seeds would be rapeseed and the rest sunflower; 2) their oil content would be respectively 36% and 41%; 3) the production would be 1.85 and 2.25 tonnes per hectare 4); the cake meal obtained as a by-product of the oil seeds pressing (4 million tonnes) would be used as cattle feed (see Chapter 5). Using these figures, the result is that around **3.7 million hectares** would be needed.

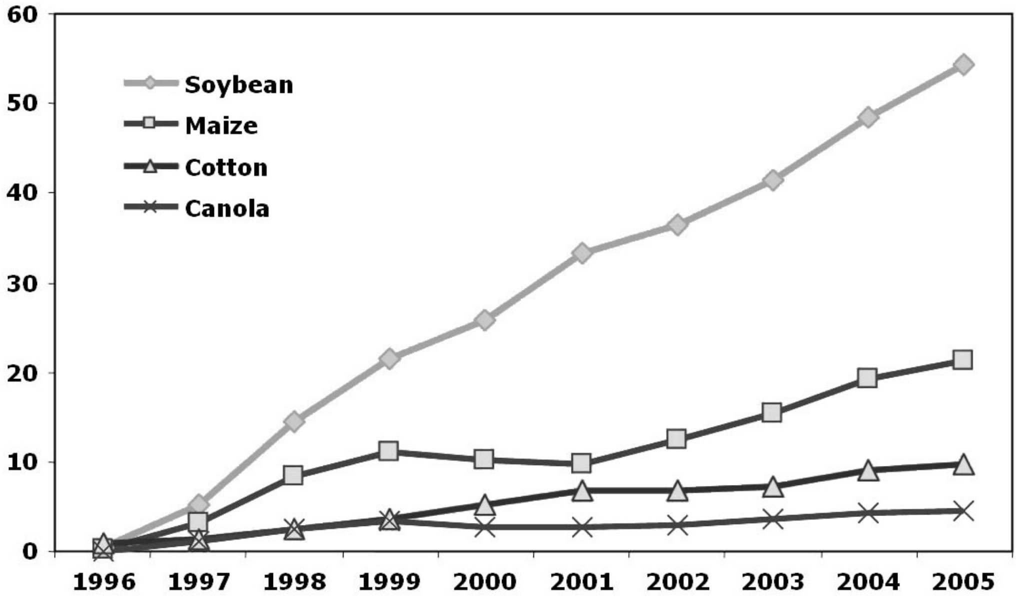
Therefore, ***in order to satisfy 5.75% of the energy demand for transport (which represents in turn 25% of the total energy use), 12% of the total Italian territory would be needed, which means 26% of the land that is presently occupied by agriculture and pastures***.

Respecting the objective of the Directive on biofuels would therefore require an enormous amount of land, and it would imply a huge effort. In fact, a massive re-conversion of the agricultural land would have to take place, with all the difficulties and the costs that it would cause, not least a big increase in food imports (see Section 6.3.4).

Agricultural biodiversity would decrease dramatically and almost one third of the Italian agricultural land would be converted to huge monocultures of sunflower and rapeseed, cultivated with intensive (and very polluting) agricultural techniques. Also, one of the consequences might possibly be an increase of the use of GMOs. In fact, rapeseed is one of the most used biotech crop, as can be seen in Figure 6.2. In 2005 4.3 million hectares were cultivated with high tech rapeseed, which represents 18% of the total[9].

[9] Clive J, 2005, http://www.isaaa.org.

Figure 6.2 Global area of main biotech crops (million hectares)



Source: Clive J, 2005, http://www.isaaa.org.

Obviously, if biodiesel were produced using imported oil seeds, no additional land would be required in Italy. Also, according to the assumptions made, around 0.8 million hectares of land that is presently cultivated with fodder plants could be used for other crops, since the cake meal could be used as cattle feed. In this case, the land requirement would therefore be **-0.8 million hectares**. The criteria scores are presented in Table 6.6.

Table 6.6 Criterion N.1 LAND REQUIREMENT-national scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Land requirement	Million ha	0	-0.8	3.7

However, it should not be forgotten that in this case, some million hectares would be needed elsewhere (in Eastern Europe according to the hypotheses made) to produce the oil seeds for Italy. Assuming for simplicity that in the producing country the oil seed yield is the same as in Italy, 3.7 million hectares would be needed there, as shown in Table 6.7.

Therefore, ***importing the oil seeds would be a savings of land only on a national scale. On a large scale, Italian citizens would be responsible for the use of 3.7 million hectares of land irrespectively of where it is used***, whether in Italy or in foreign countries.

Table 6.7 Criterion N.1 LAND REQUIREMENT-large scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Land requirement	Million ha	0	3.7	3.7

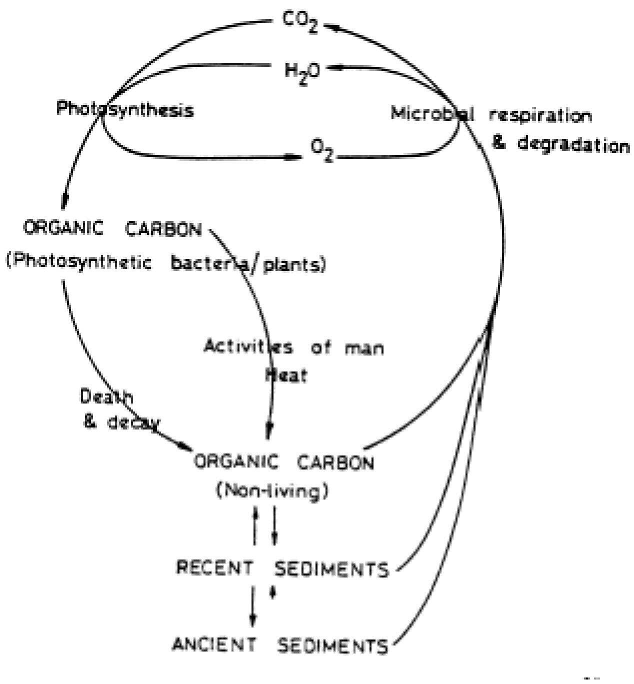
6.3.2 CO_2 savings

The CO_2 emissions released by biodiesel in the combustion phase are approximately the same as diesel because diesel emits slightly more CO_2 but also has a higher gross heat of combustion (Peterson and Hustrulid, 1998).

However, most CO_2 incorporated in biodiesel is renewable and is not accounted for in the global carbon balance. The reason is that the carbon cycle of biodiesel is much faster than the one of fossil fuels. In other words, the CO_2 released during biodiesel combustion is mainly that which was absorbed by the plant during the photosynthetic process in a recent year or in many cases in the same year, converted into biomass and then processed into biodiesel.

On the contrary, the CO_2 emitted by burning fossil fuels was removed from a carbon dioxide-rich atmosphere some million years ago through the photosynthetic process and then stored under the earth surface (see Figure 6.3). For this reason, the use of fossil fuels contributes to the increase in CO_2 concentration in the atmosphere and therefore to the greenhouse effect.

Figure 6.3 The carbon cycle



Source: Peterson and Hustrulid, 1998

However, biodiesel is also responsible for some non-renewable CO_2 emissions along its entire life cycle. In the agricultural phase, pesticides and fertilizers are used, which are derived from oil, as well as tractors and other machinery. Also, energy is used for transporting the oil seeds to the plant, and then in the extraction and trans-esterification phase. Moreover, fossil fuels are used again to transport the biodiesel to the final consumer.

One possibility is to reinvest in the process part of the biodiesel produced, in order to make the entire process renewable. However, this hypothesis is not feasible on a large scale, because an even higher share of the Italian territory than the one calculated in Section 6.3.1 would be needed. The reason is that in this case the output/input share would be much lower, because part of the output would have to be reinvested in the process. If it is already hardly conceivable to use 12% of Italian territory to satisfy only 5.75% of the energy demand for transport, it is not plausible to occupy even more land. For this reason, **I assumed that the energy inputs would derived from fossil fuels** (and therefore their emissions must be accounted for in the carbon balance).

Burning a tonne of diesel releases 3.1 tonnes CO_{2eq}[10]. Since the lower calorific value of diesel is 1.1 toe/tonne, obtaining from diesel the amount of energy that according to the Directive should be produced with biodiesel (2.8 million toe), would imply using 2.6 million tonnes diesel and emitting **7.9 million tonnes CO_{2eq}**. As a benchmark, it might be useful to remember that **the total Italian emission in 2003 were 570 million tonnes CO_{2eq} equivalent**[11] (United Nation Framework Convention on Climate Change, 2005).

In order to calculate the CO_2 emissions of biodiesel, the first step is to calculate the energy yield (output/input) ratio, which must be necessarily higher than one, otherwise the process is not worthwhile. Giampietro et al. (1997) notice that the output/ input ratio increases in a non-linear way, so if the ratio decreases from 1.5 to 1.2 (i.e. by 20%), the land, water and labour used per unit of biofuel double.

As shown in Table 6.8 different output/input ratios are calculated in the various life cycle assessments that can be found in the literature. It can be noted that the figures differ very much, according to the different assumptions, the system boundaries and the allocation rules for biodiesel and its by-products (glycerine and cake meal).

[10] IPCC, 1996.
[11] Without considering Land Use, Land-use Change and Forestry.

Table 6.8 Energy yield ratios in the literature

Reference	Energy output/input
Kallivroussis et al., 2002	• 4.5 if meal is used as fuel • 3.4 if meal is used as animal feed
Bernesson et al., 2004	• Physical allocation:3.5 (after the energy content) • Economic allocation:3.2 (after the economic value) • ***No allocation: 2.5***
Cardone et al. 2003	1.08-1.67
Venturi and Venturi, 2003	Without allocation • Sunflower: 0.3-0.9 • Rapeseed: 0.7-1.0 • Soybean 0.2-0.6 With allocation: • Sunflower: 0.4-1.2 • Rapeseed: 1.0- 1.5 • Soybean: 0.7-1.6
Janulis, 2004	With no allocation: extensive agricultural techniques: for 2; 2.5; 3; 3.5 t/ha respectively 1.04; 1.19; 1.43; 1.59 Other figures with an allocation procedure are provided
Giampietro et al. 1997	0.6-1.3
Giampietro and Ulgiati, 2005	• Use of residues as energy source, credit for feedstock: 1.21 • Use of residues as energy source, no credit for feedstock: 0.98 • No residues as energy source, credit for feedstock: 1.51 • No residues as energy source, no credit for feedstock: 1.16

When calculating the output/input rate, the crucial point is the allocation method. In fact, the biodiesel process has two by-products: cake meal, which is obtained when pressing the oil seeds, and glycerine, which is a result of the trans-esterification process (see Figure 2.4). Table 6.9 shows the weight and the energy content of the cake meal and glycerine which would be produced if the target of the European Directive were reached.

Table 6.9 Weight and energy content of the by-products of the biodiesel process if the 5.75% target were met

	Total (million tonnes)	Heating value (MJ/kg)	Total TJ[12]
Biodiesel	3.2	38.5	0.12
Glycerine	0.4	17.1	0.01
Cake meal	4.0	15.3	0.06

Source: Bernesson et al., 2004, adapted

Most Life Cycle Analyses attribute part of the used inputs and emissions to the by-products, calculating the degree of allocation in terms of weight or energy content. Obviously, the more energy requirement allocated to the by-products, the higher the output/input biodiesel balance and the more efficient the process looks.

[12] 1 tera Joule =10^{12} Joules

However, Giampietro et al. (1997) claim that this procedure is not correct because after a certain amount it is probable that there is not enough demand for by-products. This would be especially true if many European State Members tried to reach the target established in the Directive on biofuels, because in this case huge amounts of glycerine and cake meal would be produced. For a large-scale biofuel industry, by-products may become a waste to dispose of, with the related economic and energetic costs. Also, gathering, processing, transporting and using by-products would also require energy.

If the Directive's target were met, 0.4 million tonnes glycerine and 4 million tonnes cake meal would be produced (see Table 6.9). It is not obvious that a market outlet can be found for such large amounts. In fact, glycerine is a by-product of many industrial processes.

One might argue that both glycerine and cake meal could be exported. However, possibly Italy would not find in foreign countries enough demand to absorb the entire amount that would be produced in the biodiesel process. In fact, firstly if the other European countries also decided to meet the Directive's requirement, they would also produce millions of tonnes of glycerine and cake meal. Secondly, it might not be worthwhile to export it to extra-European country, due to the transport costs and low market price.

Moreover, Italy is already a net exporter of glycerine (in 2003, the net exports were 8 thousand tonnes[13]), which means that Italy already produces more glycerine than it consumes. As regards animal feedstuff, as shown in Table 6.10, Italy is also a net exporter, at least of processed feedstuff.

Table 6.10 Animal feedstuff (million tonnes), 2004[14]

Production	Imports	Exports	Net export (export-imports)
14.9	0.1	0.2	0.1

Source: Istat data-base

For these reasons, in this analysis **energy emissions were only allocated to biodiesel by-products to the limited extent in which they would replace other products** (i.e. no allocation to glycerine, and partial allocation to cake meal to account for the reduction of emissions granted by its replacing part of the fodder otherwise to be cultivated in Italy).

As explained in Chapter 3, I made very optimistic assumptions, in order to demonstrate that if even in this case biodiesel were not a promising option, then it should not be promoted. Therefore, I chose the highest output/input ratio without allocation among the ones presented in Table 6.8, i.e. **2.5** (Bernesson et al. 2004) which means that the non-renewable fraction of biodiesel is 40%. It might be

[13] OECD, 2005.
[14] It can be noted that the data shown represent only the processed animal feedstuff, whose water content (and therefore weight) is lower than that of fresh fodder plant. Also, the crops that are given to cattle without being subjected to an industrial process are not included.

observed that this ratio is much higher than the others and **it is most probably overestimating the biodiesel efficiency**.

This ratio includes both the direct energy use and the fertilizers[15]. These two items are relevant in the calculation of the emissions in the framework of the Kyoto Protocol. However, Land Use, Land-use Change and Forestry (LULUCF) are not taken into account in the Italian greenhouse effect accounting (United Nation Framework Convention on Climate Change, 2005). Therefore I ignored this issue, because I assumed that what interests the Italian government is not or not only the greenhouse emissions per se, but above all the emissions that enter in the calculation of the Kyoto protocol[16].

Taking an output/input share of 2.5, it results that for producing 2.8 million toe biodiesel around 1.1 million tonnes fossil fuels would be used, which would emit **3.5 million tonnes CO_{2eq}.**[17]

However, if the oil seeds were produced in Italy, the avoided energy use for the crops that would be replaced should be also taken into account. As already explained in Chapter 5, I assumed that 1.6 million hectares cultivated with wheat and 1.6 million hectares cultivated with temporal fodder plants would be substituted. Considering that the average wheat and temporal fodder plants yield is 3.7 and 29.6 tonnes/ha[18], the result is that **production of 5.9 million tonnes of wheat and 46.7 million tonnes fodder would be spared in Italy** as a consequence of the large-scale biodiesel production. Since their energy requirement is respectively 0.2 and 0.04 toe/tonne[19], the correspondent reduction in greenhouse emissions would be approximately **2.7** and **5.7 million tonnes CO_{2eq}.**

Also, the energy used for transporting the wheat and the fodder that would not be produced in Italy anymore must be also taken into account. For the reason explained in Chapter 5, I assumed that oils seeds, wheat and fodder would be imported from Eastern Europe. Since I took the point of view of the Italian government and assumed that the most important objective for it is to respect the Kyoto agreement, I did not consider the emissions produced outside Italy, since

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[15] The life cycle analysis by Bernessons et al. (2004) includes transport between the fields and farms, electricity consumption of 0.6 MJ/kg biodiesel for trans-esterification, fertilizers and pesticides, cultivation operations (65.9 L diesel per hectare), drying operations and oil extraction. Energy used for buildings and manufacturing of agricultural machines, transport lorries and process machines is also taken into account.

[16] Anyway, it should be remembered that oil seed plants subtract from the atmosphere more CO2 than is accumulated in the plant and burnt. In fact, part of the CO2 fixed by the plant remains in the roots and is released into the soil (Peterson and Hustrulid, 1998). According to a study cited by Peterson and Hustrulid (1998), 17-19% of the CO2 fixed by a rapeseed plant is in the roots, out of which 30-34% is released into the soil. Also, the soil micro-organisms assimilate the CO2 of the residues that are left in the field, retain some and return the rest to the atmosphere via respiration.

[17] I assumed that the fossil fuel used would be diesel (which emits 3.1 tonnes CO_2 per tonne). This assumption makes sense since in general diesel is used for agricultural machinery. However, the ratio of CO_2 per tonne of oil is not that different from the one of diesel.

[18] ISTAT data base, year 2004.

[19] Biondi et al, 1989. Average values of 11 and 16 empirical observations.

they are not taken into account in the Kyoto emission calculation. Therefore, I only included in the calculations the two trips (from the Italian border to a hypothetical oil pressing factory situated in central Italy and back), i.e. approximately 800 km, and assumed that they would be covered by road transport.

I assumed that fodder would not be imported as such, but would be transformed into pellets, in order to make it more concentrated. In this case, the water content would decrease from around 85% in fresh fodder to 10%[20] in fodder pellets. Calculated in this way, in order to substitute 46.7 million tonnes of fresh fodder, only 7.8 million tonnes of processed feedstuff (pellets) would be needed.

Considering an energy cost of 40 g diesel per tonne per km (Federici et al., 2003[21]), about **1 million tonnes CO_{2eq}** would be emitted for transporting the substituted crops (7.5 million tonnes of wheat and 7.2 million tonnes) if the case oil seeds are cultivated in Italy.

Therefore, the total savings would be 3.5-2.7-5.7+1= **-4 million tonnes CO_{2eq}**, meaning that 4 million tonnes would be spared. In order to calculate the total savings, the avoided emissions because of the spared 2.8 million toe diesel must be added. Altogether, cultivating diesel in Italy would allow reducing domestic emissions by 7.9+4= **11.9 million tonnes**.

If the oil seeds were imported, only the energy used in the processing phase (oil extraction and trans-esterification) should be taken into account. Considering an energy cost of 0.1 toe per tonne of biofuel produced (Bernesson, 2004; Cardone et al. 2003[22]), the result would be that in order to produce 2.8 million toe biofuel, **1 million tonne CO_{2eq}** would be emitted. In this case, the energy used for transporting the 8.5 million tonnes oil seeds should be taken into account, which, if calculated as before and considering a transport distance of 800km, would result in **0.8 million tonnes CO_{2eq}**. Finally, the avoided emissions for the fodder that would be replaced by the cake meal must be taken into account, i.e. **2.9 million tonnes CO_{2eq}**[23]. Therefore, the CO_2 savings would be 7.9-1-0.8+2.9 = **9 million tonnes CO_{2eq}**. The criterion scores are presented in Table 6.11.

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[20] Lardy and Anderson, 1999.

[21] Federici et al. (2003) indicate a value of 0.04 kg per tonne per km, which considers the entire life cycle of the truck. An identical value (1.7 MJ/tkm, which translates into 40.5 g/tkm) is also reported in the GEMIS database (http://www.oeko.de/service/gemis/en/data.htm). Other values ranging between 0.45 MJ/tkm (Andersen et al., 1997) and 4.5 MJ/tkm (Jarach, 1995) can be found in the literature, which essentially reflect different assumptions on truck capacity and actual load.

[22] Janulis (2004) indicates a value of 0.2 toe per tonne biofuel produced.

[23] 4 million tonnes of dry feed pellets correspond to approximately 24 million tonnes of fresh fodder plants. In fact, the water content of fresh fodder is about 80%, whether the one of dry feedstuff is 10% (Larry and Anderson, 1999, http://www.ext.nodak.edu/extpubs/ansci/livestoc/as1182-3.htm).

Table 6.11 Criterion N.2 CO_2 SAVINGS-national scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
CO_2 savings	Million tonnes CO_{2eq}	0	9.0	11.9

The conclusion is that if the main objective of the Italian government is to respect the Kyoto commitment, the best alternative would be to reach the Directive's target and to cultivate the oil seeds in Italy. This option would allow a savings of respectively **2.3% and 2.1% of the 1990 and 2003 total Italian greenhouse emissions**[24]. If oil seeds were imported, the savings would correspond to **1.8% and 1.6% of the 1990 and 2003 Italian total emissions**.

This reduction is not irrelevant and it might represent a contribution to reach the Kyoto target. However, the point is, once again, ***whether it is worthwhile to use almost one third of the Italian territory to reduce the Italian CO_2 emissions by only 2%.***

Also, it must be underlined that ***cultivating the oil seeds in Italy seems to be the best option because it would allow saving CO_2 emissions by externalizing them in part to foreign countries***. In fact, the energy inputs in the agricultural phase that would take place outside the Italian borders are not accounted for. However, Italian consumers would be responsible for the energy needed to cultivate the wheat and the cattle feed or the oil seeds that they would import, even though they do not count in terms of the Kyoto negotiations.

On a larger scale, the avoided emissions for cultivating wheat, cattle feed and oil seeds should not be accounted for as savings. Also, the total energy use for transport should be taken into account and not only that taking place inside the Italian borders.

Assuming a route of, say, 3,000 km (from Hungary[25] to Italy and back), the emissions for transport of wheat and feed pellets would be **3.6 million tonnes CO_{2eq}**. After subtracting the avoided CO_2 because of the substitution of part of the fodder cultivation with cake meal (2.9 million tonnes CO_{2eq}), the result is that the total emissions would be **4.2 million tonnes**, which represent a **savings of 3.8 million tonnes CO_{2eq}** with respect of diesel. This means that from a large scale approach, if the biodiesel directive were respected and the oil seeds were cultivated in Italy, under the most optimistic assumptions ***the reduction would be only 0.66% of the 2003 Italian emissions***.

As regards the hypothesis of importing the oil seeds needed for respecting the EU Directive, taking a large scale approach and attributing to biodiesel consumers all the emissions they cause inside and outside their country, the total emissions

[24] Respectively 511.371 and 569.828 million tonnes CO_{2eq} (without considering Land Use, Land-use Change and Forestry). Source: United Nation Framework Convention on Climate Change, 2005.
[25] Hungary is the second most important exporter of rapeseed to Italy (see Table 5.2) and the second most important world sunflower exporter (see Table 5.3).

would be the ones related to all phases of biodiesel production, wherever they take place (**3.5 million tonnes CO_{2eq}** assuming a similar yield in Eastern Europe as in Italy). The transport would again refer to 3000 km and account for **3.1 million tonnes**, and as above, the **2.9 million tonnes** of avoided emissions for producing cattle feed would be subtracted. Calculated in this way, the CO_2 emissions would be 3.5+3.1-2.9 = **3.7 million tonnes CO_{2eq}**, therefore the savings would be **4.2 million tonnes CO_{2eq}. (*0.74% of the 2003 emissions*).**

Calculated like so, the ranking is reverted for two reasons. The avoided energy use of the substituted wheat and cattle feed in the case the oil seeds were cultivated in Italy (or, which is the same, the energy used in foreign countries to cultivate the wheat and cattle feed that Italy would import) was not subtracted from the total biodiesel emissions. Secondly, the energy use for transport would be higher if oil seeds were cultivated in Italy because the wheat and cattle feed that Italy would need to import (9.7 million tonnes) would be heavier than the oil seeds that would be imported to respect the Directive (8.5 million tonnes).

These figures tell us that ***claiming that biofuels can supply an important contribution to the fulfilment of Kyoto commitments means not having the entire picture in mind***. Table 6.12 shows the CO_2 savings calculated with a large-scale approach.

Table 6.12 Criterion N.2 CO_2 SAVINGS-large scale

Name	Unit	1) Diesel	2) Biodiesel- imported	3) Biodiesel- domestic
CO_2 savings	Million tonnes CO_{2eq}	0	4.2	3.8

6.3.3 Urban pollution

The Italian Legislative Decree 351/99, which transposes the European Directive 96/62/EC, is the reference framework for air quality monitoring. It indicates the six most important air pollutants to be monitored and reduced: 1. Sulphur Dioxide (SO_2); 2. Nitrogen Dioxide (NO_2); 3. fine Particulate Matter such as soot (PM); 4. suspended Particulate Matter (PM); 5. Lead (Pb); 6. Ozone (O_3). According to the Directive (and naturally the transposing Decree), other pollutants to be evaluated are: 7. Benzene (C_6H_6); 8. Carbon Monoxide (CO); 9. Poly-nucleated Aromatic Hydrocarbons (PAH); 10. Cadmium (Cd); 11. Arsenic (As); 12. Nickel (Ni); 13. Mercury (Hg).

The Ministerial Decree 60/2002 (implementing the Directives 99/30/EC and 2000/69/EC) only sets threshold values for some of the above-mentioned emissions, i.e. SO_2, NO_2, NO_x, particulate matter (PM), lead, benzene and CO. Therefore, I assumed that for the time being the Italian government is mostly interested in controlling these latter pollutants, which are limited by a threshold established by law.

Lead can be ignored because, thanks to a regulative effort[26] and the widespread use of catalytic mufflers, emissions have been greatly reduced in the transport sector. Nowadays, the main sources of lead are industrial processes. Also, ***benzene*** is not really relevant, because it is mainly associated with petrol, whereas in this study biodiesel and diesel are compared.

Sulphur dioxide (SO_2) can also be ignored for two reasons. First of all, Italian SO_x (including SO_2) emissions decreased by 75% between 1980 and 1999. Secondly, the most important anthropogenic SO_x source (i.e. excluding volcanoes, which account for 68% of the emissions) is the energy sector (56% of the anthropogenic emissions)[27]. Cars emit only 2% of the total anthropogenic SO_x.

Therefore, the most important pollutants to be monitored are NO_x (including NO_2), PM and CO. As a confirmation of this, it can be noted that EPA (2002)'s report on biodiesel's emissions is based on these three substances (plus hydrocarbons, HC, for which an emission limit has not been set yet, but it might be soon). However, ***CO*** and ***HC*** emissions of engines running on diesel are relatively small, if compared to emissions from light-duty petrol vehicles (Graboski and Mc Cormick, 1998; Mc Cormick and Alleman, 2005). Also, the toxic effect of CO is limited to the areas of heavier traffic, and in normal conditions it can be metabolized quite efficiently by the human body, thereby being not so dangerous for human health. For these reasons, NO_x (including NO_2) and PM are considered the most important pollutants when evaluating biodiesel emissions.

Various studies have been carried out on biodiesel exhaust emissions. However, these figures are not directly comparable because the amount of pollutants depends on the technical characteristics, the operating conditions and the load level of the engine, as well as on the vehicle (heavy duty vehicles, including trucks and buses, light duty vehicles or cars), the kind of biodiesel used and the measurement technologies. For example, NO_x is emitted when the engine reaches high temperatures, and therefore the amount of emissions depends on how hot the engine gets (and therefore on load, speed and technical characteristics, as well as on the oxygen content). In general, it can be said that NO_x emissions increase with load and speed (Labeckas and Slavinskas, 2005; Graboski and Cormick, 1998)[28].

Also, it must be noticed that to a certain extent there is a trade-off between NO_x and PM. A greater PM reduction can be obtained at the cost of a larger increase in NO_x emissions (Mc Cormick and Alleman, 2005), so the level of these two emissions depend on the priorities of the engine manufacturers.

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[26] Decreto Legistlativo 66/2005.

[27] APAT (Agenzia per la Protezione dell'Ambiente e per i Servizi Tecnici, Agency for the Environmental Protection and Technical Services) data base, http://www.apat.gov.it/site/it-IT/Servizi_per_l'Ambiente/Inventario_delle_Emissioni_in_Atmosfera_(CORINAIR-IPCC).

[28] Graboski and Mc Cormick (1998) show that NOx emissions depend on speed and load. They are high at low speed and high torque, and at mean speed and low torque. At high speed and load, there is not much difference between biodiesel and diesel. NOx emissions also depend on the oxygen content and the fuel density.

The transport sector emits almost 50% of the total ***nitrogen oxides (NO_x)***[29]. NO_x are one of the main contributors to urban air pollution. They cause eye irritation and breathing illnesses such as asthma, and contribute to acid rain. Also, they react with oxygen and form ozone (O_3) and other secondary pollutants such as PAN (Peroxy-Acyl Nitrates), which are severe irritants. Finally, they contribute to the greenhouse effect. Most studies agree on the fact that substituting diesel by biodiesel produces an increase of NO_x emissions (Cardone et al., 2003; EPA, 2002; Altin et al., 2001)[30].

Particulate matter (PM) includes all liquid and solid particles dispersed in the atmosphere. They consist of sulphates, a Soluble Organic Fraction (SOF), elemental carbon and various inorganic chemicals. They can penetrate in the throat and in the lungs, releasing the pollutants they carry (SO_x, NO_x, PAH) and causing asthma, bronchitis, allergies and cancers.

Replacing diesel with biodiesel produces an increase of the solid carbon fraction and a reduction of the SOF, and again the final effect depends on the engine. In heavy-duty engine tests the first effects dominates, resulting in a decrease of PM (Mc Cormick and Alleman, 2005). In general, most studies indicate a lower amount of PM emissions in biodiesel with respect to diesel (Kalligeros et al., 2003; Graboski and Mc Cormick, 1998)[31].

Therefore, the two indicators chosen here to evaluate the impact of biodiesel on urban pollution give different results: NO_x increases and PM decreases when diesel is replaced with biodiesel. Mc Cormick and Alleman (2005) show the results of various analyses made with different engines. They all show an increase of NO_x and a decrease of PM emission. The same results are obtained by four studies cited by the Comitato Termotecnico Italiano[32] and by five analyses cited by Turrio-Baldassarri et al. (2004).

According to a study carried out by the Environmental Protection Agency (2002), if diesel is replaced with a 20% blend of soy biodiesel in heavy duty vehicles, NO_x increases on average by 2% and PM decreases by 10.1%, as it is shown in Figure 6.4.

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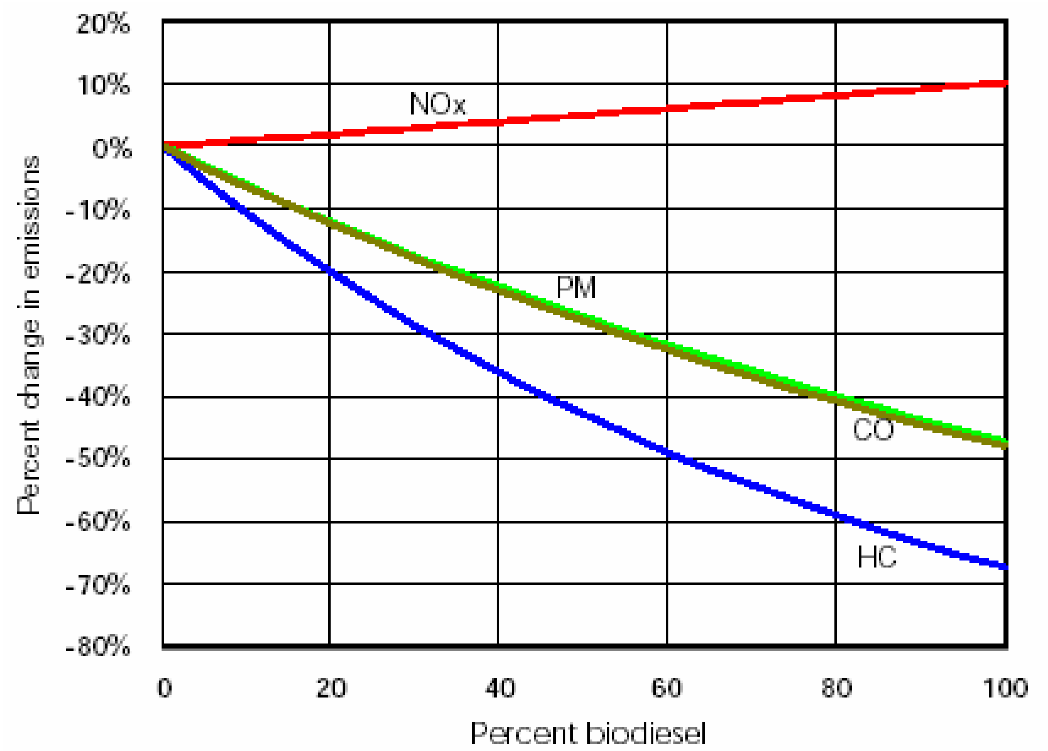
[29] APAT data- base.

[30] However, according to other studies, NO_x slightly decreases with the use of biodiesel (Kalligeros et al., 2003; Puhan et al., 2005). This is due to the operating conditions.

[31] However, according to Altin et al., 2001, PM are higher in sunflower methylesters than in diesel

[32] http://www.cti2000.it/biodiesel.htm.

Figure 6.4 Change in the most important air emissions due to biodiesel use in heavy-duty engines



Source: EPA, 2002

These values were used in this analysis, because they are the outcome of a rigorous and reliable study. Since the trends shown in Fig. 6.2 are approximately linear, it can be assumed that with a 5.75% blend, ***the reduction in particulate matter would be around 3%*** (see Table 6.13) ***which would not make a big difference***. The increase of NO_x would be negligible and was therefore ignored.

Table 6.13 Criterion N. 3 URBAN POLLUTION

Name	Unit	1) Diesel	2) Biodiesel- imported	3) Biodiesel- domestic
Urban pollution	% PM	0	-3	-3

More on urban pollution can be found in Chapter 7, which is entirely dedicated to this issue.

6.3.4 Food imports

In Section 6.3.1 it was shown that if Italy decided to meet the Directive's target with domestically cultivated oil seeds, 3.7 million hectares (12% of its territory) would have to be cultivated. In Chapter 5 it was explained that the amount of marginal, abandoned and set-aside land that is available in Italy would not be enough to reach this objective. Therefore, some agricultural production would be substituted. It was said that here the very optimistic hypotheses were made that 0.5 million hectares of abandoned and set-aside land might be used and that the cake meal obtained as a by-product of the biodiesel production might substitute part of the fodder cultivation. Even under such optimistic assumptions, 3.2 million hectares would have to be used for energy farming, which are now cultivated with food products for humans or cattle.

The consequence would be a big increase in Italian food imports. As explained in Chapter 5, I assumed that oil seeds would occupy 1.6 million hectares of land currently cultivated with wheat. Assuming a wheat yield of 2.8 tonnes/ha[33], the result is that Italy would import **5.9 million tonnes** of wheat, which is a very large amount.

In order to have an idea, it might be useful to remember that net imports and consumption of wheat in 2004 were respectively 6.27 and 14.91 million tonnes (Istat data-base). ***The total increase of net imports would correspond to 40% of wheat consumption. Cultivating the oil seeds in Italy would therefore mean almost to double wheat imports***.

As regards fodder, I assumed that 1.6 million hectares temporal fodder cultivation would be replaced by oil seeds (see Chapter 5). The average temporal fodder yield is 29.6 tonnes/ha[34], which means that fodder production would decrease by 46.7 million tonnes, which corresponds to approximately 7.8 million tonnes of processed feedstuff. Since I assumed that the 4 million tonnes of cake meal that are obtained as a by-product of the oil pressing would be used as cattle feed, the total processed feedstuff imports would increase by around **3.8 million tonnes**, which would constitute ***26% of the total consumption*** (see Table 6.10).

The criterion "FOOD NET IMPORTS" was calculated summing up the wheat and the processed feedstuff imports, as shown in Table 6.14.

Table 6.14 Criterion N.4 FOOD NET IMPORTS: wheat and processed feedstuff

Name	Unit	1)Diesel	2) Biodiesel- imported	3) Biodiesel- domestic
Food imports: wheat and processed feedstuff	Million tonnes	0	-4	9.7

It could be argued that if oil seeds were imported, the cake meal might be used for cattle feeding, with the consequences that land presently used for fodder might be used for other crops, thus reducing the food imports. However, I ignored this possibility because the possible chain of substitution is too uncertain.

6.3.4 Energy dependency

Biofuels might reduce the Italian energy dependency. However, as explained in Section 6.3.2, the reduction can be calculated in different ways, according to the scale. Without taking into account either the transport of oil seeds outside the

[33] Istat data-base, http://www.istat.it/agricoltura/datiagri/coltivazioni/ital2004.htm.
[34] Ibid.

Italian borders nor the energy used for cultivating the crops that would be imported from outside, the reduction appears bigger. Calculated in this way, reaching the target of the Directive would allow Italy to save 0.4 million toe for biodiesel produced with imported oil seeds and 1.3 million toe if the oil seeds were cultivated in Italy (see Section 6.3.2).

The energy saved can be calculated by summing these amounts to the 2.8 million toe diesel that would be used if the target of the Directive were not met. Since 94% of the oil used in Italy comes from foreign countries[35], it can be concluded that the energy dependency would increase by respectively **3** and **3.9 million toe** if the oil seeds were imported or cultivated in Italy (see Table 6.15).

Table 6.15 Criterion N.5 ENERGY DEPENDENCY

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Energy dependency	Million toe	0	3.0	3.9

Considering that the total Italian net imports (imports - exports) are 155 million toe[36], it can be stated that if the target of the Directive were reached, ***the reduction of energy dependency would be only 2%.***

Once again it is worthwhile to remember that as applies to the criterion "CO_2 SAVINGS", the option of cultivating the oil seeds in Italy appears to be the best one because neither the energy cost of producing the wheat and the fodder that Italy would have to import, nor the energy use for transport outside the Italian borders are taken into account. This kind of "accounting trick" is not really correct from a life cycle point of view, but it does represent the point of view of the Italian administration.

Also, it can be noted that if the oil seeds were imported, Italy would remain somehow dependent on the international trade for most of its energy supply. However, this kind of dependence would create fewer problems than the one on the oil exporting countries. In fact, oil seeds can be imported from many countries, whereas most oil reserves are concentrated in few and in some cases politically unstable countries. Also, the price of oil seeds does not fluctuate so much as the oil price, which has increased steadily in the last years.

6.3.6 Fertilizer requirement

Cultivating the oil seeds required by the Directive would mean an increase in fertilizers and pesticides. As explained in Chapter 5, I assumed that 0.5 million hectares of abandoned, marginal and set-aside land would be cultivated, which implies that more fertilizers and pesticides would be used in Italy.

Obviously, it is impossible to calculate exactly the amount of fertilizers and pesticides that would be needed on such a large scale, because it would depend on

[35] Eurostat data-base, year 2003.
[36] Ibid.

local conditions such as water availability, soil characteristics, crop rotation, etc. Also, the use of marginal and poorer lands would imply an increased need for fertilizers in order to compensate for the scarce fertility.

The most important chemical elements present in fertilizers are Nitrogen (N), Phosphorus (P) and Potassium (K). By convention, the latter two are measured in terms of Phosphoric Oxide (P_2O_5) and Potassium Oxide (K_2O). Table 6.16 presents data obtained in various field observations.

Table 6.16 Fertilizer requirement, kg/ha per year (various sources)

Source	Product	N	P2O5	K2O
Venturi and Venturi (2003)	Rapeseed	121	121	100
	Sunflower	121	121	100
Baldoni and Giardini (1982)	Rapeseed	135	80	70
	Sunflower	100-150	40-60	190-300
	Wheat	100-130	70-100	100-150
Grimaldi et al. (1983)	Wheat	30-200	60-80	50-100
Biondi et al. (1989)	Wheat	106	161	3
	Sunflower	107	68	155
	Maize for silage	195	226	95
	Perennial ryegrass	26.6	69	30
	Alfalfa	94	214	0
	Annual grasses	164	234	51

These figures show a great variability. Since here a hypothesis of large scale biodiesel production was to be evaluated, it seemed more correct to take the national averages (see Table 6.17) instead of the data taken in specific field experiments. It can be noted that, as one might expect, the FAO data are remarkably lower than the ones shown in Table 6.16, which mostly refer to experimental fields.

Table 6.17 Italian average fertilizer requirement, kg/ha per year

	N	P2O5	K2O
Sunflower	45	50	40
Rapeseed	80	40	40
Wheat	90	70	40
Fodder plants[37]	38	14	9

Source: FAO data-base

I considered only fertilizers and not pesticides (i.e. weed killers, anticryptogamics and insecticides). The reason for that is that the former are easier to calculate because they are normally measured in terms of weight of their principal components (N, P_2O_5 and K_2O). On the contrary, pesticides include a wide variety of different substances, which cannot be simply summed up. Also, the amount of pesticides depends very much on the local characteristics of the territory. Therefore data obtained for single crops cannot be extrapolated to a large scale. I assumed a proportionality between the use of fertilizers and of pesticides. In any case, for completeness Table 6.18 shows some data on the use of pesticides in oil seeds, wheat and fodder cultivation.

[37] Assumed as 50% silage maize/50% grassland

Table 6.18 Pesticides

Source	Product	Pesticides		Weed killers		Anticryptogamic		Insecticides	
		Kg/ha	MJ/ha	kg/ha	MJ/ha	kg/ha	MJ/ha	kg/ha	MJ/ha
Venturi and Venturi, 2003	Sunflower	-	1,800	-	-	-	-	-	-
	Rapeseed	-	900	-	-	-	-	-	-
Biondi et al., 1989	Wheat			27.5	2505	0.4	14.2	-	-
	Sunflower	8	8	1	79			8	480
	Ensiling maize	-	-	5	635	-	-	-	-
Ribaudo, 1982	Wheat			2.5		1.2		83	
	Rapeseed	-	-					1	
	Ensiling maize			3				-	
	Alfalfa					30		-	

In order to calculate the variation in the use of fertilizers, we must take into account the variation that would occur if the wheat and fodder were replaced by the oil seeds. Results are shown in Table 6.19.

Table 6.19 Variation in fertilizer requirement

	Land requirement (million hectares)	**N (thousand tonnes)**	**P_2O_5 (thousand tonnes)**	**K_2O (thousand tonnes)**	**Total (thousand tonnes)**
1) Sunflower	0.7	31	34	27	92
2) Rapeseed	3.8	303	151	151	606
3) Wheat	1.6	142	111	63	316
4) Fodder plants	1.6	59	21	13	94
5) Fodder plans substituted with the cake meal	0.8	30	11	7	48
Total biodiesel-domestic (1 + 2 - 3 - 4)		**132**	**54**	**102**	**288**
Total biodiesel-imported (- 5)		**-30**	**-11**	**-7**	**-48**
Total Italy (1996)[38]		896	562	414	1873

It can be noted that if oil seeds were cultivated in Italy ***N, P_2O_5 and K_2O would increase by respectively 15%, 10% and 25%***. The increase can be explained mainly with the fact that new land would be cultivated which is presently abandoned or under the European set-aside framework. If the oil seeds were imported, the fertilizer requirement would decrease because of the replacement of fodder with cake meal. Calculated as such, the ***N requirement would decrease by 3%, and those of P_2O_5 and K_2O by 2%***.

However, adding the fertilizer weights together is only a first approximation, because the impact of different kinds of fertilizers can vary very much. Since the most worrying effect of the use of fertilizers is eutrophication (but not the only

[38] FAO data-base.

one, see Section 6.2.6), I decided to use the Eutrophication Potential (EP) factors which are normally used in Life Cycle Assessment[39]. In this way, the overall potential contribution of the different fertilizers to eutrophication was computed by multiplying the weight of each fertilizer type by an appropriate factor that compares the specific potential eutrophication impact of that type of fertilizer to that of a reference chemical known to cause eutrophication, i.e. orthophosphate (PO_4^{3-}). These factors are 0.42 kg/kg(PO_4^{3-}) for N, 1.34 kg/kg(PO_4^{3-}) for P_2O_5, and 0 kg/kg(PO_4^{3-}) for K_2O. The results are reported in Table 6.20.

Table 6.20 Variation in fertilizer requirement expressed as eutrophication potential

	N (thousand tonnes PO_4^{3-})	P2O5 (thousand tonnes PO_4^{3-})	K2O (thousand tonnes PO_4^{3-})	Total (thousand tonnes PO_4^{3-})
Total variation biodiesel-domestic	55	72	0	127
Total variation biodiesel-imported	-13	-15	0	-27
Total Italy (1996)	376	753	0	1,130

If oil seeds were imported, there would be a savings on a national scale because of the substitution of fodder crops with cake meal. Calculated in this way, **if oil seeds were cultivated in Italy the variation would be only 11% and if they were imported -2%.** The reason is that potassium does not cause eutrophication. Also the eutrophication potential is higher for phosphoric oxide than for nitrogen, whereas the increase in terms of weight is higher for the latter.

The criterion scores are presented in Table 6.21. No need to say that if biodiesel were not produced at all there would not be any change in the use of fertilizers on a national scale.

Table 6.21 Criterion N.6 FERTILIZER REQUIREMENT-national scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Fertilizer requirement	Thousand tonnes $PO_4^{3-}{}_{eq}$	0	-27	127

However, it must be underlined again that if calculated in this way, importing the oil seeds appears to be the best option because the use of fertilizers outside Italy is not taken into account. In other words, the disadvantages of producing biodiesel in terms of increased use of fertilizers would be in part externalized outside Italy.

If one takes a large-scale approach and attribute the use of fertilizers to the final consumers (as it is normally done in Life Cycle Analyses), the fertilizers needed to produce the oil seeds in foreign countries should be taken into account. Also, if the oil seeds were produced in Italy, the fertilizers used for the replaced wheat and fodder plants should not be subtracted, because they would be needed anyway in foreign countries for the crops that Italy would import.

[39] M. Gorree et al., 1999

Table 6.22 shows the fertilizer requirement with a large scale approach. It was calculated assuming a similar average requirement of fertilizers in Eastern Europe as in Italy and subtracting from the fertilizer requirement of the oil seeds that of the 0.8 million hectares of fodder crops that would be replaced by the cake meal. Obviously, if calculated in this way there would be no difference between producing the oil seeds in Italy and importing them. The results are shown in Table 6.22.

Table 6.22 Fertilizer requirement on a large scale

	N		P2O5		K2O		Total	
	Thousand tonnes	**Thousand tonnes PO_4^{3-}**	**Thousand tonnes**	**thousand tonnes PO_4^{3-}**	**Thousand tonnes**	**thousand tonnes PO_4^{3-}**	**Thousand tonnes**	**thousand tonnes PO_4^{3-}**
Total variation	303	127	175	234	172	0	650	362
Total Italy (1996)	896	376	562	753	414	0	1,873	1,130
Increase over total	34%	34%	31%	31%	42%	0%	35%	32%

With a large scale approach, the increase in the use of fertilizers would represent approximately **35% in terms of weight and 32% in terms of eutrophication potential of the total Italian use**. The criterion scores are shown in Table 6.23.

Table 6.23 Criterion N.6 FERTILIZER REQUIREMENT-large scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Fertilizer requirement	Thousand tonnes $PO_4^{3-}{}_{eq}$	0	362	362

6.3.7 Water requirement

It is difficult to estimate how much irrigation water the different crops would need because they would be cultivated in large areas with very different soil and weather characteristics. However, a rough estimate could be made using average values. In Table 6.24 the water requirement of some irrigated fodder plants, calculated with the FAO software CROPWAT[40] are shown. The software calculates the irrigation water requirement of different crops, taking into account the plant characteristics and the rainfall.

Table 6.24 Water requirement (m^3/ha per year)

Source	Crop	Water requirement
FAO CROPWAT software (calculated for planting in Tuscany, which is taken as an Italian average)	Winter wheat	2,340
	Fodder (=50% maize + 50% grassland)	2,100
	Sunflower	2,900
	Rapeseed [41]	2,900

[40] http//www.fao.org/AG/agl/aglw/cropwat.stm.
[41] Assumed the same as sunflower, after Allen et al., 1998.

Taking these data, the variation in water use was calculated subtracting the reduction due to the substitution of wheat and fodder from the oil seed water requirement (third column of Table 6.25).

However, these figures represent the optimal irrigation, whereas in many cases oil seeds are not irrigated[42], leading to a lower yield but also lower water consumption[43]. According to the fifth Italian agriculture census[44] (Istat, 2005), only 7% of the land cultivated with sunflower in Italy is irrigated (2000 data). Applying this percentage to the above mentioned figures (and assuming that the same percentage holds for rapeseed), we obtain the figures shown in the fourth column of Table 6.25.

Table 6.25 Water requirement

Culture	Land requirement (Mha)	Teoretical water requirement (million m^3/year)	Real water use (million m^3/year)
1) Sunflower	0.7	1,982	134
2) Rapeseed	3.8	10.982	741
3) Wheat	1.6	3,700	250
4) Fodder plants	1.6	3,313	224
5) Fodder plans replaced by cake meal	0.8	1,692	114
Total biodiesel-domestic (1 + 2 - 3 - 4)		5,951	402
Total biodiesel-imported (- 5)		-1,692	-114
Total Italy (1996) [45]		56,193	

If oil seeds were cultivated in Italy, the irrigation requirement would increase by around 402 million m^3/year, which corresponds to around ***0.7% of the total Italian water use in agriculture***. If oil seeds were imported, about 114 million m^3/year would be saved, because of the replacement of some fodder cultivation with the cake meal, The criterion score is shown in Table 6.26.

Table 6.26 Criterion N. 7 WATER REQUIREMENT-national scale

Name	Unit	1) Diesel	2) Biodiesel- imported	3) Biodiesel- domestic
Water requirement	Million m^3	0	-114	402

Once again it is useful to underline that if one takes into account the water used in foreign countries to produce the oil seeds, the wheat and the fodder that Italy

[42] In fact, the low irrigation requirement with respect to other crops is one of the advantages of oil seeds.
[43] Not irrigating the oil seeds or irrigating them only a little decreases the yield with respect to the optimal one. I took this issue into account by taking the average Italian oil seed yield.
[44] http://www.census.istat.it/index_agricoltura.htm

[45] The total water use was calculated by multiplying the Water Exploitation Index by the total water availability (European Environmental Agency, http//dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=c13).

would have to import to reach the target of the Directive, the increase in water requirement would be higher. In fact, from a large scale approach, the third and fourth lines of Table 6.25 should not be subtracted from the first two (but the fifth one - replaced fodder - should be subtracted). As for the criterion “FERTILIZER REQUIREMENT”, the criterion score would be the same if oil seeds were imported or cultivated in Italy (assuming a similar irrigation in Italy and in Eastern Europe), because on a large scale it is not important where the impacts take place.

The result is shown in Table 6.27.

Table 6.27 Criterion N. 7 WATER REQUIREMENT-large scale

Name	Unit	1) Diesel	2) Biodiesel- imported	3) Biodiesel- domestic
Water requirement	Million m^3	0	761	761

This amount corresponds *to **1.4% of the actual water use for agriculture in Italy.***

6.3.8 Energy taxes

As shown in Table 6.28, in the last ten years the excise tax on diesel was around 0.4 euro per litre (it amounted to half of the total final price).

Table 6.28 Automotive diesel price and taxes in Italy (€/L)

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Price excluding taxes	0.203	0.235	0.238	0.206	0.232	0.36	0.339	0.31	0.328	0.379
Excise Tax	0.380	0.386	0.386	0.386	0.403	0.383	0.385	0.403	0.403	0.403
Value Added Tax/Other (%)	19	19	19.25	20	20	20	20	20	20	20
Value Added Tax/ Other (amount)	0.111	0.118	0.12	0.118	0.127	0.149	0.145	0.143	0.146	0.156
Total Tax	0.49	0.504	0.506	0.504	0.53	0.531	0.53	0.546	0.549	0.559
Total price	0.693	0.739	0.743	0.71	0.762	0.892	0.869	0.856	0.877	0.938

Source: IEA, 2004

As explained in Chapter 5, I assumed that in order to make biodiesel competitive with fossil fuels, the entire amount of biodiesel produced would be exempted from excise taxes. The negative effect of this policy would be a reduction of the Italian revenues. The reduction can be calculated by multiplying the excise tax by the total amount of biodiesel needed for meeting the European requirement (2.6 million toe, that is, around 3,100 ML). The result is shown in Table 6.29.

Table 6.29 Criterion N. 8 ENERGY TAXES

Name	Unit	1) Diesel	2) Biodiesel- imported	3) Biodiesel- domestic
Energy taxes	Million €	1,239	0	0

The issue might be taken into account by the government when deciding its biofuels strategy. The energy taxes that the Italian State would obtain from 2.6

million tonnes biodiesel (5.75% of the total energy demand for transport in 2010) would constitute ***4.3% of the total energy revenues in 2005 and 0.3% of the total revenues.***

6.3.9 Rural development

It is very difficult to quantify how much the agricultural sector would benefit from a large scale biofuel production. The reason is that it would depend on different factors that are hard to forecast. For example, the improvement of rural conditions would depend on the European subsidies that would be granted to energy farming. If the European Commission decided to really stake on biofuels, it might increase the incentives dedicated to oil seed cultivations for energy purposes (at the moment these amount to 45 €/ha).

Also, if it was decided to meet the Directive's target, most of the required oil seeds would replace food production (see Chapter 5). The difference in the added value obtained with the oil seeds and with the wheat or fodder that would be substituted would depend on the prices of these products, as well as on the different requirement of energy, fertilizers and pesticides, machinery and work.

However, some general considerations can be made. First of all, I assumed that if the biofuels demand were high enough (e.g., if they were tax-free or if the oil price increased so much as to make them competitive), some marginal and abandoned land would be cultivated with oil seeds. Therefore, the owners of the marginal, abandoned and set-aside land, would obtain some additional income.

Also, it can be imagined that if the biodiesel demand increased so much (from the present 0.2 to the 3.2 million tonnes required by the Directive), the price might also increase. Therefore, it is reasonable to assume that it would soon be more profitable to produce oil seeds than wheat or fodder.

In conclusion, it may be expected that a large-scale production of biofuels would bring income to the Italian rural sector. For this reason Coldiretti and Confagricoltura, the two main Italian farmers associations, are strongly in favour of biodiesel. For example, Coldiretti estimated that by cultivating biofuels in 20 - 30% of the Italian agricultural land around 300,000 jobs might be created[46]. This number is difficult to verify, but it seems rather high. This result (0.08 persons per ha) is four times the one found by the IFO-Munich (cited in Körbiz, 1999), which estimates around 0.02 persons per ha. The figure estimated by Coldiretti is 12% of the present employment in agriculture (2.4 million jobs, in average approximately one person per five cultivated hectares[47]), which is probably too much. In fact, as discussed in Chapter 5, in Italy oil seeds would mostly substitute existing crops, so the creation of jobs would be for the most part compensated for by the loss of jobs in other cultivations.

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[46] Coldiretti News, Energia: UE; Coldiretti, da biocarburanti trecentomila nuovi occupati, N. 78 - 9 febbraio 2006, http://www.coldiretti.it/docindex/cncd/informazioni/078_06.htm
[47] Istat data-base.

A rough estimate can be done by multiplying the average job per hectare by the amount of land that would be added to the production (marginal, abandoned, set-aside land), which under the assumptions made would be 0.5 million hectares. The result is around 85,000 jobs, which is 0.2% of the total employed people and 3.5% of the people employed in agriculture. The labour requirement for the industrial processing seems to be so low that it can be ignored. Van Dyne (1996) calculates 0.004 persons per ha for (temporary) construction jobs and (permanent) plant operations, the latter being only one tenth of the former.

However, these figures are too uncertain to be taken as a criterion score. Since it is very difficult to forecast how many jobs and how much income the Directive's target would provide to Italian agricultural sector, I used qualitative indicators (Table 6.30). In fact, when the uncertainty is so high, it is more correct not to cover it up under many not well-grounded assumptions.

Obviously, if either the oil seeds needed to meet the Directive's requirement were bought from foreign countries, or the target was not reached, there would not be an improvement in Italian rural development.

Table 6.30 Criterion N. 9 RURAL DEVELOPMENT-national scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Rural development	Qualitative	none	none	good

However, if one takes a large-scale perspective the rural development would be improved (and the criterion score would be "good") also if oil seeds were imported, even though it would take place outside Italy, as shown in Table 6.31

Table 6.31 Criterion N.9 RURAL DEVELOPMENT-large scale

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Rural development	Qualitative	none	good	good

In this sense, maybe ***the most important contribution of biofuels might be to support the rural sector*** in a context where food production is becoming increasingly less competitive for Europe. The combination of incentives to energy farming, de-taxation and biofuel obligations might bring an opportunity to the rural sector. In Chapter 9 this point is developed further.

6.3.10 Fuel price

The most important issue for car drivers is fuel price. It is very difficult to forecast what the biodiesel price would be if a large-scale biodiesel industry were introduced in Italy. At this moment, biodiesel cannot be bought at the pump in Italy, and it is only sold in bulk. In fact, even though Italy is the third European biodiesel manufacturer (17% of the total European production[48]), the amount of biodiesel that is generated is still small and it is mainly used for heating purposes (95%[49]) and in pilot experiments with public fleets.

[48]European Biodiesel Board, http://www.ebb-eu.org.
[49] Comitato Termotecnico Italiano, http://cti2000.it/virt/cti2000/Headbio.htm.

For this reason, I only used data on wholesale prices. Obviously, this implies an approximation of the prices by defect, because retail prices are always higher than wholesale prices. However, the market is still small, and it can be imagined that if a large-scale biofuel production were established, the prices would decrease.

The actual biodiesel wholesale price depends on the purchased quantity and the producing enterprise. For example, the price for 1,000 litres of Novaols' Diesel Bi® is 0.920 €/L plus VAT (20%)[50], i.e. 1.104 €/L. Table 6.32 shows prices for larger amounts. In order to compare these quantities with the price of diesel, I used the wholesale diesel price, which is lower than the retail price (for example, the average price at the pump on 23rd January 2006 was 1.173 €/l[51]).

Table 6.32 Biodiesel wholesale prices

Quantities	Price (€/L), incl. VAT
Biodiesel, between 29-11-2004 and 05-12-2004, 2,001-5,000 litres	1.027
Biodiesel between 29-11-2004 and 05-12-2004, 5,001-10,000 litres	1.017
Biodiesel between 29-11-2004 and 05-12-2004, 10,001-20,000 litres	1.009
Diesel between 29-11-2004 and 05-12-2004, 2,001-5,000 litres	1.015
Diesel, between 09-01-2006 and 15-01-2006, 2,001-5,000 litres	1.114

Source: Martini srl, http://www.combustibile.it

It should be noticed that on the one side, in the last years the oil products prices rose very much and experts forecast further relevant increases. On the other side, it is probable that biodiesel price will be more stable in the future. Therefore, I found it more correct to compare the 2004 biodiesel price (the last available data) with the 2006 diesel price.

Calculated in this way, the difference between diesel and biodiesel is around 10 cents. This is consistent with the prices in Germany, by far the most important European biodiesel producer (54% of the European production). German prices might represent a good approximation of the possible future Italian prices because German production is on a relatively large scale (about one million tonnes), even though smaller than that which would be required in Italy to meet the European Directive's target. Also, in Germany, biodiesel is totally tax-exempted without limits on production. As explained in Chapter 5 we made the hypothesis that in order to launch the biodiesel sector, the Italian government would take the same resolution. In Germany, the average biodiesel price is 1.013 €/L, whereas the diesel price is 1.104[52]. The difference is therefore around 10 cents, which is very similar to the figure I calculated.

[50] Personal communication during a telephonic interview carried out on 6th February 2006 to an employer of BERTELLI WALTER&ROLANDO CARBURANTI S.r.l. (http://www.bertellicarburanti.it), which sells Novaol's biodiesel (http://www.novaol.it/retedivendita.asp?sez=AAEAAA). Novaol is the most important Italian biodiesel producer.

[51] Source: Martini srl, http://www.combustibile.it.

[52] Source: UFOP, http://www.ufop.de/1299.php. VAT is included (12.5 cents/litre). The figures refers to January 2006

As explained before, I assumed that biodiesel would be mixed at 5.75% (the Directive target). Therefore, ***the difference would be approximately 0.005 € per litre*** (see Table 6.33). For example, for a 50 L tank the savings would be 0.25 €. ***Considering a typical user mileage of 15,000 km/yr and an average fuel consumption of 10 L/100km, the yearly savings would amount to 15,000 km/yr x 0.1 L/km x 0.005 €/L = 7.5 €/yr (i.e. 0.625 €/month).***

Table 6.33 Criterion N.9 FUEL PRICE

Name	Unit	1) Diesel	2) Biodiesel-imported	3) Biodiesel-domestic
Fuel price	€/L	1.114	1.109	1.109

Clearly, the difference between the diesel and biodiesel prices is at the moment very small. Nevertheless, if the oil price rose very much, biodiesel might be increasingly more competitive with oil products. In the future, the savings associated with biodiesel might be a relevant issue for the car driver.

Finally, it should not be forgotten that biodiesel is slightly cheaper than diesel (and in the future it may become considerably cheaper) because it is indirectly subsidized by the Italian citizens. In fact, whereas approximately half of the diesel price is determined by taxes (Table 6.28), biodiesel is tax-free.

6.4 Other issues to be considered

The kind of analysis I performed was rough in nature, because it dealt with a complex system, characterized by a high degree of uncertainty. A few somewhat arbitrary assumptions had to be made, which inevitably influenced the final result.

On the one side, the disadvantage of any evaluation exercise that analyzes a wide variety of impacts is that it does not go into the details thoroughly. As a consequence, it may contain some minor errors and even mistakes, which the experts in the different fields may discuss and eventually correct. Some assumptions and calculations might be further analyzed and improved.

On the other side, many times technical studies that are focused on only one aspect of the issue (such as for example biofuel exact emissions in heavy duty engines or oil seed yield in some experimental sites) might lose sight of the larger scale. For example, biofuels allow to slightly reduce PM emissions, but is it worthwhile to invest public resources in this sector if the consequences from other points of view and at a larger scale are taken into account, such as for example the high land requirement?

However, when taking a political decision that has an impact on various sectors of society, information on different aspects is needed. A Multi-Criteria Evaluation approach can offer a broad picture of the various impacts of biofuels policy, by gathering and putting together the results of various technical studies.

As already mentioned in Chapter 3, this analysis was limited by time and financial constraints, and it could not deal in depth with all the numerous factors that are involved with biodiesel policy. There are therefore some issues that might be further explored. In the rest of this section some of them are mentioned.

6.4.1 Ethanol

The entire analysis that was here presented was performed only for biodiesel. As already explained, the reason is that biodiesel is much more established in Italy than ethanol. However, in July 2005, a new big society named Alcolplus was founded[53], which will produce ethanol in Italy. Alcolplus was created through a joint venture of two Italian enterprises, Alc. Este. S.p.A. (40%) and Caviro Sca (60%). The new society has a capacity of around 120 million litres of alcohol. One of its main objectives is to produce a large amount of ethanol. According to its estimates, it could produce around 42 million litres (around 21 thousand toe, 50% of the de-taxed annual amount established by the 2004 Financial Law).

Another analysis, similar to the one presented here, could be carried out for ethanol, in order to show the possible impacts of a large scale production under different criteria. However, it can be safely anticipated that the conclusions would not change very much when dealing with ethanol instead of biodiesel, because the same issues (e.g. great land requirement versus small energy savings) would be put on the table.

6.4.2 Emissions and wastes

As any other industry, the biofuel chain produces emissions and wastes in all phases. When oil seeds are cultivated, the use of fertilizers and pesticides release pollutant emissions to water and air. The industrial phase generates potentially harmful residues.

Further research is needed to estimate the amount of residues caused by biodiesel production and their impact. Also, it should be analyzed how to process them and how much it would cost. Including in the calculations the energy requirement (and the CO_2 emitted) in the disposal phase might reduce the output/input rate. The same can be said about the economic costs of disposal, which might reduce economic viability.

Another issue to be considered is that, as explained in Chapter 6.3.2, the by-products can turn into wastes if they do not find an adequate market outlet. In this case, their disposal should be also taken into account.

6.4.3 Job creation

One of the main arguments of the biofuels promoters is that biofuels can create jobs (see for example Domac et al. 2005). In order to calculate exactly to what extent a biofuel policy would affect employment, the jobs employed in the biofuels chain should be compared to the employment created in the cereal and

[53] http://www.caviro.it/news/default.asp?id=53.

fodder chain. A careful analysis should be carried out in order to verify the availability and productivity of work that could be employed in the biofuels sector.

However, as noted by Giampietro and Ulgiati (2005), not all jobs are the same. Nowadays, the share of work force employed in agriculture (calculated in terms of time used) is below 5% in all industrialized countries. In Italy, 5% of population is employed in agriculture, 32% in the industry and 64% in the service sector (Istat data-base).

In this sense, until a certain point creating employment in the rural sector might be one of the positive effects of the shift towards a biofuel-based transport sector. However, after a certain point it might become a negative effect: possibly most European population would not be willing to move to the countryside and work as farmers.

Also, Giampietro and Ulgiati (2005) underline that the use of fossil fuels allowed humanity to dramatically increase the energy throughput per hour of work. In this way, an enormous amount of energy could be provided by a small share of population to the rest of society. This process fuelled the industrialization process and allowed a continuous economic growth and a large diversification of economic activities.

For this reason, a work-intensive energy sector which absorbs a large part of the population is not conceivable in modern societies. Shifting to biofuels might imply a wide structural change in the work distribution. The result might be a massive increase of people dedicated to agriculture at the expense of the industrial and service sectors and an abrupt decrease of the available energy and commodities.

6.5 Preliminary conclusions

Table 6.34 and Table 6.35 show the scores of the criteria on the national and large scales. The last columns express the variation with respect to the national average. The lines with a grey background contain the criteria that are in favour of biodiesel.

Table 6.34 IMPACT MATRIX-national scale

N	Criterion	Unit	Diesel	Biodiesel imported	Biodiesel-domestic	Desired direction	Comparison	%
1	**Land requirement**	Million hectares	0	-0.8	3.7	↓	Total agricultural land: 14 Mha	-7/ 26
2	**CO_2 savings**	Million tonnes CO_{2eq}	0	9.0	11.9	↑	Total: 570 Mtonnes	1.6/2.1
3	**Urban pollution**	% PM		-3	-3	↓		
4	**Food imports: wheat and processed feedstuff**	Million tonnes	0	-4	Wheat: 5.9; processed feedstuff: 3.8	↓	Wheat consumption: 14.9; Prepared feedstuff consumption:14.9	-13/ 33
5	**Energy dependency**	Million tonnes of oil eq.	0	3.0	3.8	↑	Net energy import: 155 Mtoe	1.9/ 2.5
6	**Fertilizer requirement**	Thousand tonnes $PO_4^{3-}{}_{eq}$	0	-27	127	↓	Total: 1,130 thousand tonnes $PO_4^{3-}{}_{eq}$	-2/ 11
7	**Water requirement**	Million m^3 per year	0	-114	402	↓	Total water use: 56,193 Mm^3	-0.2/ 0.7
8	**Energy taxes**	Million €	1,239	0	0	↑	Energy taxes: 28,694 M€	4
9	**Rural development**	Qual.	None	None	Good	↑		
10	**Fuel price**	€/L	1.114	1.109	1.109	↓		

Table 6.35 IMPACT MATRIX-large scale

N	Criterion	Unit	Diesel	Biodiesel imported	Biodiesel-domestic	Desired direction	Comparison	%
1	**Land requirement**	Million hectares	0	3.7	3.7	↓	Total agricultural land: 14 Mha	26/ 26
2	**CO_2 savings**	Million tonnes CO_{2eq}	0	4.2	3.8	↑	Total: 570 Mtonnes	0.7/ 0.7
3	**Urban pollution**	% PM	0	-3	-3	↓		
4	**Food imports: wheat and processed feedstuff**	Million tonnes	0	-4	Wheat: 5.9; processed feedstuff: 3.8	↓	Wheat consumption: 14.9; Prepared feedstuff consumption:14.9	-13/ 33
5	**Energy dependency**	Million tonnes of oil eq.	0	3.0	3.8	↑	Net energy import: 155 Mtoe	1.9/ 2.5
6	**Fertilizer requirement**	Thousand tonnes $PO_4^{3-}{}_{eq}$	0	362	362	↓	Total: 1,130 thousand tonnes $PO_4^{3-}{}_{eq}$	32/ 32
7	**Water requirement**	Million m^3 per year	0	761	761	↓	Total water use: 56,193 Mm^3	1.4/ 1.4
8	**Energy taxes**	Million €	1,239	0	0	↑	Energy taxes: 28,694 M€	4
9	**Rural development**	Qual.	None	None	Good	↑		
10	**Fuel price**	€/L	1.114	1.109	1.109	↓		

Biofuels are to be preferred according to five criteria out of ten. However, the difference among the alternatives is much higher in some aspects than in others. In the following paragraphs all the single criteria are discussed, beginning with those favouring biodiesel.

The least important criterion is the final price of biodiesel. Biodiesel is at the moment slightly cheaper, but the difference is so small as to be negligible (see Section 6.3.10). Therefore, unless crucial factors (e.g. oil price, fiscal rules, incentive framework) change considerably, ***biofuels should not be favoured if the final objective is to reduce the expense for car fuels***. Car drivers will be neutral with respect of fuel choice, if their main interest is fuel price. Also, it was already shown that the price of biodiesel is approximately the same as the one of diesel only because the latter is made up by one half of energy taxes, whereas biodiesel is not burdened with taxes.

As all biodiesel promoters claim, a large scale biodiesel production would allow Italy to reduce its greenhouse emissions, and, as a consequence of that, its energy dependency on the oil-exporting countries. However, the advantage in this sense would be very small (see Section 6.3.2 and 6.3.5). Even under the most favourable assumptions, the reduction would only be around 2% of the 2003 total Italian greenhouse emissions. In fact, biofuels would replace only 5.75% of the fossil fuels used in the transport sector (1.3% of the total energy use). Also, biofuel production would require the use of fossil fuels, both in the agricultural and in the processing phases. Moreover, energy would be needed for transporting the oil seeds if they were imported, or, if they were cultivated in Italy, for transporting the food products that they would substitute.

If one takes a large scale approach, the reduction of greenhouse emissions would be even more modest (0.7%). The reason is that one should consider all the energy inputs in the agricultural phase (in Italy and outside), as well as the use of energy for the international transport of crops. In conclusion, it can be safely claimed that ***reaching the target of the Directive would be only a small contribution to the solution of the energy problem***.

An advantage of biodiesel is that it contributes to reducing particulate matter (PM) in cities, which is one of the most worrying urban pollutants (see Section 6.3.3). At a 5.75% blend, a switch to biodiesel would allow Italy to reduce its particulate matter by 3%. However, ***if the objective is to reduce urban pollution, other fuels currently available on the market are much less polluting than diesel***. Chapter 7 presents a comparison among different fuels from the point of view of urban pollution.

It can be therefore affirmed that ***the only valid argument in favour of biofuels is rural development*** (see Section 6.3.9). If the oil seeds were cultivated in Italy and adequately supported through biodiesel de-taxation, agricultural subsidies and biodiesel obligations, they might constitute a chance for the agricultural sector.

This possibility should be carefully taken into account, especially because of the crisis the European agriculture is going through. As already explained before, European agricultural products are diminishingly competitive with respect to those coming from other countries. This situation will worsen when agricultural subsidies are eliminated, as agreed during the last WTO meeting. Market liberalization and globalization is progressively eroding the added value of European agriculture, which is becoming a less and less profitable activity. However, the agricultural sector plays a crucial role in a country, because it protects landscape and agrarian biodiversity, and prevents rural depopulation, avoiding in this way the loss of the capital stock (housing, terraces, etc.) built in the countryside over the centuries. For this reason, agriculture should be in some way protected against the fluctuations of the global market.

However, in the light of what we said before, we should ask ourselves ***whether biofuels are really the best option to improve rural development***. If the objective is to maintain agriculture as a profitable activity, there might be better strategies than biofuels. One possibility is ***to support other productions that are also not profitable in pure economic terms but which have more advantages and fewer drawbacks for society***, such as, for example, organic agriculture. This point is elaborated further in Chapter 8.

Compared to the minor advantages, the drawbacks of a large-scale biodiesel production would be very worrying. In order to reach the Directive's target (satisfying 1.3% of the energy demand with biodiesel), ***Italy should use 12% of its territory for energy farming, i.e. almost one third of the agricultural and pasture land*** (see Section 6.3.1). This would create huge monocultures of rapeseed and sunflower, cultivated with intensive (and very pollutant) agricultural techniques, and possibly favour the diffusion of GMO crops. As a consequence of that, the agrarian biodiversity would dramatically decrease, increasing the vulnerability of the entire Italian agricultural system. Also, the change would generate enormous costs in the transition phase.

Also, ***the increase in import of food for cattle and humans would be 33% of actual consumption*** (see Section 6.3.4), with the possible consequence of a reduction in quality control. Another point of concern is that, whereas such a big increase might perhaps be sustainable if it should regard Italy only, it would probably interfere with the international food market if many industrialized countries also decided to replace part of their fossil fuel consumption with biodiesel (as the Directive implies). On a global scale, a biofuel policy might reduce world food availability, which can be a particularly serious problem in a context of increasing population and energy demand.

A recent example is the increase in corn price in Mexico by 30% in early 2007, caused by the growing demand for corn-derived bioethanol in the USA (Mexico is a net importer of corn from the USA). Some use the term "ethanolinflaction"[54].

[54] Relea, 2007, *Nace en México la "etanoinflación". El aumento del uso del maíz para producir etanol dispara el precio de las tortillas, El País, 2/04/07,*

The consequences on the Mexican economy are very worrying since corn is at the basis of the Mexican diet.

Apart from that, other potential impacts may be a reason for concern. First of all, ***the use of fertilizers would increase*** (see Section 6.3.6). If calculated in terms of eutrophication potential, it would increase by 11% with a national scale approach and even 32% if one takes into account the fertilizer used for producing the oil seeds or the food products in foreign countries.

Secondly, ***water consumption would also increase***, even though to a smaller extent. As shown in Section 6.3.7, switching from cereal and fodder cultivation to oil seeds would imply to use more water for irrigation because it was assumed that half a million hectares of abandoned and set-aside land would be brought into production. Also, importing the oil seeds would imply to be responsible for increased water consumption in foreign countries. The total increase in irrigation would be 0.7% in Italy, and 1.4% on the large scale. An increase in water consumption would raise great concern in Italy, which already has problems of water scarcity because it is densely populated and has a Mediterranean climate, with few precipitations.

Thirdly, if biodiesel were not burdened with taxes (which is a necessary condition to make its price comparable to that of diesel), ***the total energy revenues would decrease by 4%*** (see Section 6.3.8). It is a small percentage, but still significant, provided that the Italian government already has problems in respecting the Maastricht commitment on the reduction of the public debt.

Concluding, biodiesel is not a solution for the energy problem, and does not really make a difference for the final fuel price. At the same time, it presents serious drawbacks in terms of land requirement and the consequent increase in food imports for humans and cattle. Also, a large-scale production of biodiesel would imply an increase in fertilizers and water requirement, as well as a reduction of the energy revenues.

There are however two issues that seem to be in favour of biofuels, i.e. urban pollution and rural development. The rest of my analysis is dedicated to exploring in more detail whether biodiesel may really be a solution to these two problems. Might there be other more advantageous alternatives to address them?

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http://www.elpais.com/articulo/internacional/Nace/Mexico/etanoinflacion/elpepuint/20070124elpepiint_11/Tes

7 Biodiesel as a Solution for Urban Pollution?

7.1 Introduction

Biodiesel is often presented as a solution for urban pollution (see for example the quotations of Section 4.6). As a matter of fact, as shown in Chapter 6, the reduction of urban pollution might be seen as one of the most important reasons that could justify biodiesel promotion. In fact, engines running on biodiesel emit less particulate matter (PM), carbon monoxide (CO), volatile hydrocarbons (VOC) and sulphur oxides (SO_x) than diesel (but slightly more NO_x).

However, if the aim is to reduce urban pollution, are there other more effective options? Which are the pros and cons of each of them? The rest of this chapter is dedicated to investigating the different fuels that are currently available on the market. Their potential contribution towards reducing urban pollution was evaluated together with other aspects such as costs, energy efficiency, convenience, power, and safety.

7.2 The urban pollutants

This section provides a brief overview and discussion of the main urban pollutants emitted by light- and heavy-duty vehicles. In most modern cities the transport sector is responsible for several serious health problems in the urban population, such as asthma and chronic bronchitis, as well as skin and eye irritations. Also, the long-term effects of many volatile organic pollutants can induce lung cancer.

The internal combustion engine, in its two most widespread variants (i.e. 'Otto cycle' running on petrol, liquefied petroleum gas or natural gas and 'Diesel cycle' running on diesel oil), is responsible for the following air emissions (Manahan S.E., 2000; Brimblecombe P., 1996).

Sulphur Oxides (SO_x). Traces of sulphur dioxide (SO_2) and sulphur trioxide (SO_3) are emitted by Diesel cycle engines, but the levels of these emissions have dropped dramatically since the introduction on the market of low-sulphur fuels, and the contribution of the automotive sector to the overall anthropogenic SO_x budget is only 2% (see Section 6.3.3). For this reason I decided not to consider these emissions in this study.

Carbon monoxide (CO). This gas results from the incomplete oxidation of the fuel in the engine. It forms a stronger bond to hemoglobin in blood than oxygen, hampering in this way cellular breathing. The natural background atmospheric concentration of CO is about 0.1 ppm (parts per million), and anthropogenic contributions usually account for less than 6% of the total. However, peak concentrations in heavily polluted urban areas can reach 50–100 ppm. I decided not to concentrate on discussing this pollutant in this study because the toxic effect of CO is limited to the areas of heavier traffic during rush hours, but in normal situations it can be metabolized quite efficiently by the human body.

Volatile Organic Compounds (VOC). These are a large mixture of organic compounds which include the lighter (and hence more volatile) fraction of the residual unburnt fuel, as well as partially-oxidized ***hydrocarbons*** deriving from incomplete combustion. The specific composition of the mixture varies with the fuel used. Generally speaking, the acute effects on human health are eye and skin irritation and respiratory inflammation, while among the most dangerous chronic effects is lung cancer. The latter is principally caused by the light aromatic compounds present in the unburnt fraction (e.g. benzene, toluene, xylenes). VOCs are also involved in the formation of irradiation-induced secondary pollutants, collectively known as *photosmog*.

Nitrogen oxides (NO_x). Nitrogen monoxide (NO) is formed inside internal combustion engines as the product of the atmospheric nitrogen and oxygen. This reaction is favoured by hotter engine operating conditions. At normal ambient temperatures, NO is actually further oxidized to a large extent to nitrogen dioxide (NO_2).

NO and NO_2 are commonly collectively referred to as NO_x, and their negative effects on human health and the environment are manifold. Firstly, NO acts in the same way as CO, attaching to hemoglobin instead of oxygen and reducing oxygenation. Secondly, NO_2 forms nitric acid (HNO_3), which contributes to acid rains and irritates the eyes, the skin and the respiratory system. Thirdly, NO_2 with strong sunlight react with oxygen and *ozone (O_3)*, an extremely toxic and irritating gas. Fourthly, in the presence of NO_x, ozone and VOC, a complex series of further chemical reactions can take place to produce a wide range of pollutants, including peroxides and organic nitrates. Among the latter, *peroxy-acyl nitrates (PAN)* are especially notorious as powerful eye and lung irritants.

Particulate Matter (PM). Diesel cycle engines emit significant levels of carbon-based particulate matter, which are one of the most worrying urban pollutants (Rogge et al., 1993; Morawska et al., 1998). These particles are kept suspended in the air for a long time before settling on the ground, especially in heavy traffic conditions. In particular, the smaller the particles the longer their residence time in the atmosphere.

PM causes two different kinds of effects on human health. On the one side, are the physical effects determined by the miniscule size of the particles, which easily penetrate the respiratory system and irritate the nasal cavities, the pharynx and, in case of the finer particles, even the lungs. Long-term exposure can lead to asthma and chronic respiratory problems.

On the other side, the chemical effects are determined by the composition of the particles, and by the compounds that they can release once inhaled. PM emitted from vehicle engines consists largely of *carbon soot (C)*, plus a variable percentage (up to 40%) of heavy non-volatile organic compounds. Among the latter, of great concern are the so-called *Poly-nucleated Aromatic Hydrocarbons (PAH)*, which are among the most powerful known carcinogens. PM particles also transport other airborne pollutants, such as *nitrogen* and *sulphur oxides* and *heavy* *metals*. PM is also emitted by tyre and brake wear. However, since this latter type of emissions is totally independent of engine and fuel type, I did not consider it in this study.

7.3 Comparison among biodiesel and other fuels

Many studies can be found in the scientific literature on exhaust emissions of biodiesel or biodiesel blends with fossil fuel-derived diesel at different percentages (see Graboski and McCormick, 1998). Many compare the emissions of biodiesel to those of diesel. Even though the results differ, depending on technical conditions, engine efficiency, operating conditions, the kind of vehicle, the load, and measurement methods, most studies show a slight increase in NO_x and a reduction of PM when diesel is replaced with biodiesel (see Section 6.3.3).

However, studies comparing biodiesel to other fuels and not only with diesel under the point of view of exhaust emissions are very rare, and the picture is mostly incomplete. In fact, if biodiesel is compared to other fuels currently available on the market (liquefied petroleum gas, natural gas and petrol), the conclusions about the environmental advantages of biodiesel might change. Table 7.1 shows a comparison among diesel, liquefied petroleum gas, methane, petrol and biodiesel at 5% and 20% blend.

The data are taken from a report prepared by CSIRO (Beer et al., 2004), an authoritative Australian institute and a second report published by the American National Renewable Energy Laboratory (Morris et al., 2003). The former compares two liquid fuels, i.e. low sulphur EDC 2003 diesel and unleaded petrol, to two gaseous ones, i.e. liquefied petroleum gas (LPG)[1] and compressed natural gas (CNG). They are analysed for light- duty vehicles on the basis of the mass of emissions per kilometre travelled[2]. The latter performs a literature review of twenty studies that analyze the exhaust emissions of trucks and bus engines using biodiesel or a blend of biodiesel and diesel[3]. For the reasons explained in Section 7.2, the pollutants considered here are NO_x, PM and VOC.

[1] LPG Autogas - European Drive Cycle 2003, 3rd generation.
[2] The data reported here are based on the most modern type of car (Euro 4 model).
[3] Two-stroke and four-stroke engines of different years were studied. Here the average data referring to five four- stroke engines built after 1994 were taken as the most representative of modern car engines. Car engines are smaller than track or bus engines, but percentage differences in emission levels can reasonably be assumed to be independent of engine size.

Table 7.1 Tailpipe emissions from light-duty vehicles (g/km)[4]

jj	NOx (g/km)	Difference with respect to diesel (%)	PM (g/km)	Difference with respect to diesel (%)	VOC (g/km)	Difference with respect to diesel (%)
Biodiesel (100%) [*]	0.56	+10	29.0	-37	0.003	-76
Biodiesel (20% blend) [*]	0.52	+3	41.2	-10	0.008	-24
Biodiesel (5% blend) [*]	0.51	+0.5	44.9	-2	0.011	-4
Diesel (Low-S) [+]	0.51	0	45.7	0	0.011	0
Petrol (Premium Unleaded) [	0.06	-88	2.5	-95	0.01	-9
LPG [+]	0.018	-96	2.5	-95	0.015	+36
CNG [+]	0.055	-89	2.9	-94	0.003	-73

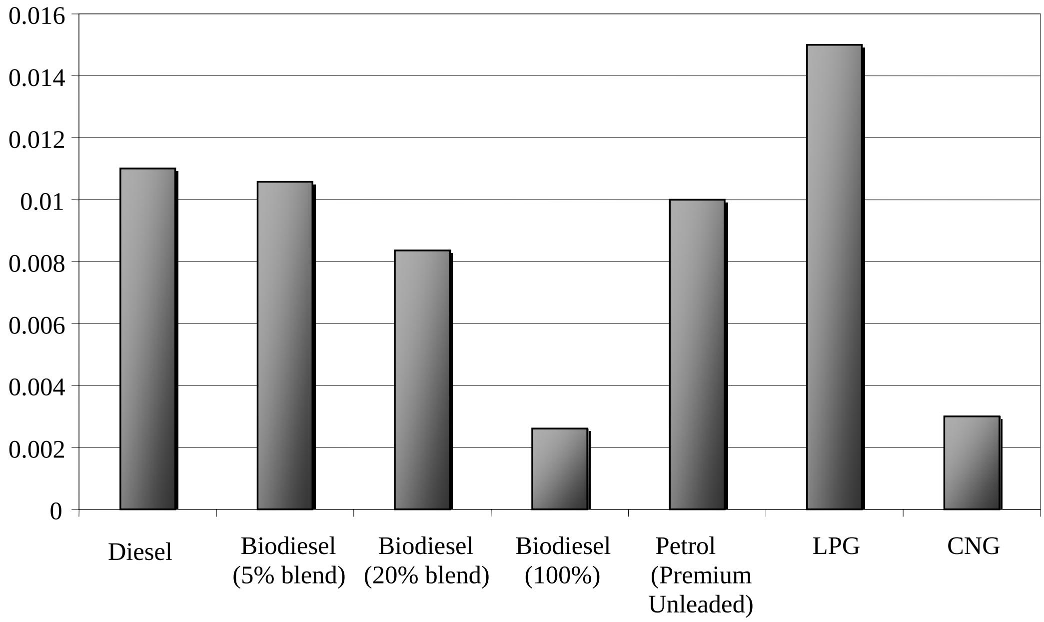
[+] Beer et al., 2004.
[*] Morris et al., 2003.

The same results are presented in Figure 7.1, Figure 7.2 and Figure 7.3 in order to make them more easily readable.

Figure 7.1 shows the emissions per km of VOC of the different fuels. Biodiesel allows to reduce them, but less than other fuels currently available. A blend of 20% biodiesel emits 24% less VOC than diesel, whereas a blend of 5% biodiesel reduces VOC by 4%. Petrol reduces the VOC emissions by 9%. The fuel that emits less VOC is CNG, which allows a reduction of 73%. If LPG is used instead of diesel, VOC increase by 36%.

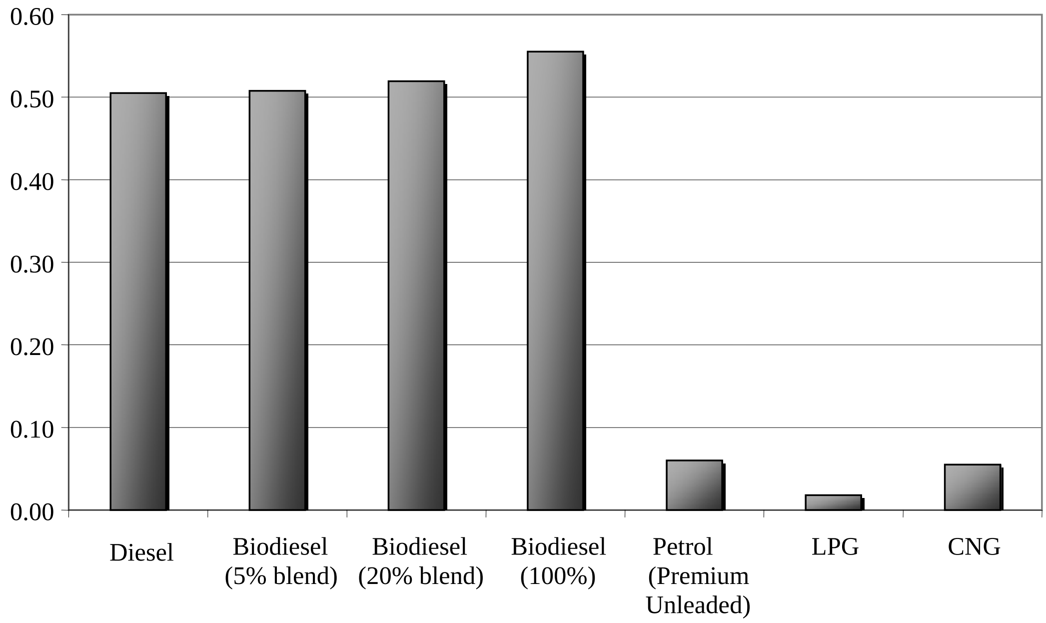
[4] NREL's data about pure biodiesel and biodiesel blend at 20% refer to bus and truck engines and are expressed in percentages. The data in terms of g/km presented in Table 7.1 were obtained referring these percentages to the data found in the CSIRO report on light duty vehicles. The data presented about 5% biodiesel blend are extrapolated from the data reported in the NREL report on emissions of pure and 20% biodiesel blend and in the CSIRO report.

Figure 7.1 Volatile Organic Compounds (VOC), g/km



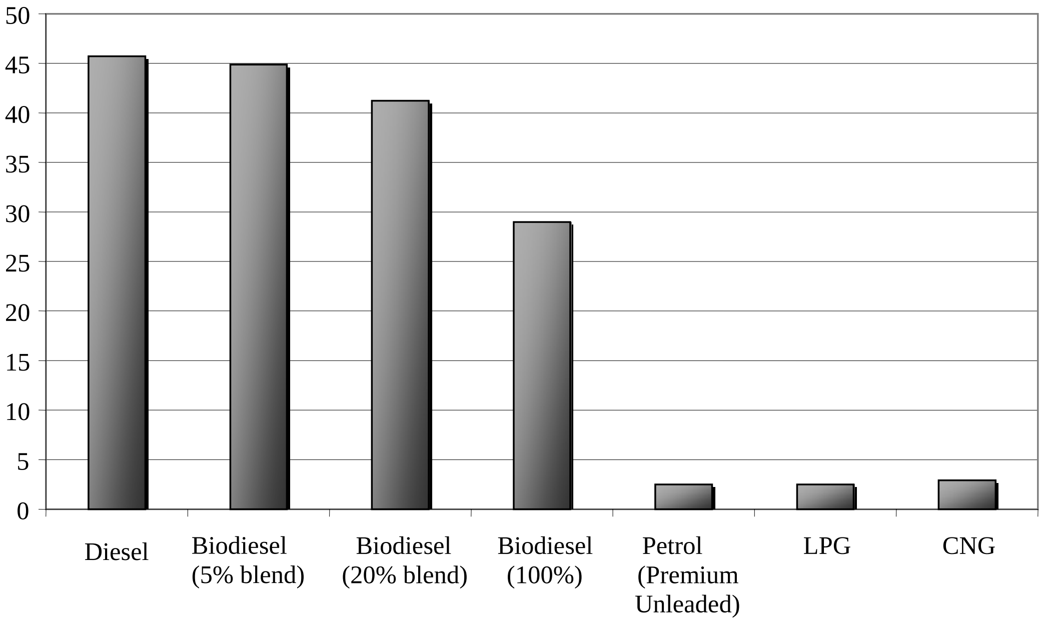
The same considerations hold for NO_x (see Figure 7.2). The results substantially confirmed the studies mentioned in section 6.3.3, and in particular the EPA report that compares biodiesel and diesel exhaust emissions. The NO_x emissions of a biodiesel/diesel blend are slightly higher than the ones of diesel only. However, the difference is 3% with a 20% blend and it is negligible with a 5% blend. On the contrary, there is an enormous difference among biodiesel and diesel on the one side, and petrol, LPG and CNG on the other side. The latter allow to reduce NO_x emissions with respect to diesel by respectively 88%, 96% and 89%.

Figure 7.2 NOx emissions, g/km



As regards particulate matter (PM), many biodiesel promoters claim that biodiesel allows a reduction of this pollutant. They are right: as can be seen in Figure 7.3, a blend of 20% biodiesel releases 10% less PM than diesel. However, other options are presently available on the market that allow reducing particulate matter much more than that. In fact, both petrol and gaseous fuels like LPG and CNG emit around 95% less PM than diesel. Therefore, if the aim is to reduce particulate matter, biodiesel is for sure not the best option.

Figure 7.3 Particulate matter (PM), g/km



It can be noted that stricter PM emission limits are going to be enforced in Europe, Japan and the USA in the next years, and research is ongoing to find viable and economical ways to reduce Diesel engines PM emissions. Special filters are being developed, but they still present some technical issues and are not yet a widespread commercial reality (see for instance Nickolas et al., 2005; Maricq, 2005).

Concluding, it can be stated that even though biodiesel allows reducing urban pollution in terms of PM and VOC, there are other options currently available on the market that are much better under this profile. If the aim is to reduce PM, then petrol, LPG and CNG allow a much bigger reduction. Moreover, they emit between 88 and 96% less NOx. As regards reducing VOC, CNG is by far the best option.

Therefore, **biodiesel is not a solution for urban pollution**, as claimed by many environmentalists, and, besides, it presents serious drawbacks in terms of land requirement that oil products do not have. The reasons why it is often claimed that biodiesel would dramatically reduce urban pollution are two: on the one side it is often only compared to diesel, and on the other side pure biodiesel is taken for the comparison. However, even a target of 5% should be considered very high. As shown in Chapter 5, substituting only 5.75% of the Italian energy demand for transport would mean using around 3.7 million ha. So it is hardly conceivable to increase the biodiesel share in the transport system more than that. Achieving this low percentage would mean ***reducing urban pollution in terms of PM and VOC only by 2 and 4%*** (and slightly increasing NOx emissions), ***and it would not make a big difference for contamination in cities***. ***Even though biodiesel is slightly less polluting than diesel (with the exception of NOx), it is much more polluting than petrol, LPG and CNG.***

Another point is that biodiesel is the most expensive option. In fact, it is competitive with diesel and petrol only if it is not burdened with energy taxes, which constitute more than half of the price of diesel and petrol. In other words, ***biodiesel is at least twice as expensive as oil-derived fuels, and this cost is paid by the entire society by means of agricultural subsidies and de-taxation***.

Another interesting point is that when comparing petrol and diesel (by far the most widespread fuels for transportation), a ***trade-off between the objectives of energy (and money) saving and reduction of urban pollution can be observed***. In other words, one or the other one should be preferred according to the objective that is considered most important, or, in other words, the scale. On a global scale, diesel is to be preferred to petrol because it is more efficient, i.e. it allows using less energy per km. In fact, Diesel-cycle engines are on the average approximately 20 ÷ 25% more efficient than comparable Otto-cycle engines running on petrol (Mandil, 2006).

Moreover, diesel is approximately 30% less expensive than petrol per unit of energy (1.2 €/L vs. 1.33 €/L[5], which translates into 0.029 €/MJ vs. 0.042 €/MJ[6]). However, it should be considered that this price difference is due to differences in taxation. OECD data for 2005 actually report petrol to be cheaper than diesel when compared without taxes (0.45 €/L vs. 0.51 €/L). The higher end price of petrol on the Italian market (1.22 €/L vs. 1.11 €/L–2005 prices) results from a higher excise tax (0.56 €/L vs. 0.41 €/L) as well as a resulting higher VAT (20% of price incl. excise tax).

All in all, the higher efficiency of Diesel engines combined with the lower price of diesel fuel at the pump makes it roughly 45% more economical to drive a diesel car[7]. The consequence is that the percentage of diesel cars is increasingly higher, and it has reached in Italy a market share of almost 58%[8]. Therefore if the most important objectives are the reduction of the dependency on fossil fuels, the reduction of the greenhouse emissions and the energy security, then diesel should be promoted. The same holds if user-costs are considered very important.

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[5] http://www.prezzibenzina.it.

[6] Diesel: (1.2 €/L) / (40.9 MJ/L) = 0.029 €/MJ. Petrol: (1.33 €/L) / (32 MJ/L) = 0.042 €/MJ.

[7] This figure results considering a maximum gain in engine efficiency of 25% and the reduction in energy cost per MJ (0.029 €/MJ vs. 0.042 €/MJ). Hence, [0.042 – (0.029 / 1.25)] / 0.042 = 0.45 = 45%.

[8] http:// www.anfia.it.

On the contrary, on a local scale, petrol should be preferred, because it produces less urban pollution than diesel. However, it should also be noted than while on the one side the energy sparing allowed by diesel is of the order of magnitude of 20-25% and the overall cost reduction is at maximum 45%, on the other side the reduction in urban pollution allowed by petrol is of the order of magnitude of 88% (NOx) and 95% (PM).

As regards biodiesel, on the one side it slightly reduces urban pollution with respect to diesel and on the other side it is much more polluting than petrol. Also, it allows to reduce the fossil fuels requirement a little with respect to diesel (which is more energy efficient than petrol), see Chapter 6. However, it must be noted that if calculated taking into account the transport costs and the emission in foreign countries, the reduction is very small. Moreover, it should not be forgotten that these advantages are counterbalanced by the enormous drawbacks of large scale biodiesel production in terms of land requirement, restructuring costs of the agricultural sector and, reduction of the agrarian biodiversity.

From the point of view of urban pollution, gaseous fuels (LPG and CNG) are less polluting than diesel or biodiesel.

CNG is also more efficient: it needs less energy per km because its energy density is higher: 56.6 kJ/g vs. 48.1 kJ/g for the average petroleum-derived liquid fuel (after di Pascoli et al., 2001). Moreover it is cheaper than petrol and biodiesel. The relative price of natural gas including taxes per MJ is about 30% of that of petrol and 40% of that of diesel. The reasons are that natural gas is more abundant and widespread; its extraction, transport and distribution costs are relatively low and also taxes are often lower than the ones on diesel (di Pascoli et al., 2001).

Di Pascoli et al. (2001) underline other advantages of natural gas if compared to fuel oil: 1) it is cleaner in the extraction phase; 2) it does not require a refining process like oil, needing less energy in the processing phase; 3) it is more geographically widespread; 4) it can be transported using pipelines, which entail less environmental impact than trucks; 5) accidental losses have lower environmental impact than oil leakages and are fewer in quantity. Also, natural gas is overall cleaner from a life cycle point of view (Riva et al. 2000).

As regards LPG, it is a by- product of the oil refinery process, thus its availability is fixed and depends on the oil demand. LPG is often separated and burned to avoid risks in the transportation phase, making it a net gain to use it for energy purposes. It can be used as a niche product instead of natural gas, because it presents most of its advantages, like being cleaner and cheaper (0.66 €/L[9]).

However, gaseous fuels present other kinds of drawbacks, in terms of flexibility (distributing network), convenience, power density and safety. In particular, the lower power density of LPG and even more so CNG with respect to petrol and diesel means that large and heavy tanks are needed to allow a reasonably long

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[9] http://www.prezzibenzina.it.

driving range. These tanks take up much more space than a liquid fuel tank sized for a comparable driving range, and this is especially inconvenient since these tanks are usually sold separately and not well integrated within the car, but end up taking up a large portion of the boot.

Another source of inconvenience is the small network of filling stations. In Italy there are a few hundred for LPG[10], and only around 500 for CNG[11]. Also, LPG and CNG vehicles are not allowed in closed parking areas because of safety concerns (gaseous fuels are of course more volatile and pose greater risks of fires in closed rooms).

From the performance point of view there are some disadvantages, too, since an engine designed to run on petrol typically loses around 7% of its power when operated on LPG and up to 15% when operated on CNG (US DoE, 1994). Of course, such power loss is even more annoying in the case of the smaller, more economical engines typically used in cars primarily intended for urban use. In specially-designed engines (OEM[12] engines) these losses can be reduced to some extent, but on the other hand this option reduces the flexibility of use, since such cars cannot use petrol any longer.

Lastly, there is the small but existent risk of explosion, which is absent in the case of the more widespread liquid fuels. Even so, the modern gas tanks are quite safe, and such risk is really only limited to major collisions under the most unfavourable circumstances (Liu et al., 1997).

For all these reasons, the share of cars running on CNG and LPG is (still?) very low in Italy. More specifically, CNG vehicles are approximately 382,000[13] over a total of 32.5 million[14] (i.e. under 1%), while LPG cars are around 1.4 million[15] (i.e. around 4%).

Table 7.2 summarizes the pros and cons of the analyzed fuels discussed so far (standard low-sulphur diesel is taken as the reference for comparison).

[10] http://www.stargassrl.com/stazioni_gpl_italia.asp.
[11] http://www.iangv.org.
[12] Original Equipment Manufacturer.
[13] http://www.iangv.org.
[14] http://autoinsight.blogosfere.it/2006/04/index.html.
[15] http://www.ecomotori.com/it/introduzione_gasexpo.asp.

Table 7.2 Pros and cons of analyzed fuel options (-=worse; +=better)

	NOx (g/km)	PM (g/km)	VOC (g/km)	convenience[16]	Safety	Price	Engine performance
Diesel (Low-S)	0	0	0	0	0	0	0
Biodiesel (5% blend)[17]	0	0	0	0	0	0	0
Biodiesel (20% blend)	-	+	+	0	0	-	0
Petrol (Premium Unleaded)	+++	+++	+	0	0	-	+
LPG	+++	+++	--	--	--	++	-
CNG	+++	+++	++	---	--	+++	--

As a concluding remark, it is important to remember that all fuels considered so far depend on the availability of oil and natural gas. Even biodiesel itself is not immune to this general problem, since when considered over its entire production cycle the oil savings are very small (see Section 6.3).

Natural gas itself is overall the least polluting and most efficient fuel, but its use has some practical disadvantages (as explained above), and it creates a strong dependence on Russian and Algerian exports, which can be a sensitive political issue these days. In any case, all oil-derived fuels (petrol, diesel and LPG) entail a dependence on Middle Eastern countries. Also, as it is well known, the price of oil has been increasing steadily over the last few years, causing increasing public concern.

7.4 Other options

When looking for the most promising strategy to curb urban pollution, three more alternative fuel vehicle options are to be considered: Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV) and Hydrogen Vehicles (HV). None of these technologies are yet as mature or widespread as those based on traditional fuels, but they might possibly develop into viable commercial alternatives in the future.

7.4.1 Battery Electric Vehicles (BEV)

A Battery Electric Vehicle is powered by an electric motor energized by a conventional battery, which produces power through a chemical reaction and which must then be recharged by connecting it to the electric grid.

During normal driving a BEV does not emit pollutants (in fact, these vehicles are sometimes classified as “zero-emission vehicles” or ZEV), with the only

[16] also considering the scarcity of fuelling stations.
[17] The data for the 5% biodiesel blend are obtained with a proportion, extrapolating the data of NREL on emissions of pure and 20% biodiesel blend.

exception of some PM emissions from tyre and brake wear. In other words, they are the best option under the point of view of the reduction of urban pollution.

However, it must be realized that from a life cycle point of view, what these vehicles do is actually move the problem from the tailpipe to the phase of electricity production. The amount and geographical distribution of the associated emissions will be entirely dependent on the electricity mix that is used in the region. The overall life-cycle energy efficiency and greenhouse gas emissions per km travelled will also be dependent on the distributed electricity mix, and in many cases will be comparable to those of a conventional vehicle powered by an internal combustion engine (Anastasia et al., 2002).

Several types of batteries can be used in electric vehicles (both BEV and HEV– see following section). The most common and cheaper are the lead/sulphuric acid batteries, which are reliable and up to 98% recyclable. However, the lead and sulphuric acid are potentially very harmful for the environment and need to be disposed of carefully (an important point, since the lifetime of a battery pack is much shorter than that of a car). Nickel-metal hydride and lithium-ion batteries are more advanced options, but are also considerably more expensive (Delucchi et al., 2001).

The main practical issue with BEVs is that the batteries are large, heavy, expensive and the energy they hold allows to drive only for few km, (no economically viable BEV has a range of more than 200 km[18]). The problem is that, using present technologies, the energy density of the batteries is still very low when compared to that of a tank of petrol, and a conventional car would have to be fitted with hundreds of kg of batteries to be able to drive as far between charges as an ordinary car can drive between fill-ups. This is not only impractical, but would also make the car excessively heavy, slow and of course expensive.

Very few commercial EVs have been introduced on the consumer market so far, and most of them for only a limited time and only in California, where emission regulations are stricter. For instance, the Toyota RAV-4 was available for sale in the USA for approximately 8 months in 2003 (at US$ 42,000 vs. US$ 15,350–16,100 for the conventional petrol versions[19]), but was then discontinued because of low sales[20]. The General Motors EV1 was made available for leasing for some time, and it too has been discontinued. At the moment, there is no way to purchase or lease any new production electric vehicle from any manufacturer, and even the California Air Resources Board[21] now seems to favour fuel cell vehicle research and development instead (Brooks, 2004).

[18] http://www.rmi.org/sitepages/pid447.php.

[19] http://research.cars.com/go/crp/buyingGuides/Story.jsp?year=2003&story=Toyota&section=makes&subject=makes.

[20] http://www.toyota.com/html/shop/vehicles/ravev/rav4ev_0_home/index.html.

[21] http://www.arb.ca.gov/homepage.htm.

7.4.2 Hybrid Electric Vehicles (HEV)

A Hybrid Electric Vehicle is powered by a conventional internal combustion engine (either Otto or Diesel cycle), with an electric motor added for enhanced fuel economy and reduced emissions. The electric motor is energized by a battery, which is continuously recharged by a generator that is driven by the internal combustion engine.

The first large-scale experiments with HEVs were made in the late 1990s (e.g. aXcessaustralia Concept Car, 1998; aXcess2, 2000), and the first commercial hybrid passenger cars reached the Japanese and US markets in the following years (e.g. Honda Insight, Toyota Prius, Ford Escape). However, very few more HEVs have been introduced by car manufacturers since (e.g. Honda Accord and Civic Hybrids[22]), and the actual market share of this technology is still negligible.

From a technical point of view, in most cases the electrical motor is used for propulsion, and the internal combustion engine can be reduced in size compared to a traditional car, since it is only used to recharge the battery and only needs to provide the average continuous power that is needed during driving. The most energy expensive phases (starting and accelerating) are fuelled by the battery itself. As a consequence, HEVs are responsible for much less urban pollution than conventional cars. The average reduction in fuel consumption and hence tailpipe emissions is about 40-45% (Beer et al., 2004; Anastasia et al., 2002.) Some of the latest-generation HEV can also run only on batteries for short trips (e.g. in city centres), thus temporarily behaving as ZEVs.

There are also some cons to HEVs. First of all, even though to a much lesser extent than BEVs, HEVs are also dependent on large, heavy, expensive and potentially polluting batteries, which are responsible for non-negligible recycling and disposal issues. Secondly, they are inevitably heavier and more complex than a traditional car (they require two separate engines, and all the extra parts needed to integrate them), which also turns into higher production costs and higher material and energy requirements per unit. For instance, the Honda Accord Hybrid is about 13% more expensive than its petrol-only variant[23].

In any case, HEV are considered by many (Romm, 2006) to be the best option among all alternative fuel vehicles.

7.4.3 Hydrogen Vehicles (HV)

A hydrogen vehicle uses hydrogen gas as its primary source of power, in one of two methods: either direct combustion or fuel-cell conversion.

In direct combustion, hydrogen is burnt in Otto cycle engines in fundamentally the same way as petrol or LPG, even though the engine must be specially re-designed for the different characteristics of the fuel. Practically the sole emission

[22] http://corporate.honda.com/environment/hybridization.aspx?id=hybridization_products.
[23] http://www.automart.com.

of a hydrogen-fuelled engine is water vapour, with the only trace pollutant being NOx, and at a much lower level than that from petrol- or LPG-fuelled cars (Keller at al., 2001).

In fuel cell vehicles (FCVs), on the other hand, hydrogen is not burnt but it reacts with atmospheric oxygen like in a battery, making electricity, which is then used to drive the car. The only other output of the fuel cell is water vapour.

Research in experimental hydrogen vehicles has been carried out since the late 1970's, and a significant amount of research is still underway to make these technologies viable.

BMW produced the first commercial HV, in the early 1990s. This was a luxurious car adapted to be able to run both on hydrogen and unleaded petrol. A 140-litre insulated tank was fitted for liquefied hydrogen storage. Even though the car represented a notable achievement from the reliability point of view and did prove that a real, production-scale HV was doable, it is interesting to note that BMW chose to only produce one hydrogen model, and that that model was derived from its most powerful and expensive car. Its engine was very large and powerful: in its original version (run on petrol), it could deliver 320 HP[24]. However, when running on hydrogen, the maximum power output was 204 HP (-36%). Therefore, even though this particular powerful engine could maintain a satisfactory performance when running on hydrogen, a smaller engine could suffer more severely from a similar percentage of power loss.

Mercedes-Benz and FIAT are among the first European car manufacturers who produced fuel-cell prototype cars. However, the technical difficulties to be overcome with this technology are larger, and Mercedes itself refers to its prototype as a "research vehicle", which will not reach full production maturity at least before 2012.

A small demonstration fleet of FIAT Panda Hydrogen cars, employing a fuel-cell system, will begin operating in 2006 in the framework of a wider-ranging demonstration programs promoted and supported by the European Union and by the Italian Ministries and Regions[25]. FIAT declared that the ultimate goal for such vehicles is to enter the market within the next 15 to 20 years, showing that much research is still needed to obtain a reliable and competitive product.

Some other Japanese and American manufacturers (e.g. Ford) have presented prototype fuel cell hydrogen vehicles too, but generally without mentioning the foreseen commercialization date. The only notable exception to this general trend is represented by the Honda FCX , which is actually the first and only fuel cell car available for commercial use (lease only, 500 US$/month).

[24] http://www.bmwworld.com.

[25] http://www.fiatautopress.com/index.php?method=news&group=1&action=zoom&id=2006021303 32401d6d51d2874287d9541e3c6eaef98b0e.

In 1999, the California Fuel Cell Partnership[26] was founded to promote the commercialization of hydrogen fuel cell vehicles in California and, subsequently, in the rest of the USA. The Partnership now includes 31 member companies (car manufacturers, energy companies, fuel cell technology companies and government agencies) who are working together to develop and sponsor demonstration programmes.

Fuel cell vehicles have also been tested for public transportation purposes. The firs experience of fuel cell vehicles was started by Ford Motor Company, Natural Resources Canada and Fuel Cells Canada in June 2003, with plans to place a fleet of hydrogen-powered fuel cell buses on the streets of Vancouver in 2004[27]. Other similar projects are currently underway in North America, Australia and Europe[28], but their relevance on the global scene is still marginal.

HV are clearly better than vehicles using more traditional fossil fuels under the point of view of urban pollution because they are not responsible for harmful pollutant emissions, except a limited amount of NOx and some PM caused by tyre and brake wear.

However, it must be remembered that hydrogen is not available as a free energy source, and must be produced on purpose. There are basically two methods for hydrogen production: chemical reforming of natural gas and water electrolysis. The reforming process can be carried out in centralized plants or directly on the vehicle. In this latter case, use of the readily available fossil fuel distribution network could be made. However, some pollutant emissions would be reintroduced (CO, VOC, NOx–exact estimates are still uncertain because of the prototype nature of such on-board reformers), and extra weight and build complexity would be added to the vehicle. Hydrogen production by water electrolysis uses electricity from the grid and is necessarily a centralized process. The associated emissions and impacts are dependent on the electric mix that is used in the region.

In terms of the full life cycle scale, HV using hydrogen produced from electricity entails more GHG emissions, pollution and cost per mile driven, than would the direct consumption of a traditional fuel (e.g., diesel, NG or petrol) in a modern internal combustion engine (General Motors, 2002). This is especially true if hydrogen is produced by water electrolysis using the European electricity mix. In fact, it could be argued that a much more efficient use of electricity itself can be made by employing it directly in a BEV, instead of using it to produce hydrogen. For instance, an electric car running on batteries could drive just as far on a single charge as a fuel cell car could on a tank of hydrogen, about 200 km, but the fuel cell car would need four times more electricity (Brooks, 2004). This is because the whole cycle of producing hydrogen with electricity and running a fuel cell car is much less efficient than charging a battery and running an electric car.

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26 www.fuelcellpartnership.org.

27 http://www.fuelcellscanada.ca/Industry%20news/vfcvp.html.

28 http://www.navc.org/fuelcellbuses.html.

Generally speaking, this kind of result can be explained with the Second Law of Thermodynamics, which states that in each energy transformation step there is always a loss of usable energy, which is irreversibly converted into heat. Therefore, as a general trend, the more the steps in an energy transformation process (e.g. from a fossil fuel to electricity, then from electricity to hydrogen, then again from hydrogen to electricity, and finally from electricity to mechanical work in the car), the larger this loss of usable energy.

If the objective is only reducing greenhouse gas emissions, one possible solution might be the use of nuclear power (the Second Law still holds, of course, but since nuclear electricity is almost GHG-free, the lower thermodynamic efficiency does not translate into higher CO_2 emissions). In fact, some technologically-optimistic scientists claim that the combination of nuclear energy and hydrogen is the preferable option for future transportation needs. However, a more widespread deployment of nuclear power plants would raise drawbacks such as risk of radioactive contamination, safe disposal of residues, risk of proliferation, which a large part of population might not be willing to accept.

Other areas of concern that require further research efforts are those of hydrogen storage and distribution. The first issue presents reliability and weight issues, besides being very expensive (Bossel et al., 2003). As regards the distribution network, hydrogen can damage the common natural gas pipelines. As a consequence, a completely new and expensive infrastructure would be needed for hydrogen distribution to the pumps.

Last but certainly not least, there is the issue of cost. Fuel cells for vehicle applications currently cost around 4000 US$/kW, a figure two orders of magnitude higher than that for conventional internal combustion engines. For example, Honda affirmed that if their fuel cells car was to be sold at its full commercial price, it would cost about 1.5 million Euros (Freeman, 2005). Of course, it could be argued that these are prototype-costs which would be greatly reduced if produced on a large-scale. However, it is not obvious that enough subsidies will be available to sustain FCVs in the many years while they are still not economically competitive (Romm, 2006).

In conclusion, all these issues contribute to make the hydrogen diffusion less probable than some scholars (e.g. Rifkin, 2002) would let us believe.

There is possibly one single exception to this conclusion: the ongoing project of a hydrogen-based economy in Iceland (Sigfússon, 2003; BBC News, 2002). In 2002 president Olauf Ragnar Grimsson declared that by 2050 Iceland will have completed its transition to a full hydrogen economy. Whether such high target will be met is yet to be verified, however the first steps in that direction have already been made. Besides supporting research in the private transportation sector, Iceland launched its first hydrogen-fuelled bus fleet in Reykjavik in 2003, and the first fuel-cell ocean vessel in 2006. However, Iceland is extremely suitable for the centralized production of hydrogen via water electrolysis because of its many geothermal springs and waterfalls that can be used for generating electricity.

In these conditions, hydrogen can be used as a universal energy carrier and effectively reduce the country's dependence on foreign oil. However, the example of Iceland is unlikely to be followed by other countries with less favourable conditions for the development of a large- scale hydrogen production.

Table 7.3 summarizes the pros and cons of the alternative fuels discussed in this section (a standard diesel-fuelled car is taken as the reference for comparison) and the evaluation is referred to 2006.

Table 7.3 Pros and cons of alternative fuel options (-=worse; + =better)

	Local emissions	Global emissions	CO_2 savings	convenience[29]	safety	price	practical feasibility
Standard diesel car	0	0	0	0	0	0	0
BEV	+++	0	0	-	+	--	0
HEV	++	+	+	0	0	-	0
HV (internal combustion)	+++	--	--	---	-	---	-
HV (fuel cell)	+++	--	--	---	-	---	---

[29] also considering the scarcity of fuelling stations.

8 Biodiesel versus Organic Agriculture

8.1 Introduction

The main result of the analysis performed up until now was that the only sound reason to promote a large scale production of biodiesel is possibly rural development.

European agriculture is not profitable any more from a strictly economic point of view. If left to the dynamics of the free market, it would not thrive. This is even more so because of the increasing liberalization of the international markets of food, which deliver much cheaper food products than the European farmers could ever do.

However, society considers that the agricultural sector generates more values than the pure economic ones, and for this reason it must be “artificially” kept alive through public incentives. In fact, agriculture is multifunctional in nature: besides producing food, it protects the landscape, can maintain biodiversity (but only if properly implemented, as will be discussed in this chapter), the rural architectural patrimony and local knowledge. Also, it allows creating employment, thereby preventing rural de-population in peripheral areas and favouring a balanced distribution of population throughout the territory.

The European Union considers the survival of agriculture so important that it assigns approximately 46% of its budget to the Common Agricultural Policy (CAP), the instrument dedicated to agriculture and rural development (55 billion euros in commitment appropriations in 2006).

One of the main points (and a reasonable one) of biodiesel promoters is the following. On the one side society considers the survival of agriculture a priority objective, which requires an intense subsidizing system. On the other side, subsidizing food production may result in two problems: 1) over-production, which tends to cause a decrease of prices (for this reason, the 1999 reform decoupled the European subsides from the production quantities and launched the set-aside scheme); 2) subsidizing European agriculture damages the interests of the Southern countries that export alimentary products to Europe, because their competitiveness is artificially reduced. Also, European subsidies lead to Europe dumping food exports to the detriment of Southern food security. Biodiesel is often presented as a way out from this impasse: subsidizing energy farming for biodiesel production would allow to support European agriculture, without interfering with the international food market and avoiding food over-production.

However, even though biodiesel is often presented as a sustainable product, energy farming also causes environmental impact. As explained in Chapter 5 and 6, if produced on a large scale, biodiesel would require the use of intensive agricultural methods, which include monocultures (and therefore loss of agricultural biodiversity), use of oil-derived products like fertilizers and pesticides, and possibly of GMOs to increase resistance against pests. The reason is that cultivating oil seeds with environmentally friendly methods would lower the yield and increase even more the land requirement, which is already very high. As explained in Chapters 6 and 7, as a counterpart of these environmental impacts, the advantages in terms of energy savings, reduction of greenhouse effect and local pollution are very modest.

The thesis presented in this chapter is that if the objective is rural development (and not energy saving or reduction of urban pollution), there may be other ways to use public resources (both in terms of agricultural subsidies and de-fiscalization, as well as policies of demand creation), that provide more valuable services to society and with fewer disadvantages.

An example might be organic agriculture. Like energy farming, organic agriculture is not economically competitive with its conventional alternatives (oil products in the case of biofuels and food produced with conventional agriculture in the case of organic farming), and would probably not survive without a subsidizing scheme. However, it is subsidized because it delivers to society other services that are considered important (healthier food, landscape diversity, protection of agricultural biodiversity, etc.).

In the rest of this chapter an introduction to what characterizes organic agriculture is given, and the differences between organic agriculture and conventional agriculture (and energy farming in particular) are discussed, in order to assess which strategy is more advisable.

8.2 *Organic agriculture*

Organic agriculture is a method of agricultural production which uses natural means to try to increase yield and reduce pests. In particular, the main features of organic agriculture are (EEC Regulation 2092/91):

1) **Crop rotation**. This is a practice whereby different kinds of crops are cultivated one after another each year on the same plot of land. In this way, the available soil nutrients are exploited more evenly, since different kinds of plants have different needs for specific nutrients. For example, cereals are alternated with legumes, which are able to fix atmospheric nitrogen in the soil (see Section 8.3.1) and thus replenish the nitrogen reserves in the soil.
2) **Significant restrictions on the use of fertilizers** that may jeopardize the environment or human health. The fertility of the soil must be assured by the use of legumes, green manures or deep rooting plants. The use of organic manure in place of chemical fertilizers allows enriching soil fertility, by feeding back to the soil some of the nutrients extracted from it by the plants.
3) **Reduced use of pesticides**. Natural methods for pest management are used, which means that natural enemies of pests are favoured (e.g. through hedges, nesting sites, release of predators), to naturally get rid of pests. Also, pests, diseases and weeds are controlled by choosing appropriate species and varieties, as well as with mechanical cultivation procedures and flame

weeding. Finally, rotating crops reduces the vulnerability to pests and plant diseases (Van Bruggen, 1995).

However, in many cases the idea of organic agriculture goes beyond these minimum requisites. Many farmers who decide to undertake the conversion to organic agriculture have ethical motivations. The same ethical reasons are shared by the organic food consumers, which are willing to pay a higher price for that. In this view, organic agriculture is not only the accomplishment of some rules stated by a law, but also the trend towards a change in the agricultural model. For this reason, in many cases more attention is paid by organic farmers to landscape maintenance, crop diversity and closing agricultural cycles (reuse of the wastes for greater efficiency in the use of materials and energy).

Some basic data on organic agriculture can be found in a report published by the European Commission in 2005[1]. In the EU-15 5.1 million hectares of land are organic or in conversion, which represent around 3.6% of the total utilised agricultural area (2003 data), out of which one million are in the Italian territory. The main use is grassland and fodder crops (3.1 million hectares), followed by arable crops (1.3 million hectares), mainly cereals (70% of the land dedicate to organic arable area), and horticulture (0.4 million hectares). Organic products represented in 2001 1% of the total food sold. The highest consumers were Denmark, Sweden and Germany.

In the following sections the advantages of organic agriculture with respect to conventional agriculture (including energy farming) are examined and discussed.

8.3 What distinguishes organic agriculture from conventional agriculture (including energy farming)

8.3.1 Soil

In a healthy natural soil, the nutrients necessary for plant growth are constantly kept in circulation. Earthworms and other small invertebrates prevent the upper soil layer from becoming too dense and anaerobic by digging holes through it, while different species of soil bacteria carry out the chemical reactions needed to convert the available inorganic chemicals to compounds which can be used by the plants.

Among the most important chemical elements needed for plant growth is nitrogen. Nitrogen constitutes about 70% of the Earth’s atmosphere, but it cannot be used by plants in this form, and needs to be transferred to the soil first. One type of bacteria are capable of doing this by transforming nitrogen into ammonium, a compound which can be utilized by plants as a nutrient. Most of these nitrogen-fixing bacteria live in symbiosis with the roots of leguminous plants.

[1] European Commission, DG Agriculture and Rural Development, 2005.

Other bacteria involved in the nitrogen cycle are nitrifying and de-nitrifying bacteria. The former convert ammonium to nitrate, a second form of nitrogen that can also be effectively used by plants. The latter kind of bacteria close the cycle, by converting the residual nitrate that has not been used by plants back into atmospheric nitrogen.

Similar cycles exist also for other important plant nutrients, such as for example phosphorous and sulphur.

In modern industrialized agriculture, artificial nitrogen-rich chemical compounds (fertilizers) are added to the soil in order to make it more productive. Most of this additional nitrogen is delivered in the form of ammonium, which is produced industrially. Since the naturally occurring conversion of ammonium to nitrate operated by nitrifying bacteria (and also the conversion of nitrate back to atmospheric nitrogen made by de-nitrifying bacteria) results in a loss of the total available nitrogen to the crops, anti-bacterial compounds (antibiotics) are added to the fertilizers to kill the soil bacteria and thus stop the natural nitrogen cycle. As a consequence, more and more ammonium fertilizers are needed each year, and in the long run this practice leads to a sterile soil which is no longer capable of supporting plant growth on its own without the addition of artificial fertilizers.

This is especially the case in tropical regions, where the soils are intrinsically poorer (lateritic soils) and the only way in which the nutrients can be kept circulating is through an intricate web of ecosystemic relations[2]. It should not be forgotten that it is precisely from the Southern countries of the tropical latitudes that the industrialized world intends to import most of its energy crops (see Section 4.3).

Organic agriculture offers a clear-cut solution to this problem, since it relies on crop rotation and organic manure and not on mineral fertilizers and soil antibiotics to maintain the natural soil fertility (Cobb et al., 1999, Pacini et al. 2003).

8.3.2 Water pollution

The use of fertilizers and pesticides in conventional agriculture causes two serious water-related problems, i.e. groundwater contamination and eutrophication (see Chapter 6).

The issue of the availability of pristine drinking water is not to be underestimated, especially in densely populated countries where the natural reservoirs are shrinking year after year. The time necessary for the recharge of an underground aquifer is in the order of magnitude of several decades, and even low contamination levels of Persistent Organic Pollutants (POPs) such as the typical pesticides are virtually impossible to revert, and can cause intoxication in humans[3].

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[2] Mc Neil, 1972.

[3] See for example the WWF campaign on the POP human chronic intoxication: http://www.wwf.it/lavoro/campagne/detox/home.asp.

The excessive proliferation of algae in freshwater bodies and in coastal ecosystems as a consequence of fertilizer runoff (eutrophication) is also a serious issue, leading to the loss of biodiversity (fish death caused by abnormal consumption of dissolved oxygen).

Once again, the complete lack of fertilizers and pesticides in organic agriculture prevents these problems from arising altogether.

8.3.3 Biodiversity

A common practice in conventional agriculture is the use of weed-killers, which are toxic chemicals that kill a wide range of unwanted plant species and only spare those plants which are intended to be cultivated as crops. Crops are also treated with toxic chemicals (pesticides) which are applied in order to control pests such as leaf-damaging insects. Both these types of chemicals kill the animals living near and in the cultivated fields (earthworms, beetles, butterflies, etc.) reducing their biodiversity. Also, weed-killers and pesticides jeopardize the animals occupying higher trophic levels (birds, reptiles and mammals) for two reasons: firstly, they can be affected by the lack of small animals that they normally eat, and, secondly, they can be intoxicated because of bioaccumulation[4]. The latter effect was first pointed out in the famous book by Rachel Carsson "Silent Spring" (1962).

On the contrary, land cultivated with organic methods can host more natural biodiversity. In organic farm soils, the presence of beetles, earthworms and other invertebrates (bees, butterflies, bumblebees and spiders) is larger, as well as the variety and number of natural weeds (van Masvelt et al., 1998). In particular, biodiversity is especially rich in field margins, due to the variety of habitats they host and also their role in the dispersal of species in the agricultural landscape. If the margins are free from weed killers, they can host more flowers, which attract more bees, butterflies and other insects. This will in turn result in a positive effect on pollination and also on the bird population. (Cobb et al., 1999).

A second type of biodiversity that is equally important is that of the crops themselves, i.e. agricultural biodiversity. In most cases, conventional agriculture relies on few highly selected varieties, which are cultivated extensively on large plots of land. This practice not only impoverishes the soil, as explained in section 8.3.1, but also causes a severe reduction of the food diversity available to consumers. Roughly three quarters of the thousands of crop varieties that were originally selected by mankind in almost ten thousand years of farming have been wiped away by industrialized agriculture practices in the 20th century alone, and this trend is ongoing[5].

[4] Bioaccumulation is a term used to describe the increase in concentration that happens when a toxic chemical (e.g. a pesticide) is transferred from a lower trophic level (e.g. plants or small herbivore animals) to a higher one (e.g. carnivores) through feeding.

[5] http://www.fao.org/newsroom/en/news/2004/47027.

Besides being a huge genetic loss in itself, this mass extinction of agricultural varieties exposes humankind to larger and larger potential risks, since large monocultures are more easily susceptible to epidemics and pests, and require continuous treatment with pesticides. In these conditions, pests easily develop resistance to treatment, and more and more aggressive treatments are needed, establishing a negative loop.

All these problems related to the impoverishment of agricultural biodiversity are taken to more extreme consequences in the case of GM crops, where the lack of genetic variability increases. In GM crops the gene pool is severely restricted, and in the event of a disease outbreak the consequences could be worse than in traditional crops. It is noteworthy that rapeseed used for biodiesel production is among the most widespread GM species[6], together with soy, corn, cotton.

On the contrary, organic agriculture always uses a much larger number of crop species, since it relies on natural crop diversity instead of mineral fertilizers and pesticides for resistance to diseases and local environmental conditions. This wider range of agricultural species not only provides more variety to the consumer, but reduces the stress to the soil, functions as a preventive measure against invasive weeds and pests and limits the risk of a massive loss in the case of disease outbreaks.

The international Convention on Biological Diversity (CBD) was signed by 188 countries at the United Nations Conference on Environment and Development in Rio de Janeiro (1992)[7], with the aim of promoting conservation and sustainable use of natural and agricultural biodiversity. More recently, further recognition of the importance of agricultural biodiversity in particular was achieved in the International Treaty on Plant Genetic Resources for Food and Agriculture (2001), ratified by 55 countries[8]. However, little has been done in practice until now to halt the current trend towards in situ reduction of agricultural biodiversity, and the more widespread adoption of organic agriculture and its preservation where it already exists appear to be the only viable option in this sense.

8.3.4 Landscape

Landscape maintenance is increasingly recognized as an important function of agriculture. Landscape is defined as the appearance of an area, which is produced by the interaction among natural and cultural factors (Council of Europe, 2000). Also, landscape can be characterized as organized land (by nature and by man), i.e. as a complex of geographically, functionally and historically interrelated ecosystems (Doing, 1997).

A landscape can be said to have a high quality when it allows an identification and orientation in space and time (Hendriks et al., 2000). This means that an observer perceives it as a coherent and harmonic unit, which provides on the one

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[6] Clive J, 2005, http://www.isaaa.org.
[7] http://europa.eu/scadplus/leg/en/lvb/l28102.htm.
[8] http://www.fao.org/ag/cgrfa/itpgr.htm.

side legibility and orientation in space, and on the other side information on the historical development and on the seasonal variation (orientation in time). According to Hendriks et al. (2000), another aspect which is very important in determining the landscape quality is diversity, which is considered a positive aspect if accompanied by landscape coherence (order), otherwise it would be seen as chaos and lack of planning.

Shifting from conventional to organic agriculture improves in many cases the quality of rural landscape. It can be said that in general conventional agriculture produced a homogenization and an impoverishment of the landscape appearance. The reason is the reduction of the number and variety of cultivated crops because of the search for scale economies and for the varieties with highest yield (in terms of tons produced per hectare). The consequence is a smaller diversity of biotopes, and therefore reduced ecological infrastructures and degradation of landscape.

On the contrary, as a consequence of more agricultural and natural biodiversity, organic agriculture has a positive effect on rural landscape. This is confirmed by a study conducted by van Mansvelt et al. (1998) on four Dutch organic farms and their neighbouring conventional farms. The observations were complemented by a study on three organic and four conventional farms conducted in west Friesland (The Netherlands).

The organic farms were found to differ significantly from their neighbouring conventional farms and presented more diversity of species and habitats. In particular, organic farms were characterized by: a) more land-use types (e.g., crops, grasslands, husbandry, vegetables, fruits, shrubs), together with greater diversity in biotopes; b) more farmland surface dedicated to natural elements, more species of herbs in the grasslands, the vergers of the crops, along the roads, in the orchards, the hedges, around the compost heaps, etc. c) more crop rotations and more land with a greater diversity of vegetables and fruits, as well as more species of animals; d) higher number and more species of woody elements (trees and shrubs), present in more types of spatial arrangements (forests, hedges, bushes, lanes, yard plantations); e) more elements on the yard; f) more variable sensorial information, that is, more forms, colours, sounds, spatial experience.

The authors explain the higher landscape quality of organic farming mainly with the need for wide crop rotations, which results in a greater variety of crops and more colours, forms and textures and in a more harmonic relationship of the farm with its surrounding. Also, organic farmers are usually more interested in nature protection, including landscape appearance (Hendriks et al., 2000).

8.3.5 Food safety and food health

One of the main reasons why organic agriculture is becoming more and more widespread, even among the general public that is not especially concerned with environmental protection, is the concern about food safety and food health. Various food scandals associated with intensive cattle breeding contributed to the increasing perception of the risk derived by conventional agriculture: salmonella in eggs in 1987, BSE in 1996, dioxins and PCBs in Belgian animal feed in 1999, illegal steroid hormones in animal feed and meat in 1999, nitrofen, a banned pesticide, in German feed grains in 2002, and recently chicken' flu in 2006. Also the presence of GMOs in the raw ingredients used in the food industry (such as for example corn and soy beans) is cause for debate and notable concerns among many citizens, because the effects on the human organism are still not adequately assessed.

Also, the green revolution and the intensive techniques of cultivation and cattle breeding, while increasing productivity (measured as tons produced per hectare or as financial net income), may produce drawbacks in terms of food health. The reason is the intensive use of pesticides and fertilizers, whose residues can increase the risk of serious diseases such as cancer and others. The same holds for cattle breeding: the artificial feedstuff, and the associated medicinal compounds like hormones and antibiotics may have an adverse effect on human health.

One of the consequences of modern agriculture and cattle breeding is the increased "anonymity" of food. Food chains are much larger than in traditional agriculture and consumers do not have control on the way the food they buy is produced, and often not even on its geographical origin. Such geographical and knowledge chasm between producers and consumers needs a trust relationship among them. However, when trust is broken for the reasons explained before, consumers start looking for alternative ways to be sure that the food they consume is safe and healthy and may become willing to pay a price differential for it. Organic food certifying bodies play this role, assuring the consumers of the food quality (Banks and Marsden, 2001).

Organic food buyers believe that organic food has more desirable nutrients and fewer harmful residues. However, little unbiased high-quality literature has been produced on the exhaustive comparison of organic and conventional food.

Table 8.1 reports the frequency of positive samples with respect to pesticide residues (i.e. those above the limit of method detection) in a large American database (94 000 samples) and in a Belgian one (a few thousand samples). As one might expect, conventional food is more often found to contain traces of pesticides, whereas pesticides residues are more rarely found in organic food. Integrated Pest Management (IPM) occupies an intermediate position.

Table 8.1 Pesticide residues (% of the frequency of positive samples)

	USA (Baker et al., 2000)			Belgium (AFSCA- FAVV, 2001)	
	USDA (1994-1999)	California DPR (1989-1998)	Consumers Union (1997)	Federal State, 2000	Large scale distribution 1995-2001
Organic	23	6.5	27		12
Integrated Pest Management	47		51		
Conventional	73	31	79	46	49

Source: Pussemier L., 2006

The same results were reached also by Woese et al. (1997) and Baker et al. (2002). The former, who performed a wide literature review (more than 150 papers), found a slightly lower content of pesticide residues in organic vegetables and fruit. However, when pesticides were found in conventional crops, they were still well below the maximum allowed amount. The latter analyzed three data bases that gathered information on pesticide residues in more than 90,000 samples of the 20 most common crops. The result was that, as expected, organic crops contained fewer and less concentrated pesticide residues than conventional crops. IPM crops again occupy an intermediate position. On the average, they contained pesticides approximately one third as often as conventionally grown foods did.

According to various authors, the fear for pesticides is exaggerated (Brandt and Mølgaard, 2001, Trewavas, 2004, Pusemier et al., 2006). They claim that the difference with conventional food is very small thanks to the more and more restrictive rules on pesticides. It was never demonstrated that the residues below the actual legal limits represent a hazard for human health.

To this argument it might be replied that it is always very hard to try and scientifically prove the effects of low-level chronic contamination, since in order to collect the necessary experimental evidence impractically large samples and long observation times would be required. Furthermore, it would be necessary to isolate the investigated cause from all the others which are known to contribute to the same chronic diseases (e.g. traffic pollution, tobacco smoke).

In any case, it is incontrovertible that chemicals can have unexpected effects in the long run due to accumulation of various substances and synergy with other sources of pollution. For this reason, it would seem to be wise to adopt a precautionary principle.

In the review by Woese et al. (1997) it was found that organic food is often found to contain less nitrate than conventional agricultural products, due to different fertilization methods (manure fertilization instead of mineral fertilization). A study from the Belgian AFSCA FAVV confirms this finding: the mean value of nitrate content in their samples was 1,703 mg/kg for the organic products and 2,637 mg/kg for the conventional ones. Exposure to nitrates can be a worrying concern for two reasons: 1) nitrate is hazardous for humans because in the intestines it is converted to nitrite, which then combines with haemoglobin, thus reducing tissue oxygenation; 2) nitrate and nitrite are also precursors to carcinogenic nitrosamines, which form in the acidic conditions of the stomach.

There is still much ignorance about the difference in health effects of organic and conventional food. For example, some authors argue that organic food might be more dangerous because not using of synthetic pesticides increases the possibility to be affected by mycotoxins (toxines produced by fungi, the most commonly affected crops are cereals) and biotoxins such as phytotoxins (natural defence mechanism against insects, diseases or as a reaction to stress).

However, different analyses give contradictory results. On the one side, avoiding pesticides makes plants more vulnerable to pest attacks, on the other side organic methods of production (long crop rotations, soil ploughing to control weeds, choice of varieties) reduces the risk of contracting them (Pussemier et al., 2006). Therefore, it is not correct to say that organic agriculture automatically leads to a higher content of mycotoxins.

As regards phytotoxins, the effects of their higher content in organic food is also not clear. In fact, organic food proponents argue that artificial pesticides make the plants loose the metabolites involved in self-defence, which are considered healthy for the human body, since they are similar to medicines. On the contrary, organic food opponents argue that the higher content of defence-related metabolites is bad for the human body, because of their similarity with pesticides and other poisons (Trewavas, 2004).

Another point to investigate is the difference in content of desirable nutrients in organic and conventional food. Some of the studies reviewed by Woese et al. (1997) find that organic potatoes have a higher vitamin C content. Some studies on vegetables arrived at the same conclusions. Apart from that, little difference is often found in the content of the most important plant nutrients (carbohydrates, proteins, vitamins and minerals). In any case, according to Brandt and Mølgaard (2001), the possible lower content of nutrients in conventionally-grown crops would not make a difference in the average western diet, which already contains more of these elements than what is needed.

One further issue is that of food intolerances. These ailments are becoming more and more common in industrialized societies, and there is growing concern that they may be spurred by excessive exposure to a very limited range of genetically homogeneous crops. Of course, this is even truer with GMO-containing food, both because of the severely restricted gene pool of GMOs, and because of the introduction in these organisms of new proteins to which the human body is not accustomed at all. Scientific evidence of the hazards posed by GM food is still scarce but there is reason for concern (Paparini et al., 2004; Domingo, 2000; Pryme and Lebcke, 2003). Once again, the adoption of the precautionary principle seems to be the wiser choice.

One last point is that of the better taste of the organic products, which is nonetheless more traceable back to the different production techniques rather than to the absence of pesticides. In fact, organic agriculture products tend to be gathered when they are more ripe, while early gathering of conventional vegetables and fruit reduces their taste.

Summing up, it is not (yet?) proved that organic agriculture has clear and decisive beneficial effects of human health. However, the precautionary principle tells us that when the effects of a technological innovation (such as conventional agriculture in this case) are not scientifically proven but potentially dangerous and irreversible, it is wiser not to use it. Organic agriculture might be seen as a way to apply the precautionary principle to our alimentation.

8.4 *Financing mechanisms: the Common Agricultural Policy*

The most important financing source for Italian agriculture (as well as for that of the other European countries) is the Common Agricultural Policy (CAP). The CAP provides mechanisms rewarding the attempts to reduce the environmental impact of agriculture, especially after the 2003 reform. The Agenda 2000[9] establishes that the CAP is made up of two ”pillars”: 1) market and income policy and 2) sustainable development of rural areas.

The CAP promotes good environmental practices in two ways. First of all, farmers are not granted CAP funds if they do no respect some minimal environmental protection requirements, the so-called *cross compliance conditions*, which have become compulsory since the 2003 CAP reform. The cross compliance conditions are defined by Member States. They include rules on soil protection, maintenance of landscape and habitats, and the preservation of permanent pastures.

Secondly, the *agro-environmental scheme* compensates farmers that commit themselves to using environmentally friendly farming techniques, which include low-intensity pasture systems, integrated and organic management, maintenance of landscape and historical features (e.g. hedgerows, ditches and woods), protection of biodiversity and ecologically valuable habitats.

In order to benefit from agri-environmental financing, farmers must commit themselves for a minimum of 5 years. The upper financing ceiling is established at 600€/ha per year for annual crops and 900 €/ha for specialised perennial crops. These amounts can be exceeded by Member States, if they declare it as state aid. In 2003 the average share of organic or in-conversion land of the total supported land under the agri-environmental scheme was 7%. In the same year, agri-

[9] Agenda 2000 include a set of twenty legislative texts that are aimed at strengthening the European policy and at giving the European Union a new financial framework for the period 2000-2006. One of its four axes was related to the agricultural sector: the objectives are to continue the changes began in 1988 and in 1992, to increase European competitiveness and environmental protection, and to ensure a fair income for farmers (for further information see http://ec.europa.eu/agenda2000/index_en.htm). Also, the idea was to simplify the legislation and decentralise its application.

environment programmes supported almost half of the organic land area in the EU-15[10].

Subsidies are one of the main drivers for conversion to organic agriculture, together with the reduction of profitability of European conventional agriculture (Mielgo et al., 2001). For example, Pacini et al. (2003) show that two out of three organic farms taken as case studies presented higher gross margins than the corresponding conventional farms (the third farm analyzed experimented higher difficulties because it was in the conversion phase). This was due not only to the premium price (the higher prices for organic products) and the lower cost for fertilizers, but also to the agricultural subsidies. In two of the analyzed farms, agricultural subsidies accounted for more than half of the total revenues.

In 2006, 2,282 million euros were devoted to agri-environmental schemes, i.e.19% of the funds assigned to rural development (12,012 million euros), which constitute 22% of the total agricultural budget (55,449 million euros).

In the EU-15 5,098,246 hectares of land are organic or in conversion (2003 data, source: Eurostat data-base). Around one fifth of this land is cultivated in Italy (1,052,002 hectares). In Table 8.2 some figures on the agro-environmental scheme are reported. The data refers to 2002 because more recent data are not available yet.

Table 8.2 Funding granted under the agro-environmental scheme [11]

		Area (hectares)	**Public expenditure committed (thousand euros)**		**Average premium per hectare (2002)**
			Total	of which EAGGF	
Italy	Total	1,353,379	299,341	148,845	221
	of which organic farming	297,919	100,261	52,568	337
Total	Total	35,515,026	3,249,440	1,761,190	91
	of which organic farming	2,484,753	460,207	246,963	185

8.5 *Organic Agriculture vs. Energy Farming*

One of the main objectives of the new CAP is to guarantee the sustainability of the agricultural sector. As stated in art. 22 of the 2003 CAP reform:

"*Support for agricultural methods designed to protect the environment, maintain the countryside (agro-environment) or improve animal welfare shall contribute to achieving the Community's policy objectives regarding agriculture, the environment and the welfare of farm animals. Such support shall promote:*
(a) ways of using agricultural land which are compatible with the protection and improvement of the environment, the landscape and its features, natural resources, the soil and genetic diversity,

[10] European Commission, DG Agriculture and Rural Development, 2005
[11] http://ec.europa.eu/agriculture/agrista/2004/table_en/3623.pdf

(b) an environmentally-favourable extensification of farming and management of low-intensity pasture systems,
(c) the conservation of high nature-value farmed environments which are under threat,
(d) the upkeep of the landscape and historical features on agricultural land,
(e) the use of environmental planning in farming practice,
(f) the improvement of animal welfare[12]*"*

As explained in Section 8.1, ***the objective of reducing the environmental impact of the agricultural sector, as stated in art. 22 of the CAP reform, contradicts the objective of supporting a large scale biodiesel sector. Instead, it is well respected by organic agriculture***. This point can be further developed following the first four points required by the article quoted above.

(a) Energy farming does not really assure protection and improvement of the environment. In conventional agriculture, fertilizers and pesticides are used. On the contrary, organic agriculture, by using natural methods for increasing fertility and reduce plant diseases, is responsible for less air, water and soil pollution. Natural resources are normally not managed in a sustainable way in conventional agriculture, because of a progressive reduction of soil fertility (see Section 8.3.1). Finally, a large-scale biodiesel sector would imply a dramatic reduction of agrarian genetic diversity, because it would imply to transform a large part of the European land in huge monocultures of oil seeds.

(b) In order to increase yield and profitability, energy farming is normally performed using intensive agricultural methods. On the contrary, organic farming is performed, by definition, with extensive methods.

(c) For all the reasons explained in this chapter, the conservation of high-natural-value farmed environments is more likely to occur under organic agriculture conditions, where the crops to be cultivated can be chosen according to the potentiality of the locally-available natural resources.

(d) Also, landscape and historical features are better maintained and improved by organic agriculture, because of the increased diversity and the higher sensitivity to landscape values that organic farmers often have. On the contrary, a huge monoculture occupying almost one third of the Italian agricultural land would dramatically change the rural landscape and produce a vast homogenization. It is worthwhile to remember that one of the features that give quality to the landscape is variation (see Section 8.2.4).

Supporting biodiesel requires the employment of public resources, and it would be more and more so if the target of the Directive were to be respected.

Energy crops are subsidized by the CAP in two ways. First of all, farmers receiving the subsidies for set-aside land can cultivate energy crops. Secondly, a

[12] Council Regulation 1783/2003.

new energy crop aid was established with the 2003 CAP reform, consisting in 45 € per hectare. The aid includes a maximum guaranteed area of 1,500,000 hectares (this means that the maximum amount of financing is 67,500,000 €), and it is granted only to farmers who have an agreement with a processing industry (not necessarily in the same Member State). Also, energy crops are subsidized by the governments in two ways (see Chapter 4): 1) with de-fiscalization measures, which means a reduction in energy revenues for the state; 2) with biofuel obligations, which will have as a probable consequence an increase of the fuel final price for car drivers. Furthermore, biofuels are financed by means of subsidies to research granted in the framework of the Sixth and Seventh Framework Programmes (see Section 4.3.5).

The point that is being made here is that ***it is not worthwhile to invest public resources and such a large amount of land for an activity that presents so many serious drawbacks in terms of environmental impact and such modest advantages in terms of fossil fuel savings. It would be better to use the same resources to promote rural development through the organic agriculture sector***, which has fewer drawbacks and provides more valuable services to society (i.e. maintenance of soil fertility, reduction of water pollution, biodiversity protection, landscape improvement, healthier, safer and tastier food). Also, ***by reducing the use of fertilizers and pesticides, organic agriculture contributes to reducing the energy need of agriculture***.

Like biodiesel, organic agriculture should be stimulated both through agricultural incentives from the European Commission and demand policies from the governments (in the case of biodiesel, de-fiscalization and biofuel obligations; in the case of organic agriculture, information campaigns and purchases by public administration)[13].

Besides, ***the services provided by the organic agriculture are perhaps better regarded by consumers than the ones provided by biodiesel***. In fact, consumers are willing to pay a premium price for organic agriculture, which compensate for its higher costs and lower yields. On the contrary, in general, despite the numerous campaigns promoting it, biodiesel is sold only if its price is similar to the one of diesel.

For example, a survey conducted in Southern Norway (Torjusen et al. 2001) demonstrates that when buying food part of the consumers take into account not only the price but also environmental, ethical, social and health factors. This is interpreted as a reaction to the increasing perception of the risks associated to modern agriculture (risks for health, risk for agro-biodiversity, risks related to the increasing air, soil and water pollution, etc.). The same observations are made by Saba and Messina (2003), who carried out a survey with a sample of almost one thousand questionnaires. They also found that people tend to give a higher value to organic fruits and vegetables, because they consider them to be healthier, more environmentally friendly, tastier and more nutritious than conventionally grown

[13] European Action Plan for Organic Food and Farming, SEC(2004) 739

food. Also they find a positive correlation between organic food consumption and the perception of the risk associated with pesticides. Bank and Marsden (2001) mention another survey carried out by the English Soil Association which finds out that one third of the general public buy organic food because it is healthier (53%) and tastier (43%), it is free of GMOs (30%) and it is environmentally friendly, and assure animal welfare (25%)

Summing up, ***if the real objective of biodiesel policy is to promote rural development, organic agriculture is a better strategy.*** As Banks and Marsden point out (2001): "*the option of conversion to organic status is now being regarded as one key trajectory for agricultural development and the agro-food sector*" (pag.109).

9 Conclusions[1]

In order to make it competitive with oil-derived fuels, biodiesel must be supported through 1) agricultural subsidies, 2) de-fiscalization and 3) biofuel obligations. Also, energy farming requires a large extension of land that must at least in part be subtracted from other uses. This work was meant to investigate whether it is an advisable strategy to invest public resources and large extensions of land to promote biodiesel.

The strategy on biodiesel is a matter of public policy. It involves many different social actors and may have various (positive and negative) impacts. Therefore, an integrated evaluation is necessary in order to take into account all relevant issues, in different dimensions and at different scales. One effective way to discuss the social opportunity of investing public resources and using a large extension of land for large-scale biodiesel production is to structure the analysis using a Social Multi-Criteria approach.

By doing this, it was demonstrated that many of the points that are often used to claim that biodiesel should be supported are groundless. In order to further develop this conclusion we may refer to the arguments of biodiesel promoters listed in Section 4.6.

1. ***A large-scale biodiesel production would only give a small contribution to the reduction of greenhouse emissions***. The reason is that the entire biodiesel process requires several energy inputs, which are generally derived from fossil fuels. If the process were to be fuelled with biodiesel itself, the output/input energy ratio would be even lower and therefore the land requirement would be higher. Taking into account the energy requirement of biodiesel production (fertilizers, pesticides, fuel for transport and for machinery in the agricultural and in the processing phases), the delivered energy of the biodiesel production chain is a very small amount. Moreover, if one also takes into account the energy required for transporting the oil seeds (if they are produced in foreign countries) or the food that must be imported as a consequence of the substitution of food crops (if oil seeds are produced nationally), the energy savings appear to be irrelevant.

2. As a consequence, ***biodiesel would not allow Italy to increase its energy self-sufficiency and energy security***.

3. ***A large-scale biodiesel production would not be a solution for the increasing energy expenditure***. In fact, biodiesel is approximately twice as expensive as oil products and the fact that the final price is similar is only due to tax exemption. Also, it might be imagined that, since fossil fuels are used in all production phases, increases in oil prices will translate into increases in biodiesel price.

[1] The conclusions discussed here refer only to earmarked energy crops and not to recycling used materials such as agricultural residues and frying oil. The latter is an advisable option, because it allows simultaneously reducing the need for raw materials and the amount of wastes. In this sense, it does not need further analysis and should always be encouraged. What might be controversial is to dedicate land, water and human labour to producing biodiesel instead of other crops.

4. ***Biodiesel is not the best solution for reducing urban pollution***. If compared with diesel, it allows a slight reduction in particulate matter and volatile organic compounds (the most relevant indicators for urban pollution). However, in general biodiesel is much more polluting than other fossil fuels currently available on the market, i.e., petrol, natural gas and liquefied petroleum gas.

Against the modest advantages (a small substitution of fossil fuels and a slight reduction of urban pollution with respect to diesel), the disadvantages of a large-scale biodiesel production are apparent.

Due to the low yield, ***the land requirement is enormous***. If the target of the European Directive 2003/30/EC were to be reached (5.75% of the energy demand for transport, that is, only around 1.3% of the total energy demand), under the most favourable hypotheses in Italy about 3.8 million hectares would be needed, i.e. 12% of the total Italian territory and almost one third of the total agricultural land. In other words, if the oil seeds needed to accomplish the European Directive were cultivated in Italy, they would at least partially substitute food crops. The result would be a ***big increase in food imports***.

Also, far from being "green" as frequently advocated, biodiesel is ***responsible of great environmental impacts***. In order to increase the low yield, methods typical of intensive agriculture would likely be employed, i.e. fertilizers, pesticide, machinery, large monocultures, and possibly biotech crops.

The only sound argument in favour of biofuels is rural development. European agriculture is passing through a crisis, because the prices are high with respect to the international competitors. The Common Agricultural Policy (CAP) faces this problem through a subsidizing system that absorbs almost half of the entire European budget. However, the CAP subsidies are increasingly blamed for distorting free competitiveness, keeping the European prices artificially low and thereby damaging the interest of the Southern food-producing countries. ***Biodiesel might be a solution for this problem: the European Union might continue financing the European agriculture without interfering with the food markets, and supporting rural development***.

However, if the objective were rural development, ***the CAP financing could be granted to other activities, which are also not competitive under a strictly economic point of view, but deliver more valuable services to society and present less serious drawbacks. An example might be organic agriculture***, which helps to reduce human pressure on the local ecosystems and preserve the natural fertility of the soil for future generations, besides providing healthier and better-tasting food and reducing the energy consumption of the agricultural sector.

The many services delivered by organic agriculture are considered valuable by a part of society. As a matter of fact, whereas car drivers choose biodiesel only if its (de-taxed) price is comparable to that of diesel, a small but growing share of population is willing to pay a premium price for organic crops.

In any case, if the biodiesel sector were really going to take off, the most likely scenario would be that it would import most of the required oil seeds from foreign countries. As a matter of fact, in Annex 11 of the Biomass Action Plan, it is calculated that in order to reach the target established in the 2003/30/EC Directive, almost one fifth of the European tillable land would be needed. For this reason, the European Commission states very clearly both in the *Biomass Action Plan* an in the *EU Strategy for Biofuels* that that it intends to support energy farming in Southern countries, where biomass productivity is higher and production cost lower.

It is easily foreseeable that if the European demand for biofuels increased because of biofuel obligations and other supporting policies, Southern countries might be stimulated to replace if not food crops at least native forests with big monocultures. The commodity frontiers for biofuels will penetrate into the Amazon and other tropical forests.

Energy farming would presumably have a big role in deforestation, because pristine forests would be cut down in order to cultivate energy crops. The consequences would be, besides a worrying reduction of wild biodiversity, a decrease in soil fertility, water availability and quality, and an increase in the use of pesticides and fertilizers, as well as negative social effects like potential dislocation of local communities, and an increase in CO_2 emissions due to deforestation.

Summing up, biodiesel cannot contribute to the solution of the problems related to the high dependency of our economy on fossil fuels, and it is arguably not the best solution for rural development. If we really want to reduce our oil consumption, we should look for other strategies, such as promoting energy efficiency and supporting other sources of renewable energy.

PART IV

CONCLUSIONS

Conclusions

1 Lessons learned

In this thesis, the SMCE approach was applied to two energy policy issues.

In the first case-study, the problem at hand was how to provide some isolated rural households in a natural park near Barcelona with electricity, whether by extending the grid or installing stand-alone photovoltaic systems. The issue caused a conflict between 1995 and 2000 among the Park administration (in favour of solar energy) and the household inhabitants and owners, plus the Mayor (in favour of traditional electricity). A retrospective SMCE was performed in order to explain the positions of the involved stakeholders and the factors that help the diffusion of off-grid photovoltaic systems in rural areas.

The second part of the thesis deals with the opportunity for the Italian government of supporting a large-scale biofuels production. The pros and cons of satisfying part of the energy need of the transport sector with biodiesel were analyzed through a variety of assessment criteria and taking into account different scales and dimensions.

Even though the case-studies dealt with two different renewable sources (solar energy and biomass), and referred to two different scales, i.e. local and national, some common considerations from the application of a SMCE approach to the evaluation of energy policies apply to both.

1. The need for incentives for renewable energy makes an integrated assessment of energy policies crucial for an efficient use of public financing.

In most cases, renewable energy is not competitive with traditional energy. In order to be profitable, it needs public incentives. For example, in Montseny Natural Park PV panels were cheaper because almost 80% of the expense was subsidized by the public administration. Biodiesel price is comparable with that of diesel because it is not burdened with taxes, which determine half of the price of diesel.

In order to guarantee a good use of the resources invested in supporting renewable energy, an integrated assessment is crucial to analyze the long-term impacts of the available alternatives in different dimensions and scales, and taking into account the consequences on the involved social actors.

2. The analysis of an energy policy requires an integrated assessment of a variety of different issues.

When evaluating a policy that might have wide impacts on different dimensions, such as normally happens when dealing with energy policies, an integrated and multi-disciplinary assessment is needed to have an idea of the trade-offs (for example in the case of biodiesel, greenhouse gas emissions reduction versus land requirement). The added value of SMCE with respect to mono-criterion analyses is clear in the two case-studies presented in this thesis.

In the Montseny case, if only the costs for the users and the local environmental impact were considered, PV systems would seem to be the best option and it would be difficult to understand the local opposition against them. However, if other criteria are included in the analysis, e.g. the possibility of having a rural enterprise, the conclusions on the pros and cons of different modalities for rural electrification might change.

As regards the second case-study, producing large amounts of biodiesel would have a variety of consequences in terms of land requirement, substitution of food crops, environmental impact of the agricultural sector, rural development, reduction in greenhouse emissions, etc. A great number of papers have been published on one or the other aspects, but they all offer a partial view on the issue, with the risk of giving biased policy recommendations. For example, if considering only the savings of greenhouse emissions, it could be claimed that biodiesel is environmentally friendly and should be promoted. However, if the energy savings are compared with the high land requirement and the use of water and fertilizers, they do not appear so worthwhile. The evaluation presented here takes simultaneously into account all relevant aspects and not only one issue at a time, allowing to clarify the relative importance of pros and cons of a possible large biodiesel production in Italy.

3. The evaluation of an energy policy requires taking into account the social dimension

Energy policies have an impact on different groups of social actors at different scales, and for this reason their objectives and interests should be taken into account. In this sense, SMCE is helpful because it allows structuring the evaluation using information from the social actors in all evaluation phases and deriving the criteria from their objectives. This aspect is evident in the two case-studies presented in this thesis.

In the analysis on rural electrification in Montseny, a technocratic analysis would have simply compared prices, environmental impacts and performances of PV systems vs. the electric grid, giving only a partial view on the real reasons of the conflict. However, the institutional analysis and the interviews were crucial for interpreting the position on rural electrification as a consequence of the expectations on the development strategy of the park. Therefore, one or another available alternative for rural electrification becomes the most advisable one according to the kind of management strategy that is chosen, i.e. conservationism or economic development. Putting the issue in this way may enhance the social debate on the real sources of disagreement and facilitate the achievement of an agreement.

The analysis of pros and cons of biodiesel in Italy also takes into account the objectives of the various social actors involved (car drivers, farmers, environmentalists) and derive some (but not all) criteria from them. In this way, the analysis can include a wide range of different aspects and give an all-encompassing picture of the possible consequences of a large-scale biodiesel sector.

4. When evaluating energy policy, the geographical and temporal scales are very crucial.

Decisions on the scale of the evaluation can significantly change the results. For example, in the Montseny case paradoxically a longer time horizon favours the grid extension against the PV systems. In fact, PV components must be replaced after some years, whereas the grid may last for a long time without replacement. Also, stand-alone PV panels do not produce environmental impact on a local scale, whereas an analysis of their entire life cycle would underline some pollution in the production and disposal of the PV components, especially the batteries. On the other hand, the greenhouse emissions saved by PV panels are not considered important by the decision-makers acting at a local scale, but might be important on a larger scale.

In the same way, the conclusions on the impacts of biodiesel production vary considerably at different scales. Using wastes (e.g. used oil or agricultural residues) to produce biofuels is an advisable strategy on a local scale, because it allows reducing the costs and the environmental impact of waste disposal, while at the same time reducing the use of fossil fuels. However, producing a large amount of biodiesel would require a large extension of land and would cause considerable environmental impact in the agricultural phase. Also, if considering a global scale, a large biodiesel production in Italy would even increase, and not decrease as normally expected, the total greenhouse emissions.

This raises the issue of who are the relevant stakeholders time-wise and space-wise in a SMCE.

2 Social Multi-Criteria Evaluation for energy analysis

This work has shown that Social Multi-Criteria Evaluation (SMCE) can be of great usefulness to support decision-making in energy policy. It has proven to be a flexible method, which can be used both for deciding about a project on a local scale (as in the first case-study) and for discussing about the pros and cons of an energy policy at a national scale (as in the second case-study).

Also, in this thesis SMCE has proven to offer valuable support to energy decision-making by allowing to link the consequences of alternative energy policies to the objectives and the interests of the involved social actors. Including in the analysis the social and economic aspects is important to avoid over-simplification and the consequent failure of energy policies. In fact, the success and the acceptability of energy policies depend not only on technical issues but also on their match to social requirements.

Last but not least, at the methodological level, SMCE has been shown to be more useful than either *Cost-Benefit Analysis* or purely technical analyses because it allows taking into account incommensurability, by not expressing all criteria in a single unit of measurement. This is particularly important when dealing with energy policies, which have different consequences in the environmental, social and economic spheres and at different scales.

Moreover, since renewable energies are in most cases not yet economically competitive with fossil fuels, they need public resources to gain a market. This is another reason why it must be made sure that public financing is used in the most socially desirable way, trying to find a compromise among the objectives and the interests of the groups of social actors. SMCE can provide a good framework for this task, shedding light on the different and sometimes conflicting aspects of energy problems and taking into account the interests and the objectives of the social parts.

3 Open problems and future directions of research

The strong dependency of Europe on fossil fuels is a reason for increasing concern because of the related problems in terms of environmental impact and energy security. Supporting renewable energy is seen as a necessary step to reduce the use of fossil fuels.

The Green Paper on Renewable Energy established in 1996 a target for renewable energy of 12% by 2010[1]. In January 2007, the European Union approved a set of measures with the objective of obtaining 20% of its overall energy from renewable sources by 2020[2]. Now the share of renewable energy in the European energy mix is about 6%.

SMCE can be widely used to help achieve the ambitious objectives of the European Union in matters of energy policy, on local, national and European scales. It can be used both for deciding whether to invest public resources to support a source of energy (as it was done for biodiesel in this thesis) and - on a smaller scale - a project (such as rural electrification through photovoltaics in Montseny Natural Park). Also, SMCE can be used to compare and choose among different alternative energy strategies.

Interesting possible future applications of SMCE may include analyses on the social desirability of various energy mixes and comparisons among different renewable energies. Also, the retrospective use of SMCE can in future be applied to other case-studies to help improve the quality and the social acceptability of energy policy.

The first case-study presented in this thesis showed how a retrospective SMCE can help investigate the factors that help or hamper the diffusion of a renewable

[1] COM/96/0576 final.
[2].http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/29&format=HTML&aged=0&language=EN&guiLanguage=en

energy source in a certain context and to better design energy policy in the future. Retrospective analyses are still quite unusual in public policy analysis, but they might constitute a useful tool to increase the public accountability of the decision-making processes. Also, retrospective analysis can constitute a useful basis for the public debate in those cases where a decision was already made but some other choices on the same issue must be still made.

As regards the second case study presented here, biofuels and biodiesel are increasingly a hot topic in the European debate on energy policy, as they are often presented as part of the solution of the energy crisis. With the Directive 2003/30/EC, the European Commission established that the share of biofuels in fuels sold at the pump must be at least 5.75% by 2010. The new energy strategy presented by the Commission on 10th January 2007 establishes a target of 10%[3]. They are ambitious goals, since we have not yet reached 1%.

Reaching this target will require an enormous amount of resources, both in terms of public funds and of land. For this reason, before implementing such an ambitious set of measures in favour of biofuels, it is important to take into account the wide range of different possible consequences.

In this context, it is important to give a comprehensive picture of the potentiality and the possible impacts of biofuel production, in order not to give messages based on simplistic projections that only take into account one aspect or the other. In particular, some points that are worth investigating further on biofuels are listed in Section 6.4 of Part III. Also, an interesting future direction of research can be to extend the analysis to other scales, i.e. analyze in more depth the effects of the European Directive on the producer countries. In fact, an increasing demand for vegetal oils might spur deforestation and other environmental impacts (soil erosion, contamination and excessive use of water, reduction of biodiversity). Other consequences can be a reduction of food sovereignty in Southern countries and an increase in the price of some basic commodities that might also be used as raw materials for biofuels (as it happened in January 2007 for corn in Mexico).

Finally, even though a large scale production of biofuels was shown to be undesirable due to the high land requirement, they still may give a contribution to the reduction of the European dependency on fossil fuels in small niche productions. Some examples include recycling used oils, energy farming in areas which are not suitable for food production (e.g. contaminated areas), and in small productions for the farmers' own use. These uses of biofuels can increase the overall efficiency of the energy system. In this sense, any possible niche biofuel use that does not compete for land with food production is worth to be further investigated.

3 http://europa.eu/rapid/pressReleasesAction.do?reference=IP/07/29&format=HTML&aged=0&language=EN&guiLanguage=en.

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Car manufacturers:
Automart (http://www.automart.com)
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KW Motori (http://www.kwmotori.kataweb.it/kwmotori/kwm.jsp?idContent=1330690&idCategory=902)

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http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=513
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UFOP (http://www.ufop.de/1299.php)
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Fuel Cells Canada: http://www.fuelcellscanada.ca/Industry%20news/vfcvp.html
FX History: historical currency exchange rates: http://www.oanda.com/convert/fxhistory
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Italian Biodiesel producers:
COMLUBE (www.comlube.it);
DP LUBRIFICANTI;
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GDR BIOCARBURANTI (www.biodiesel.it);
ITAL BI-OIL (www.italbioil.com);
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Curriculum vitae

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EDUCATION

2001-2007: Ph.D. in Environmental Sciences, Autonomous University of Barcelona. Dissertation: "*Social Multi-Criteria Evaluation and renewable energy policies. Two case-studies*", supervised by prof. Giuseppe Munda.

2001-2004: MSc. in Ecological Economics and Environmental Management with first class honour, Autonomous University of Barcelona. Dissertation: "*Social Multicriteria Evaluation of Rural Electrification. The case of Montseny Natural Park*", supervised by Prof. Giuseppe Munda.

1995-2001: Degree in Environmental Economics with first class honour, University of Economics Richard Goodwin of Siena. Dissertation "*Sustainability and European regional policy: the management of Structural Funds in the energy sector in Toscana and in Nordrhein- Westfalen*", supervised by Prof. Alessandro Vercelli and Prof. Riccardo Basosi.

1990-1995: High school "Liceo Ginnasio Statale C. Rinaldini", Ancona, Italy. Final score: 58/60.

GRANTS AND STAYS ABROAD

April-August 2007: research grant of the Department of Economics and Economic History, Autonomous University of Barcelona

2005-2006: Visiting scholar in Siena University, Department of Chemistry, under the supervision of professor Sergio Ulgiati and under a grant of the Agency for Management of University and Research Grants (AGAUR) of the Catalan government

January 2003-December 2006: Pre-doctoral grant of the Agency for Management of University and Research Grants (AGAUR) of the Catalan government, Autonomous University of Barcelona, Spain.

December 2002: Annual scholarship of The International Graduate School of Catalonia, Autonomous University of Barcelona, Spain, interrupted because it was incompatible with the AGAUR pre-doctoral grant.

January 2002-December 2003: Research grant of Siena University.

November 2000-March 2001: Scholarship of Siena University for a stage at the Wuppertal Institut für Klima, Umwelt, Energie, department of Material Flows and Structural Changes, Germany, under a research grant of Siena University.

October 1999-July 2000: Scholarship "Erasmus", University of Oldenburg, Germany.

August-November 1993: AFS exchange program, Dennis Morris High School of St. Catharines, Ontario, Canada.

RELEVANT COURSES ATTENDED

25th-31st July, 2004 "*Integrated Assessment for Environmental Management: Concepts, methods and tools for managing complex environmental problems"*, coordinated by Prof. Claudia Pahl-Wostl, Prof. Anne van der Veen, Prof. Jan Stel, Osnabrück University, Germany.

12th-13th December 2003, "*Industrial Ecology and Industrial Metabolism"*, held by Prof. R.U. Ayres, Autonomous University of Barcelona, Spain.

25th–29th April 2002: "*Social metabolism. Physical indicators of unsustainability*", organized by the Environmental Studies Centre of the Autonomous University of Barcelona with the collaboration of Interdisciplinary Studies Institute (IFF) of Viena, Autonomous University of Barcelona, Spain.

17th–20th July 2001: "*Pasivos Ambientales y Deuda Ecológica*", organized by CONACAMI Perú and Acción Ecológica, with the participation of Prof. J. Martinez– Alier, Lima, Peru.

11th –15th March 2001: "*Physical Accounting: Material Flow Accounting, Energy Flow Accounting, and Human Appropriation of Net Primary Product*", held by the researchers of the Interdisciplinary Studies Institute (IFF), in the framework of an Integrated Action Spain-Austria, between the Autonomous University of Barcelona (UAB) and the IFF, Viena, Austria.

PUBLICATIONS

Munda G. and Russi D., in press*, Energy policy for rural electrification: a Social Multi- Criteria Approach*, Environment and Planning C,

Russi D., 2006, *An integrated assessment of biodiesel policy. The Italian case.* Proceedings of the Ninth Biennial Conference of International Society for Ecological Economics, New Delhi, 15-18 December 2006

Raugei M., Russi D., 2006, *Biodiesel: A Solution for Urban Pollution?,* Proceedings of the Ninth Biennial Conference of International Society for Ecological Economics, New Delhi, 15-18 December 2006

Gamboa G., Munda G. and Russi D., 2006, *Tackling Local Conflicts Caused by Renewable Energy Sources: Lessons Learned from Real-World Case Studies*, in van den Bergh J.C.J.M., Bruinsma F.R., Vreeker R and Idenburg A., The Transition to renewable Energy: Theory and Practice, Springer-Verlag

Russi D., 2004, *La Deuda Ecológica*, El Ecologista, Nº 42: 48-50.

Cialani C., Russi D., and Ulgiati S., 2004, *Investigating a 20-year national economic dynamics by means of emergy-based indicators*, in the proceedings of the Third Biennial Emergy Research Conference, held on 29th-31st January 2004, in Gainesville, Florida.

Cañellas S., González A.C., Puig I., Russi D., Sendra C., Sojo A, 2004, *Material Flow Accounting of Spain*, International Journal of Global Environmental Issues, Vol. 4 (4): 229-241.

Ortega M., Puig I., Ramos J., Russi D., Ungar P., 2003, *Deuda Ecológica. El Norte está en deuda con los países del Sur*, Editorial Icaria, Observatori del deute en la Globalització, UNESCO for the Sustainability, Polytechnic University of Catalonia (published also in Catalan, Italian, French).

Russi D, Muradian R., 2003, *Gobernanza global y responsabilidad ambiental*, Ecologia Politica n°24: 95-105, Icaria Editorial, Barcelona.

Russi D., Martinez–Alier J., 2003, *El pasivo ambiental*, Ecologia Politica, n°24: 107-112, Icaria Editorial, Barcelona.

TEACHING

2004- 2006: Lecturer of the degree course "Principios de Economía", Autonomous University of Barcelona (35 hours per year)

PARTICIPATION IN PROJECTS

2006-2007: "*Anàlisi del Metabolisme Energètic de l'Economia Catalana*", financed by the Catalan Government

2001-2004: "*Development and application of a multi-criteria decision analysis software tool for renewable energy systems (MCDA-RES)*", financed by the European Commission (NNES-1999-NNES/273/2001).

LECTURES

18th November 2006: *Ecological Economics,* Master in Sustainable Development and Promotion of the Territory, organized by COREP (Consorzio per la Ricerca e l'Educazione Permanente), Università degli Studi di Torino (8 hours).

26th October 2006: *Criterios de sostenibilidad,* Master in Public Management and Sustainable Development, Universitat Autònoma de Barcellona, Spain (4 hours).

14th June 2006: *Social Multi-Criteria Evaluation of renewable energy systems,* Summer School Themes, Universitat Autònoma de Barcelona, Spain (5 hours).

3rd May 2006: *Il biodiesel in Italia: una vera opportunità? Un'analisi sociale, economica e ambientale*, Degree in Ecological Economics, Università di Pisa, Italy (2 hours).

26th November 2006*: La valutazione monetaria (caso di studio: il treno ad alta velocità in Val di Susa). La valutazione multi- criteriale sociale (caso di studio: il biodiesel in Italia)***.** Master in Sustainable Development and Promotion of the Territory, organized by COREP (Consorzio per la Ricerca e l'Educazione Permanente), Università degli Studi di Torino (5 hours).

2nd-6th June 2005: *Métodos de integración; Métodos de soporte a la decisión*; Master in Management of Coastal and Estuary zones, Universitat Politècnica de Catalunya, Barcelona, Spain (4 hours).

18th May 2005: *El análisis Multi- Criterial. El método lexicográfico y la MAUT. Un caso de estudio,* Master in Sustainable Development, Escola Industrial, Universitat Autònoma de Barcelona, Spain (4 hours).

10th – 12 May 2005: *La Evaluación Multi-Criterial Social*. *El análisis de Flujos de Materiales* y l*a metodología MIPS*, Specialization Course in Sustainable Development, organized by the Chamber of Commerce of Sabadell, Barcelona (6 hours).

5th May 2005: *Politiche energetiche per l'elettrificazione rurale. Un approccio basato sulla Valutazione Sociale Multi- Criteriale,* seminar for the Department of Economics, Università di Pisa, Italy (2 hours).

20th April 2005: *La Deuda Ecológica***,** III Curs d'Introducció a la Solidaritat i Cooperació Internacional, Fundació Autònoma Solidària, Universitat Autònoma de Barcelona, Spain (2 hours).

11th March 2005: *La valoración economica. Instrumentos de soporte a la gestión integrada* Master in Management of Coastal and Estuary zones, Universitat Politècnica de Catalunya, Barcelona, Spain (3 hours).

16th September 2004: *La deuda ecológica*, course "Globalization and North/South Imbalance", Universitat Internacional de Menorca Illa del Rei, Spain (2 hours).

23 Settembre 2004: *Evaluación multicriterio social para la gestión de los conflictos de la sostenibilidad,* Universidad Internacional del Mar, Moratalla (Murcia), Spain (3 hours).

21st May 2004: *La evaluación Multi- Criterial Social aplicada al debate sobre electrificación rural en el Parke Natural del Montseny,* course "Complex Systems, Public Policies and Environment", Ph.D. program in Environmental Science, Gerona University, Spain. (4 hours).

17th November 2003*: La deuda ecologica*, post- graduate course on Globalization, Cooperation and World Governability, Universidad Politècnica de Catalunya, Terrassa, Spain.

23rd October 2003*: El Análisis de Flujos de Materiales aplicada a España*, course on Industrial Ecology organized by the Catalan Industrial Ecology Network, Universidad Autònoma de Barcelona, Spain.

6th August 2002: *La responsabilidad social*, Master in Social Environmental Studies, Quito, Facultad Latinoamericana de Ciencias Sociales, Ecuador.

PARTICIPATION IN CONFERENCES AND WORKSHOPS

15th-18th December 2006, two papers presented in the 9th Biennial Scientific Conference of the International Society for Ecological Economics, New Delhi, India: *"An integrated assessment of biodiesel policy. The Italian case"* and "*Biodiesel: A Solution for Urban Pollution?"*

23rd–27th August 2005, paper presented in the 45th Congress of the European Regional Science Association "Land Use and Water Management in a Sustainable Network Society", Special session: "Transition to renewable energy", Vrije Universiteit Amsterdam, Olanda, "*Tackling Local Conflicts Caused By Renewable Energy Sources – Lessons Learned From Real-World Case Studies*"

5th May 2005: workshop "*Politiche energetiche per l'elettrificazione rurale. L'approccio della Valutazione Multi- Criteriale Sociale*", Department of Economics, Pisa University, Italy

11th-14th July 2004, paper presented in the 8th Biennial Scientific Conference of the International Society for Ecological Economics, Montreal, Canada: "*A Social Multicriteria Analysis of the conflict on rural electrification in Montseny Natural Park*".

10th May 2004, presentation in the workshop "Il Debito Ecologico. Chi deve a chi?", organized in the framework of the Degree in Regional and Environmental Economics and of the Degree in Sciences for the Peace, Pisa University, Italy: "*The Ecological Debt".*

5th November 2003, joint presentation with Prof. Giuseppe Munda in the workshop "L'energia solar fotovoltaica", Universitat Autònoma de Barcelona, Spain: "*El rendimento de las aplicaciones solares fotovoltaicas. Aplicaciones en ámbito rural*".

8th-10th October 2003, paper presented in ConAccount Workshop "Quo vadis MFA?", Wuppertal, Germany: "*Material Flow Accounting for Spain*".

28th-30th June 2003, poster presented in the 12th Annual Conference of the European Association of Environmental and Resource Economists, Bilbao, Spain, "*Material Flow Accounting for Spain*".

12th-15th February 2003, paper presented in the 5th Biannual Conference of the European Society of Ecological Economics "Frontiers 2", held in Tenerife, Spain: "*Material Flow Accounting for Spain*".

LANGUAGES

Mother language: Italian.

Foreign languages:

Spanish: very fluent
English: fluent
German: DSH certificate obtained in 2000 (intermediate level)
Catalan: basic