International Congress on Environmental Modelling and Software

1st International Congress on Environmental Modelling and Software - Lugano, Switzerland - June 2002

Jul 1st, 12:00 AM

Sesamo – DSS for Sustainable National Electric Power System

A. Caizzi

G. Catenacci

C. Cavicchioli

P. Girardi

F. Sala

Sesamo – DSS for Sustainable National Electric Power System

Caizzi A., Catenacci G., Cavicchioli C., Girardi P., Sala F.

CESI Centro Elettrotecnico Sperimentale Italiano (girardi@cesi.it)

Abstract: Many attempts have been made in order to approach the problems connected with the "sustainable development". Two way have been followed: integration of the environmental and social aspect into economical valuation (externalities) or evaluation of the environmental effects or damages, using complex models and a set of indicators. CESI has developed a decision support system (DSS), SESAMO, aimed at supporting national electric power system planning, giving awareness on the related environmental impacts. The system is composed of two main parts. In the first, users can create different power generation alternatives at national, regional and local scale, choosing among different energy sources and different power plant technology. Hence, he can choose among different kind of transmission net. The second part of the DSS permits users to perform environmental evaluation and to start a multi criteria decision process through inventory data, environmental indicators, at different grade of aggregation. SESAMO is a tool that can be advantageously applied when a decision should be taken dealing with National Electric Power Supply System, considered as a multi-goals problem (environment, economic, social), with more than one decision maker.

Keywords: Decision Support System, Electricity, Sustainability, LCA.

1 ELECTRIC POWER AND SUSTAIANABLE DEVELOPMENT

1.1 Introduction

The development of the a national electric power supply system can be considered as an indicator of the growth of a nation. The amount of available electricity per person can affect either public welfare or the economical growth. Moreover, for the whole industrial system the electric sector can be seen at the same time as a need and a driving force. So, it seems that providing the electric power supply system will support the development of the nation. In conclusion we can state that the electric power supply system plays a decisive role in the sustainable development of a country. So achieving a "sustainable electricity" can be one of the most important challenges towards a "sustainable Italy".

1.2 Tools for sustainability

Many attempts have been made in order to approach the problems connected with the "sustainable development"[De Leo et al., 2000 and 2001]. The aim of those approach were to introduce the environmental variables in the decision making process. We can state that two way have been followed:

1. Integration of the environmental and social aspect into economical valuation [European commission 1995 and 1997]. Following this approach the external cost (externalities), associated to an industrial system are evaluated [Crapanzano et al., 1997]. This approach enlarges the application field of the cost-benefit analysis, but keeps all the limitation of the mono-criteria methods.
2. Evaluation of the environmental effects or damages. These approaches use complex models that try to follow the pathway of the

pollutant. Usually a set of indicators is used to summarize the results. These methods are complex, need data not always available and usually refer to a specific geographical situation. On the other hand they are precise and science – based.

These two kinds of approach have different advantages and have been widely used. But, they cannot be applied successfully to strategic plan or policy, such as decisions concerning the future asset of the national electric power supply. This is a typical "multi-dimensional" problem, involving many stakeholders and several point of view. We do believe that a Decision Support System (DSS) is the right tools to face this kind of strategic problems. A DSS enables decision-maker to see trade off between different goal (economic, social, environmental) and *sub-goal* (atmospheric pollution, water, eutrophication, global warming…) and makes each different decision-maker aware of the environmental consequences of his decision and of the items of the others decision-makers.

2 THE DSS SESAMO

CESI has developed a decision support system, called SESAMO, aimed at supporting national electric power system planning, focusing on the related environmental impacts.

The SESAMO DSS is a multi-users tool. Each user can follow his decision process, using the evaluation tools in which he feels confident and stressing the goals that he considers more important.

The system is composed of two main parts. In the first, each user can create different power generation alternatives at national, regional and local scale, choosing among different energy sources (natural gas, wind…) and different power plant technology. Hence, he can choose among different kind of transmission net. Than an Inventory, based on a Life Cycle Assessment database, of the defined electric system will be available. The results of the Inventory can be now aggregated into a set of indicator (such as Greenhouse effect, Air Acidification, Water Eutrophication…) [ANPA 2001] different for each user. This two operations take the name of "building of the alternatives" and "analysis of the alternatives". The second part of the DSS is the evaluation phase. In this phase it is possible to evaluate the alternatives and the users can compare their own alternatives and their own criterion with each other. In other words a *decision making process* starts. A manager of the system controls the *decision making process*.

2.1 Building of the alternatives

The first part of the DSS, is ruled in a stand-alone modality. Each user can build his own electric power supply system. In order to help the user to perform this phase three tools are made available:

1. A database concerning the other economic sectors, describing the forecasted electric and energy demand at national, regional and local (provincial) scale. More over there is a description of the environmental stresses related to each sector. This database is called "other sector dB". The "other sector dB" can be a guide for the user in choosing the amount and the distribution of the electric power production.
2. A GIS database, describing the state of the environment at the three different geographical scales (national, regional provincial). The "state of the environment" should help in choosing the power generation technologies on the basis of the environmental vulnerabilities.
3. A LCA database describing the different power generation technologies already present in the Italian scenario and the technologies that will be available in a short middle – term scenario. The database also includes the upstream phases (i.e. production of fuels) the construction and decommissioning of each type of power plant and, of course, the power generation phase. Moreover the database comprehends a LCA of different kind of lines and cables for High Voltage, Middle Voltage and Low Voltage electric energy transmission. This database is called "electric system dB". It enables each user to develop a complete and comprehensive LCA of the Electric Power supply system he is building up.

Using these tools the user can build up his electric power supply system choosing to use a provincial, regional or national scale.

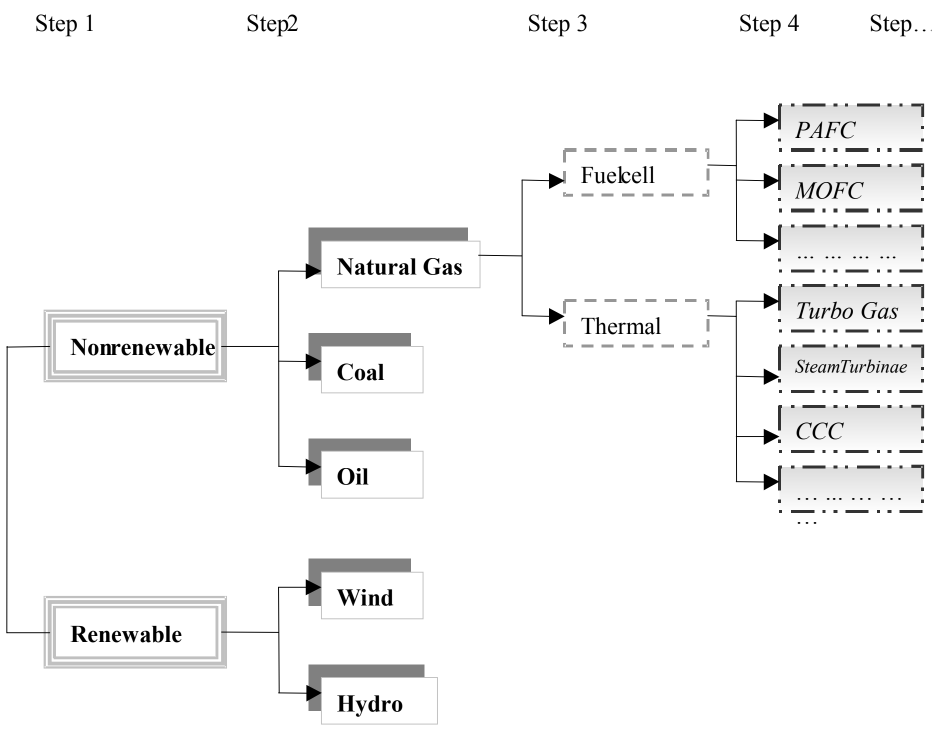

Figure 1 Different step available in building the alternatives. The first two step refer to energy sources while further steps refer to technological choices.

He can perform this phase through different steps: he can choose the amount of renewable and non-renewable energy, than the amount of each energy sources, than the different kind of technologies used for power generation and, finally, different technologies in pollution prevention. The user can jump from one step to another or bypass some steps. Figure 1 is an example of the different step available in building the alternatives.

The energy sources and the derived fuels available in SESAMO are: Natural Gas, Coal, Fuel Oil, Lignite, Orimulsion, Diesel Oil, Wind Energy, Hydro Energy, Solar Energy, Energy Crops, Urban Waste, Bio-gas. Once the supply system (i.e. the alternative) has been built, the related LCA inventory is made available by SESAMO. Since an Inventory is usually a long list of flow and it is not user friendly, SESAMO give the chance to group the results into environmental impact categories chosen by the user.

Some examples of environmental impact categories may be Greenhouse effect, Air Acidification effect, Depletion of non-renewable Resources and so on. These aggregations are called "technical" since the political assumptions beyond them are not so relevant.

2.2 The analysis of the alternatives

Once the user has built one ore more alternatives, he can analyse them from the "sustainability" point of view. It is not compulsory to build an alternative to perform the analysis since one user can prefer to analyse an alternative built by another user or by the manager of the system.

During the analysis the user describes the alternatives through a valuation vector. This valuation vector can be built using goals and criterion on a different scale of aggregation. An example of goal 1 can be improving environmental quality. A sub-goal (criterion 1) can be the reduction of atmospheric pollution. A further sub-goal or criterion (criterion 1.1) can be the reduction of emission of greenhouse gasses or the reduction of gasses that can lead to acidification.

Figure 2 resumes the structure described above and it is called valuation tree.

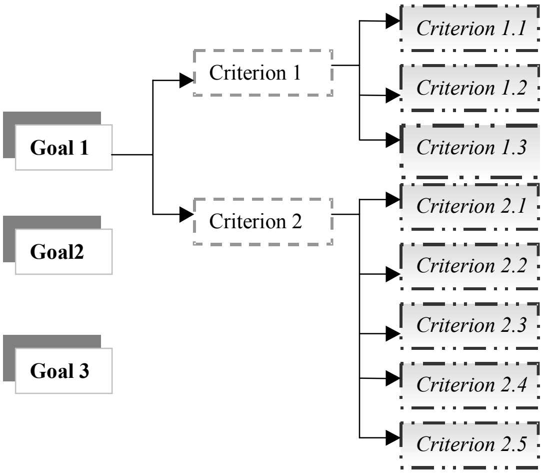

Figure 2 Example of evaluation tree

The valuation can be composed of goals, or criteria, belonging to each level or by a mix of them. Once the valuation vector is built up the user can assign weight to the different selected criteria. In other words the valuation phase starts.

2.3 The valuation phase

The valuation phase can be performed in a stand-alone modality or in a multi-user modality. Once an alternative is selected it is possible to view the valuation vector and the related valuation tree. In this phase it is possible to assign and to change utility functions and weights to the different criteria. In those operation the users are supported by the “other sectors dB” that enables them to compare the sustainability of the electric sector with the other sector and by the “state of the environment GIS” that aware users about the existing environmental pressure and vulnerability at the different scale. This is an important aid in weighting goals and in choosing utility function.

For example if one user’s goals is Air Acidification reduction, it could be helpful in weighting this goal and in shaping its utility function, to see the vulnerability map to this kind of pollution at provincial and regional scale (figures 3 and 4).

Those information are tools for a single user or for multi-decisors for choosing utility function

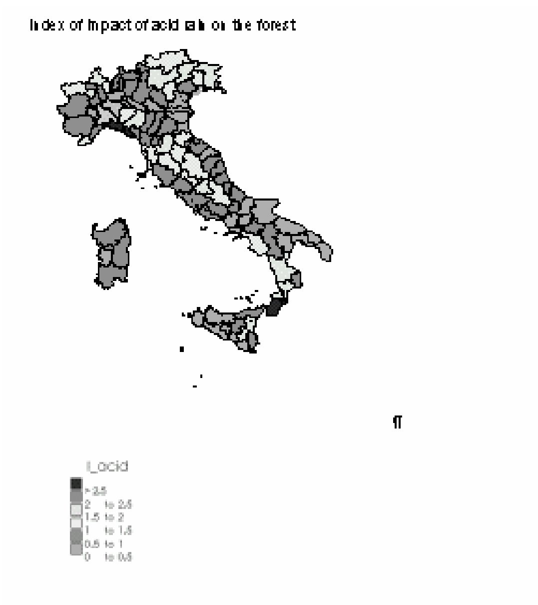

Figure 3 An example of vulnerability map of SESAMO “state of the environment”: Index of impact of acid rain on the forest at provincial scale defined as I_Acid= the ratio between the local and national deposition rate times the ratio between the local forest percentage and the national one.

It is possible for the users to see several kind of map regarding the “state of the environment” and to see also the values assumed by the goals at the same scale. Moreover, in order to permit a multi-decision-maker process, each users can see the alternatives, the goals, the utility function and the weight selected by the other users.

A system administrator manages this multi-users modality via web.

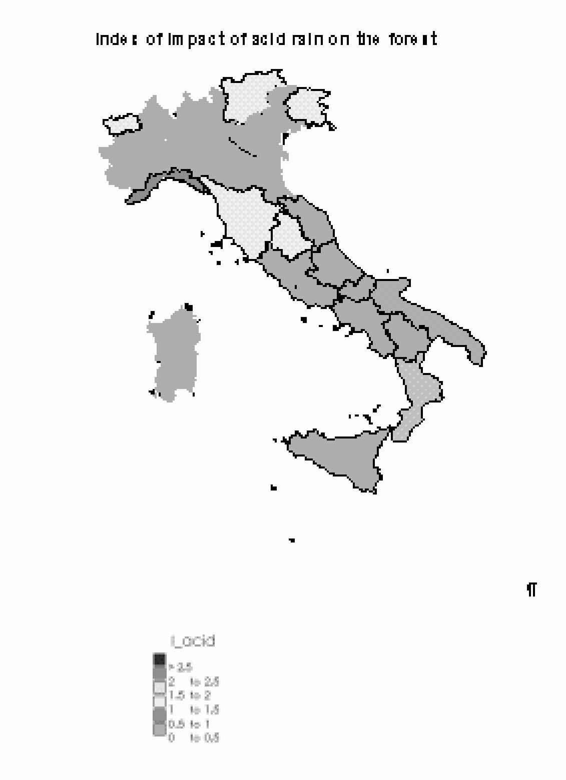

Figure 4 An example of vulnerability map of SESAMO "state of the environment": Index of impact of acid rain on the forest at regional scale.

It is not compulsory for the user to perform all the described phases but he can use a pre-built alternative or a pre-built valuation tree. Moreover he can use aggregated indicator, or ecological score, such as MIPS [Schmidt Bleek F, 1996], or Ecological footprint [Wackernagel M., Rees W. 1996] to evaluate the electric power supply system he has selected. In Figure 5 we can see an example of the Ecological footprint, an aggregated indicator. The larger the footprint of Italy is, the worst the alternative is.

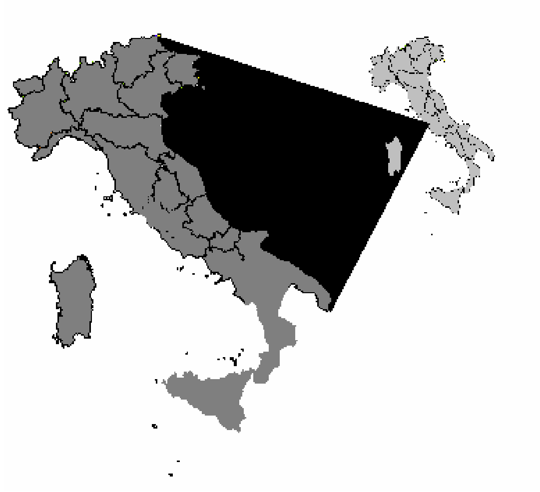

Figure 5 An example of aggregated indicator: the ecological footprint. The figure represent the geographical area of Italy (top right) and the "ecological footprint" of its electric power system (approximately 1.8 Italy surface). The ecological footprint can be seen as the space needed for the sustainability of the system

3 CONCLUSION

The DSS SESAMO could be very helpful in understanding the role played by the electric energy sector in the sustainability of the Italian economic system. According to recent applications of the sustainability development concept (A21, ESA…) [ANSEA, 2002] SESAMO allows to:
Approach the problem in a multi-dimensional way defining different and conflicting goals: different approaches (i.e. monocriterial approaches) could lead to sub-optimal solutions;

1. Approach the problem from different stakeholders points of view: non-shared decision could generate strong oppositions and project failure;
2. Define several goals and sub-goals, in order to define a core set of shared objectives;
3. Analyse all the potential impact from "cradle to grave" of the entire system: in order to avoid hidden trade-off among different solutions;

Comparison of future scenarios on the basis of the sustainability, can also help the decision maker pool to build new wide shared alternative scenarios.

On these basis, we can conclude that SESAMO is a tool that can be advantageously applied when a decision should be taken dealing with National Electric Power Supply System, considered as a multi-goals problem (environment, economic, social), with more than one decision maker.

REFERENCES

Crapanzano, G., L. Del Furia, M. Pavan, S. Ascari, M. Fontana, A. Lorenzoni, F. Maugliani, 1997. ExternE National Implementation, Italy. FEEM, Milano

De Leo G.A., Rizzi L., Caizzi A. 2000. Environmental externalities and industrial costs of energy production: which future for renewable resources? Proceedings of the 29th International Conference on "Automation and Decision Making". pp. 247-256 (FAST, Milano, Italy, 8 November 2000).

De Leo G.A., Rizzi L., Caizzi A., Gatto M. 2001. The economic benefits of the Kyoto Protocol. Nature, 413: 478-479. - De Paoli, L. & Lorenzoni, A. 1999. Economia e politica delle fonti rinnovabili e della cogenerazione. Franco Angeli, Milano.

European Commission 1995. ExternE: Externalities of Energy, Vol.1-6, EC, Bruxelles.

European Commission 1999. ExternE: Externalities of Energy, Vol.7-10, EC, Bruxelles.

Wackernagel M., Rees W. 1996. Our ecological footprint. Reducing Human Impact on the Earth, New Society Publischer, Philadelphia.

Schmidt-Bleek, F. (1996), MIPSBOOK or the Fossil Makers-Factor 10 and more, Wuppertal Institute for Climate, Environment, Energy, Germany.

ANSEA 2002 New Concepts in Strategic Assessment Towards Better Decision Making, FEEM Italy.

ANPA, Unità per la Qualità Ecologica dei Prodotti (2001) Linee guida per la dichiarazione ambientale di prodotto