

A Decision Support System applied to the Italian national allocation plan for the reduction of the GHGs emissions

Prof. M. Cellura¹

Phone: +39 091 236 131; Fax: +39 091 484 425; e-mail: mcellura@dream.unipa.it

F. Ardente¹, G. Beccali¹, M. Fontana¹, A. Marvuglia¹

¹Dipartimento di Ricerche Energetiche ed Ambientali (DREAM), Università degli Studi di Palermo, viale delle scienze, Edificio 9; 90128 Palermo, Italy

ABSTRACT: The first step accomplished by the Italian government toward the reduction of the greenhouse gases (GHGs) emissions is represented by the endorsement of the Kyoto protocol in 1997. In order to comply with the target of 6.5% reduction of GHGs emissions with respect to the emissions of 1990, a specific National allocation Plan for the Reduction of GHGs emission levels was arranged. The implementation of the actions foreseen by the plan (which involve the industrial and public services sectors) implies some investment costs, therefore it is important to select the most effective initiatives and give them a priority of implementation. In the achievement of this difficult task, a decision support model as the one described in this paper can help the decision makers to select the “best” compromise among economical, environmental and social items, that are often clashing. After a selection of a set of independent indicators able to describe the plan, nine different scenarios for the GHGs emissions reductions were evaluated and they were sorted according to the principles of the classical Multi-Criteria analysis. The results of the evaluation process show that the preferable options are also the ones accomplishing a good compromise between economic investment and reduction of GHGs emissions. Although the model is necessarily affected by some subjective choices made by the expert, it is characterized by an high level of transparency and scientific foundation.

Keywords: Greenhouse gases, Decision Support Systems, Multicriteria Decision Making, National Allocation Plan

1. INTRODUCTION

Anthropogenic emissions of greenhouse gases (GHGs) led, over the past two centuries, to a considerable increase in their concentration in the atmosphere and the global warming problem has been recognized as one of the most important

policy issues to be addressed for the preservation of the global environment.

The Kyoto Protocol, which came into force in 2005, represents the first step to cope with global climate change caused by anthropic activities. It binds the contracting countries to reduce the GHGs emissions by 5.2% on the whole, in the period 2008-2012. The level of emissions reduction imposed to

each country varies according to the technology efficiency and historical emission levels.

The Italian commitment under Council Decision 2002/358/EC [1] is to reduce its GHGs emissions by 6.5% with respect to the levels of 1990. To meet such commitment, on December 19th, 2002, the Interministerial Committee for Economic Planning (CIPE) approved the National action Plan for the Reduction of GHGs emission levels (NPR) [2].

Taking in mind that Italian emissions have been increasing since 1990 [3]: in 2000 they were equal to 546 Mt, and the projections for 2010 yield 580 Mt. In order to fill this gap (93 Mt between the projection for 2010 and the emission level of 1990) the most of the actions envisioned by the reference scenario of the NPR should be implemented.

The plan identifies three groups of actions: 1) the ones included in the reference scenario; 2) the ones to be implemented in the agriculture and forest sector (aiming to increase carbon's storage capacity); 3) further reduction measures both at national and international level through the utilization of cooperation mechanisms as Clean Development (CD) and Joint Implementation (JI).

Altogether these actions foster a more efficient production of heat and electricity, as well as a more rational use of energy in all the productive sectors (domestic, industrial, tertiary, agricultural and transportation sectors) and an increase in the utilization of carbon free fuel and renewable energy sources.

In this case study a decision support model was created in order to compare nine different scenarios and evaluate the preferable alternative on the basis of the selected indicators. Some of the scenarios are contained in the NPR, others are obtained as combinations of some of the scenarios contained in the NPR.

2. CASE STUDY

2.1 Choice of the indicators

In multicriteria decision making (MDM) theory a decision alternative x is described by means of a set of attributes (or criteria). The value of the alternative on the i -th criterion is expressed by means of a function (called *value function*) $v_i(x)$. Under the assumption of mutual preferential independence of attributes one can use the standard additive aggregation rule [4]. Then the overall value of an alternative x is computed as:

$$v(x) = \sum_{i=1}^n w_i v_i(x) \quad (1)$$

where n is the number of attributes, w_i is the weight of the i -th attribute and $v_i(x)$ is the rating of an alternative x with respect to the i -th attribute. The sum of the weights is normalized to one, and the component value functions $v_i(\cdot)$ vary between 0 and 1. The weights w_i indicate the relative importance of the i -th attribute changing from its worst level to its best level, compared with the changes in the other attributes.

The set of indicators selected for this case-study is based on the DPSIR model [5]. In a first analysis several indicators had been taken into account, belonging to the civil, transportation, industrial and agricultural sectors. However, they didn't respect the independence condition. The final choice was addressed to the following independent indicators:

- the GHGs emissions (MtCO_{2-eq}) from different sectors;
- the economic investments (M€) related to each alternative envisioned by the plan in each sector.

The complete list of used indicators is here reported: 1) GHGs emissions by energy industries; 2) GHGs emissions by industrial processes; 3) GHGs emissions by transportation systems; 4) GHGs emissions by civil sector; 5) GHGs emissions by agriculture sector; 6) GHGs emissions by waste management; 7) GHGs emissions by

other sources; 8) Economic investment in energy industries; 9) Economic investment in industrial processes; 10) Economic investment in transportation systems; 11) Economic investment in civil sector; 12) Economic investment in agriculture sector; 13) Economic investment in waste management sector; 14) Economic investment in other sectors.

2.2 Alternatives selection

In order to select a set of possible alternatives and rank them according to a rational criterion, different methods have been conceived [6]. The validity of the accomplished analysis is also highly dependent on the evaluation criteria used,

from the trend scenario by adding the interventions already set, even if not put into action. Altogether these measures, including the ones related to the carbon credits which is possible to obtain from JI and CDM projects, can allow a reduction of 51.8 MtCO_{2-eq}/year in the period 2008-2012. The overall cost of the interventions contained in this scenario is 9,189.0 M€.

The following Tab. I describes the actions foreseen by the “reference” scenario.

Table I: Main actions included in the “reference” scenario.

Energy use	Emissions reduction 2008-2012 (MtCO _{2-eq} /year)
Electricity Industry	26.0
3,200 MW ¹ expansion of Combined Cycle Plants	8.9
2,300 MW ² expansion of import capacity	10.6
2,800 MW ³ increase of renewables exploitation	6.5
Civil sector	6.3
Legislative decrees on energy end-use efficiency	6.3
Transportation sector	7.5
Buses and cars run with carbonless fuels (methane, LPG, fuel cells)	1.5

that, as a consequence, have to be carefully chosen.

Starting from the NPR, the following alternatives have been compared in the decision making process.

A1) Frozen scenario

It is the trend scenario of the plan or “zero alternative”, i.e. the scenario based on any specific action aimed to bridle GHGs emissions. According to this scenario it is possible to foresee 579.7 Mt of CO_{2-eq} emissions in 2010. This scenario is based on the regulations in force and on the GHGs emissions trends deriving from the utilization of fossil fuels and other energy sources;

A2) “Reference” scenario

The “reference” scenario is obtained

- Systems for the optimization and collectivization of the private transport (<i>car pooling, car sharing, collective taxis</i>)	2.1
- Remould of the tax on mineral oils	
- Activation of informatics/telematics systems	
Development of national infrastructures and fostering of the combined transportation via railway and of cabotage	3.9
Carbon credits from JI and CDM	12.0
Total	51.8

¹in addition to the 20,000 MW already considered in the trend scenario;

²in addition to the expansion till 5,500 MW foreseen in the trend scenario for the completion of the Italy-Greece power line;

³the increase foreseen by the trend scenario is 2,000 MW

A3) “Reference” scenario + actions concerning use of the soil and reforestation

This scenario is made up of the actions contained in the “reference” scenario and of the interventions in the sector of the use of the soil and forest plantation foreseen in the NAR.

Table II shows the actions aiming to carbon storage and the related costs.

The total emissions foreseen by this scenario in 2010 amount to 490.94 MtCO_{2-eq} and the overall investment amount to 9,715.7 M€.

Table II: Maximum national potential of CO₂ absorption

Actions concerning use of the soil and reforestation	Absorption (Mt CO _{2-eq})
Forests management	4.1
Agricultural lands, pastures, rivegetazione	0.1
Natural reforestation	3
Afforestation and reforestation (old forests)	1
Afforestation and reforestation (new forests)	1
Afforestation and reforestation (new forests) in areas subject to hydrogeologic risk	1
TOTAL	10.2

A4) “Reference” scenario + further GHGs emission reduction actions dependent on energy use

The further GHGs emission reduction actions referred to in this alternative encompass the industrial, civil, agriculture and transportation sectors and involve a GHGs reduction of 32.49 MtCO_{2-eq} with respect to the “reference” scenario and an additional investment of 11,106 M€;

A5) “Reference” scenario + further GHGs emission reduction actions dependent on energy use + use of the soil and reforestation;

A6) “Reference” scenario + further GHGs emission reduction actions independent on energy use

The further GHGs emission reduction actions referred to in this alternative encompass the industrial (reduction process emissions of adipic and nitric acid), agriculture (CH₄ reduction from animal excrements storages, NO₂ reduction from soils), waste management (stabilization of the organic portion of waste) and other sectors (PFC emissions reduction by aluminium recycling, utilization of abatement systems and substances with a lower GWP in the semiconductors production, reduction of HFC leakage from car air-conditioners, reduction of SF₆ leakage from electric appliances) and involve a GHGs reduction of 47.83 MtCO_{2-eq}.

eq with respect to the “reference” scenario and an additional investment of 18,518 M€.

A7) “Reference” scenario + further GHGs emission reduction actions independent on energy use + use of the soil and reforestation;

A8) “Reference” scenario + different further GHGs emission reduction actions

The further GHGs emission reduction actions referred to in this alternative encompass those initiatives (dependent and independent on energy use) which, for each sector, allow the largest emission reduction with the smallest economic investment.

A9) “Reference” scenario + further GHGs emission reduction actions (c) + use of the soil and reforestation.

The further GHGs emission reduction actions referred to in this alternative encompass the industrial, agriculture and waste management sectors and involve a GHGs reduction of 41.0 MtCO_{2-eq} with respect to the “reference” scenario and an additional investment of 10,259.5 M€.

2.3 Value functions creation

In this case-study three different kinds of decreasing value functions (linear, piecewise linear and exponential) were used and the obtained results were compared.

The linear function was obtained by assigning the highest utility to the minimum value of the corresponding indicator over the whole set of alternatives and the minimum utility to the maximum value of the indicator. The piecewise linear function for each criterion was built by taking the different values assumed by the 9 alternatives on that criterion. The exponential function is obtained as the exponential regression function computed with the same points used to create the piecewise linear function.

2.4 Choose of the weights and ranking of the alternatives

In order to observe how a different choice of the criteria weights can affect the ranking of the alternatives, two pairwise

comparison matrices have been created. In each of them, when two indicators are compared, a greater weight is attributed to the environmental indicator rather than to the economic one, being the reduction of the GHGs emission the main target of the NPR.

With both of them the consistency check was accomplished through the consistency index defined by Saaty [7].

Afterwards, six simulations were run by using each of the defined pairwise comparison matrices with each of the three kinds of value functions. For every pairwise comparison matrix, by applying the eigenvalue method [7,8], it was obtained a vector of normalized weights, i.e. such that

$$\sum_{i=1}^{14} w_i = 1.$$

Once assigned the weights to each criterion, the overall performance or score of each alternative was evaluated by the simple additive weighting method (Eq. (1)).

Finally it was possible to rank all the alternatives in descending order on the basis of their performances.

The ranking of the alternatives was also accomplished by using the concordance and discordance analysis [9], the weak dominance criterion [10] and the max-min method, which is based on the logic of minimizing the risks of the choice or the inequity of the distribution of damages and benefits. According to this method the best alternative is the one that performs best in the worst case.

Five different rankings were thus obtained for each of the six simulations.

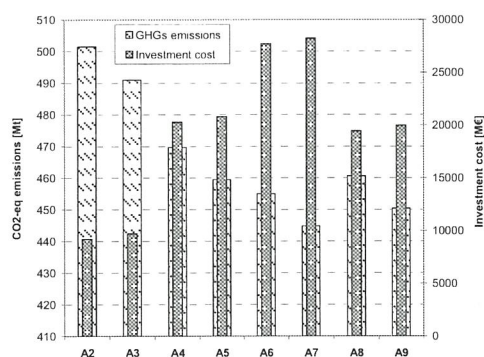
The alternative A1 was not taken into account because the decision maker has necessarily to comply with the constraint imposed by the Italian Kyoto protocol commitment and the frozen scenario does not allow to respect it.

The alternatives appearing the most of the times in the first position of the 30 different ranking obtained are the alternatives A9 and A8, which, as it is possible to see in Fig. 1, realizes a good trade-off between the money

power needed for its implementation and the GHGs emissions foreseen in 2010.

The alternative A2 never was classified as the first of the ranking, even if the money investment required is far lower than the other alternatives. This is a consequence of the higher weights assigned in the pairwise comparison matrices to the environmental indicators with respect to the economic ones.

Figure 1: GHGs emissions foreseen in 2010 and global cost of the investment associated with each of the alternatives (excluded the frozen scenario) evaluated.



3. CONCLUSION

The paper describes the application of multicriteria analysis (MCA) to the extended impact assessment of the Italian National Allocation Plan for the reduction of the GHGs emissions (NPR).

In order to compare the differences in the expressed preferences, several methods have been implemented, like classical MCA, concordance/discordance analysis and the max-min criterion.

Nine different alternatives were compared, by using 14 different independent economic and environmental criteria belonging to seven sectors of intervention (energy industries, industrial processes, transportation systems, civil sector,

agriculture sector, waste management, other sectors).

In the different simulations carried out taking into account different weight vectors and various value functions, the alternatives which are always on the top of the ranking (and as a consequence are to be preferred) are the ones which potentially allow the best compromise between reductions of GHGs emissions and cost of the investment needed. The accomplishment of the actions related to these alternatives, is supposed to have positive effects not only on the environment but also on the economy of the country. In order to decrease the GHGs emissions, every productive sector has to improve its technological efficiency, with a consequent impact on the number and profile of the requested personnel.

On the other hand, the rise of the energy rate produced by renewable sources is supposed to change the national entrepreneurial framework with the opening of new markets for the realization of international cooperation mechanisms as foreseen by the Kyoto Protocol.

However characterized by subjective judgements introduced by the decision maker, the approach based on the MCA is transparent and reproducible, and it gives to the stakeholders a better insight on the difficult problems taken into account.

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