Development of multicriteria models to classify energy efficiency alternatives

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Abstract
This paper aims at describing a novel constructive approach to develop decision support models to classify energy efficiency initiatives, including traditional Demand-Side Management and Market Transformation initiatives, overcoming the limitations and drawbacks of Cost-Benefit Analysis. A multicriteria approach based on the ELECTRE-TRI method is used, focusing on four perspectives:

1. an independent Agency with the aim of promoting energy efficiency;
2. Distribution-only utilities under a regulated framework;
3. the Regulator;
4. Supply companies in a competitive liberalized market.

These perspectives were chosen after a system analysis of the decision situation regarding the implementation of energy efficiency initiatives, looking for the main roles and power relations, with the purpose of structuring the decision problem by identifying the actors, the decision makers, the decision paradigm, and the relevant criteria.

The multicriteria models developed allow considering different kinds of impacts, but avoiding difficult measurements and unit conversions due to the nature of the multicriteria method chosen. The decision is then based on all the significant effects of the initiative, both positive and negative ones, including ancillary effects often forgotten in cost-benefit analysis. The ELECTRE-TRI, as most multicriteria methods, provides to the Decision Maker the ability of controlling the relevance each impact can have on the final decision. The decision support process encompasses a robustness analysis, which, together with a good documentation of the parameters supplied into the model, should support sound decisions.

The models were tested with a set of real-world initiatives and compared with possible decisions based on Cost-Benefit analysis.

Introduction
The demand-side of the energy meter has been "managed" since the beginning of the electric industry. Electric utilities have always attempted to improve the exploitation of the electric energy systems through price mechanisms or direct load control. During the 1980s, the term Demand-Side Managed (DSM) was coined to define a set of intervention forms with which the electric utilities aimed to improve their own economic efficiency by promoting energy efficiency (EEff) of end-uses and the traditional mechanisms referred to above. DSM became an integral part of the utilities planning process, especially in the most developed countries, where Integrated Resource Planning, considering demand-side and supply-side options as alternative options, was a current practice.

For a long time, DSM was recognized as an effective tool for increasing the energy efficiency of the economy and reducing the environmental impact of energy use. Utilities were stimulated through regulation to promote DSM with financial compensations to turn Cost-Benefit analysis more to the benefit side. Incentives have faded away with the current trend of deregulation and market liberalization has led to a dramatic reduction of DSM investments by utilities. In this new context, DSM has been replaced by the concept of Market Transformation (MT) in which the set of energy efficiency promoting agents has extended beyond the electric energy sector companies. The contribution of electric companies to the MT efforts can only proceed or arise by their own initiative if *ex-ante* evaluations provide profit assurance, in the respect of any legal or regulatory constraints that may exist. Other entities have been using public funds, sometimes collected through specific levies, to implement these initiatives but have the limitation of being external to the market. The main purpose of MT initiatives is to change the market on a permanent basis, reducing the barriers to the natural adoption of EEff as a criterion of equipment choice or everyday practice by end-users.

The motivation for these initiatives has now several dimensions. Having started as a good idea in economic terms, the promotion of EEff became a strategy for the climate change mitigation effort, the improvement of low-income households' welfare, the reliability improvements on the electric energy systems and other political reasons such as employment creation, reduction of the dependence on imported energy sources, etc.

The consideration of all advantages and disadvantages of EEff promotion leads naturally to a multicriteria decision problem, since multiple evaluation aspects of its merits are at stake. The traditional solution is to aggregate all these multiple benefits and costs into a single additive index, using a common monetary scale. In this way it is easy to use common procedures of investment analysis to compare EEff initiatives, and to compare these with other options.

The methodologies called Cost-Benefit Analysis and Cost-Effectiveness Analysis have been applied to the analysis of EEff initiatives since the 1980s, mainly after the publication of a set of "tests" by the California Energy Commission and California Public Utilities Commission (CEC&CPUC, 83, 87; CPUC, 2001b). These tests became almost universal, being used by many utilities and regulatory entities in other US states and outside the US (ELSAM, 93). There are five perspectives addressed in these methodologies: the Participant (consumer) in the programme, the average ratepayer (Ratepayer Impact Measure), the Utility Cost, the Total Resource Cost and the Societal Cost.

The beginning of the market liberalisation process and the multiplicity of market situations in Europe, where simultaneously public monopoly frameworks existed, fostered the development of a specific methodology for Europe. A EU funded project (SRCi, 1996) created such a methodology, which although similar in concept to the California methodology, included a few innovations, namely the choice of perspectives and impacts to include in the analysis as a way of adapting the methodology to the diversity of situations and the inclusion of non-monetary impacts as a qualitative help to the decision. Other methodologies developed in the US after the beginning of the market deregulation process also adopted this latter principle in order to include benefits which were difficult or impossible to monetise (Eto et al., 1998; CPUC, 2001a, 2003).

However, there are several issues that challenge the validity of these methodologies for judging EEff initiatives. Firstly, the basic assumptions of the Welfare Economics theory are not universally accepted. Secondly, value judgements are done by analysts and somehow hidden in the calculations, not being available to the decision makers. Thirdly, the methods which could lead to more reliable data, namely the economic value of impacts, may be difficult or impossible to apply, forcing the use of questionable data. An example is the use of the cost of control instead of the damage cost for environmental impacts. These difficulties were also used to justify simplifying assumptions made during the EU funded ExternE project which aimed to define the external costs of each energy source (European Commission, 1999a; 1999b; Krewitt, 2002). These assumptions included the absence of transboundary effects or the disregard of some pollutants due to the unavailability of compatible assessment processes. The disparity of the results of the ExternE and other external costs assessments (Krewitt, 2002; Sundqvist, 2004) may also lead to a lack of confidence on a decision based only on a net benefit or benefit-cost ratio, and even more if the calculation details are hidden from the decision maker.

An alternative approach is to consider models and methods that explicitly consider the multiple dimensions of reality. Instead of looking for an "optimal" solution, the aim is to identify the solutions that better suit the preferences stated by the decision maker. A carefully chosen procedure may also include the treatment of the uncertainty of data, allowing the analysis of the decision robustness.

This paper summarizes a proposal for a multicriteria evaluation framework for the process of analysis of EEff initiatives.

The first section describes the perspectives of analysis, the choice of the multicriteria method to be used for the evaluation, and the selection of criteria. The second section makes a brief presentation of the multicriteria method chosen to provide decision support. The following section shows the results of applying the proposed methodology to a set of DSM/EE initiatives. Finally, some conclusions are drawn regarding the use of this approach and a comparison is made with the traditional Cost-Benefit Analysis.

Main perspectives of analysis

The definition of a new analysis framework, based on a paradigm different from Cost-Benefit Analysis and the new realities of the electricity market with new market players and new relations of power suggested the need of a fresh view of the problem. There were several useful starting points such as the European Benefit-Cost Methodology (SRCi, 1996), the California Standard Practice and a multicriteria approach described in Hobbs and Horn (1997) for the British Columbia Gas.

On a first structuring phase (Neves et al., 2004), the main actors and some of their points-of-view regarding EEff were identified and the knowledge about the problem was extended. This step allowed us to identify the entities that could be interested in using such an evaluation system: the Energy Agency, representing an entity with the purpose of using the public funds usually collected through non-bypassable levies, eg., the System Benefit Charge (or Public Benefit Charge) to promote EEff in the U.S.; the Regulator, the authority which still regulates the remaining monopoly activities of the Electric Energy Market, namely the "wires" business; the Distribution utilities, still regulated and that in some countries have been chosen as EEff promoters by removing the disincentives in the revenue definition mechanism (Pagliano et al., 2001); the competitive Supply companies which, although naturally aiming at an increase in sales, may look to EEff as a marketing strategy to attract or to keep customers.

The main characteristics of the multicriteria method, to use as a tool for deciding about EEff investments, were also identified in this first stage, namely the capacity of evaluating each initiative in absolute terms, and not only in comparison with others, and the independence towards scales, to permit the inclusion of impacts measured in different units, and even of impacts measured in qualitative terms. Such characteristics suggest the use of the ELECTRE TRI method (Yu, 1992).

A second phase involved the development of hierarchies of fundamental objectives and their expression in terms of criteria to use in the evaluation models (Neves et al., 2005), based on the knowledge developed in the structuring phase. The process of constructing the multicriteria models through the development of the hierarchies of fundamental objectives addressed the need of an evaluation system that may be applied to any future EEff initiative, by discovering the points-of-view of the decision makers, instead of looking only to the distinctive characteristics of each alternative in a decision problem. An example of the result of this step is the tree of fundamental objectives of the Energy Agency, shown in Figure 1.

The shaded boxes in Figure 1 represent the objectives which gave rise to the criteria used in the evaluation model. The first two, to minimize consumption impacts and to minimize impacts related to demand, are used as proxy measures for the objectives of lower levels due to the problematic

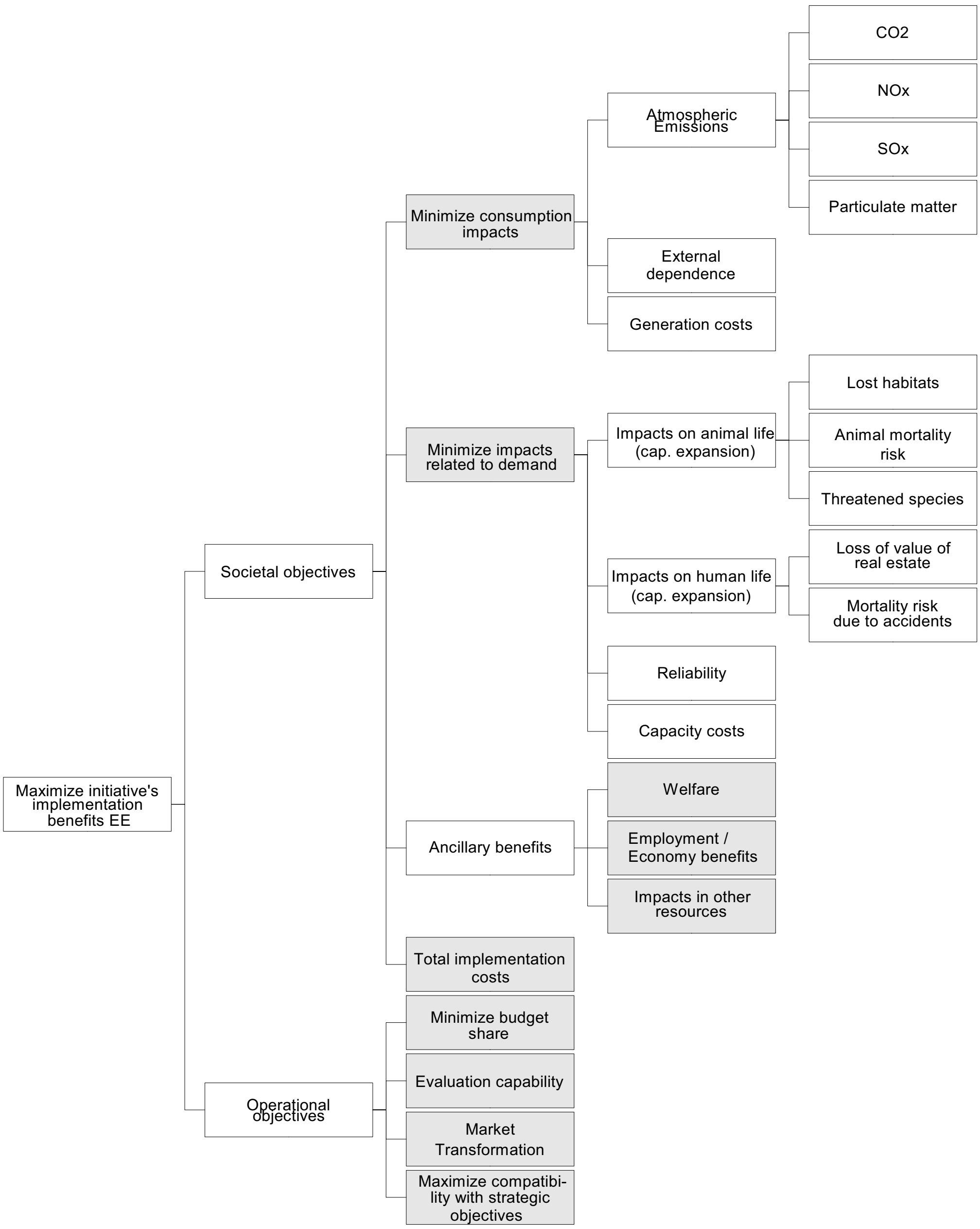

Figure 1. *Tree of fundamental objectives of the Energy Agency.*

conversions involved and their clear relation, specially when considering electric EEff initiatives.

The tree of fundamental objectives of the Regulator is similar to that of the Agency, since both address the societal perspective, except for the operational objectives. The Regulator has the purpose of balancing the need to assure adequate revenues to the regulated utilities and the protection of consumers from monopolistic power. The trees of the companies balance the objectives related to the net value of energy services and the ancillary benefits and costs of the implementation of EEff initiatives.

Implementation

The choice of a method to implement the multicriteria evaluation of EEff initiatives resulted, as already stated, from the understanding of its desirable properties in this context. The ELECTRE TRI method (Yu, 1992) belongs to the ELECTRE family of multicriteria methods developed by Bernard Roy and his co-workers (Roy, 1991; 1996). This specific method is dedicated to the classification problem: to assign each alternative to one of a set of pre-defined ordered categories according to a set of evaluation criteria. The categories (C^x) are defined by specifying their boundaries (b^y) by means of reference actions, in terms of performance in each criterion, as shown in Figure 2.

The assignment of each action to one category is done by comparing its performances in each criterion to the performances of the reference actions. The procedure assigns each action to the highest category such that its lower bound b^{lw} is outranked by *a*. The outranking relation is decided by comparing a credibility index, computed using the differences in performances and the criterion weights, with a cutting level λ ($\lambda \in [0.5,1]$) which defines the "majority requirement". For further details about ELECTRE TRI see Yu (1992) and Mousseau et al. (1999). The software package IRIS 2.0 (Dias and Mousseau, 2003) was selected to provide decision support for the models developed. This software implements a methodology developed by Dias et al. (2002), based on the ELECTRE TRI method, but accepting uncertainty in the input parameters. Its main characteristics include:

- Acceptance of imprecision regarding the criterion weights and the cutting level through the definition of intervals for each parameter, or the definition of linear constraints.
- Acceptance of classification examples, with the input of the better and worse category that each action can be assigned to. This is translated by the software into constraints to the parameters that ensure these results are reproduced.
- Inference of a combination of parameters that will limit the violation of the constraints in the case of inconsistency, minimizing the maximum deviation. It is also possible to find the constraint subsets, which must be removed to restore consistency.
- Inference of a central combination of parameters through the maximization of the minimum slack, when the constraints are consistent. For each action, it is shown which category represents this central combination, and the other possible classifications that respect the imposed constraints.

Case study

DATA GATHERING

Quantitative data

A data set was needed for testing the proposed methodology with different kinds of initiatives, implementation types, target consumers, and promoting entities.

The existence of public databases with evaluation data of DSM/EEff programmes made possible the use of actual data regarding costs and savings, which were then adapted by using the electric tariffs in the Portuguese market. The INDEEP database from the DSM project of the IEA was chosen (http://dsm.iea.org).

The INDEEP database contains data from more than 200 DSM/EE programmes, implemented in several countries, most of them active participants in the INDEEP project, since the 1980s to the present. However, not all the programmes listed have all the needed data available. The selection of the set of initiatives for using in the test of our models had to comply with the following conditions:

1. Existence of savings data: energy and / or peak demand.
2. Existence of implementation cost data.
3. Recent implementations to minimize money value adjustments.
4. Programmes compatible with the Portuguese market size: from a country or region of similar size.
5. Programmes focusing on electric energy.
6. Enough diversity of programmes to address the objectives already referred to.

The selected initiatives are presented in Table 1

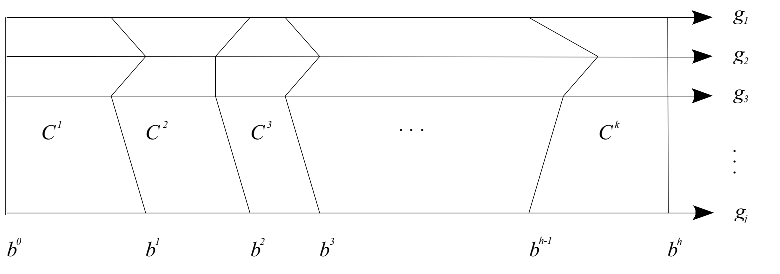

Figure 2. *Definition of categories C^h with reference actions b^h.*

Table 1. Selected DSM/EE Initiatives

Ref.	Title	Description
a1	Load management for commercial clients.	Installation of a load controller for peak cutting and load shifting in commercial consumers, complemented with education through seminars.
a2	Improvements in manufacturing processes.	Industrial engineering support and financial incentives to allow customers and utility staff to explore specialized industrial energy savings opportunities, complementing rebate programmes.
a3	Industrial Power Smart: Employee involvement.	Incentive to industrial employees, for identifying energy-efficiency measures with the aim of acquiring low-cost savings. The programme is promoted on the industrial customers and seminars are offered to the employees, which receive a monetary incentive for each efficiency action suggested and for the effective savings.
a4	Industrial Power Smart: Compressed air component.	Detailed study of the participant's compressed air system, action plan and financial assistance.
a5	Efficient lighting for schools.	Performance contracting for a school building, aiming at energy saving measures for an efficient illumination system for schools (Pilot Project).
a6	Bonus for savings above 15%.	Consumers that save more than 15% of their annual electricity use get a bonus of 50 Euro. Information about energy savings is provided to participants on request.
a7	Promotion of home appliances with low stand-by losses.	Subsidies to high efficient home appliances with low stand-by losses or automatic switch off in the stand-by mode.
a8	Energy management in the public sector.	Education of directors, technical staff and remaining personnel in the public services through seminars, and the arrangement of cooperative networks between energy managers of the public institutions.
a9	Energy management in buildings with area > 1500m^2.	Annual energy audits to big buildings with classification regarding energy consumption and a mandatory efficiency measures planning.
a10	Washing at lower temperatures.	A marketing campaign with the purpose of reducing the number of laundry washes above 60ºC.
a11	Energy consultancy for industries with energy consumption above 2 GWh/year.	Free audits conducted in big industrial consumers which can apply for external subsidies regarding measure installation costs.
a12	Night rate campaign.	Campaign for night rate tariff supporting electricity use in off-peak hours.
a13	Heat storage with night time rates.	Introducing accumulated hot water and heating storage systems in the residential sector through rebates.
a14	Variable Speed Drives (VSD) and efficient motors.	Promotion of electronic speed regulation of engines or the replacement of old motors by high efficiency units.
a15	Heat pumps.	Promotion of heat pumps for domestic space heating.
a16	Efficient lighting in SMEs.	Promotion of high efficiency lighting systems for Small and Medium size Enterprises (SMEs).
a17	Domotics.	Installation of consumption search equipments to rationalize the electric consumption in the domestic sector, improving general comfort.
a18	Promotion of A and B label fridges.	Rebates in domestic fridges of efficiency classes A and B to make them more attractive to consumers (minimization of the initial cost difference to lower efficiency models).
a19	High efficiency motors.	Promoting high efficiency motors for industries
a20	Public lighting efficiency improvements.	Installation of regulation and/or replacement with more efficient components.
a21	Combined DSM actions.	Marketing campaigns and rebates for the domestic and commercial sectors on two specific geographic areas: 1) of predominating residential loads (55%), and 2) of predominant commercial loads with the purpose of saving energy and peak demand.
a22	Compact Fluorescent Light bulbs (CFLs) paid back through the bill.	Dissemination of CFLs in the residential sector by supplying bulbs to residential consumers which will be paid back through the differences in the electricity bill.
a23	Low flow shower heads.	Promotion through rebates of low flow shower heads to consumers with electric water heating systems.
a24	Cool storage.	Promotion of cool storage systems for commercial buildings.

The main quantitative data obtained from the databases (Table 2) were used to compute the remaining quantitative estimates needed for the set of selected initiatives, based on the Portuguese electric tariffs, assuming a probable distribution by type of electric customers (voltage level). The useful life considered for the savings calculations is limited to ten years assuming that this would be the maximum accepted by the different entities to minimize the risk in estimates.

Qualitative data

A significant number of criteria for the defined evaluation models had no estimates in the evaluation databases. Although there are methods for estimating some of these impacts, like the employment impact of EEff initiatives, most of them can only be assessed through qualitative scales. For addressing this problem it is necessary to define measurement scales for each criterion and a reliable process of evaluating the performance of each initiative according to each

Table 2. Main quantitative data for the selected initiatives

Ref.	Participants	Useful life	Energy savings	Peak savings	Part. cost	Promoter cost	Total cost
		(years)	MWh	MW	(10^3 Euro)	(10^3 Euro)	(10^3 Euro)
a1	6	10	2 592	67.5	5 330	17 780	23 110
a2	517	10	390 025	29.3	12 408	4 653	17 061
a3	15	8	4 080	0.1	0	251	251
a4	181	10	65 703	9.9	3 391	3 567	6 958
a5	1	10	270	0.0	2	66	68
a6	150	10	540	0.0	16	8	24
a7	250	10	80	0.0	0	8	8
a8	700	5	197 750	4.5	6 653	2 069	8 722
a9	2 500	10	200 000	2.3	5 887	4 701	10 588
a10	279 586	10	139 793	16.0	0	977	977
a11	12	5	79 326	1.8	0	1 864	1 864
a12	54 736	10	0	61.0	17 682	5 474	23 156
a13	1 872	10	0	3.7	0	1 471	1 471
a14	7	10	15 130	0.3	0	55	55
a15	156	10	76 800	7.2	521	368	889
a16	77 330	10	98 980	1.2	782	644	1 426
a17	252	10	7 050	0.9	151	50	201
a18	6 898	10	18 936	0.2	472	194	666
a19	83 688	10	1 081 500	18.2	2 667	750	3 417
a20	30 000	10	107 102	2.5	479	251	730
a21	3 870	8	12 508	1.2	529	461	990
a22	60 000	6	16 200	0.0	316	61	377
a23	50 000	5	15 000	1.0	77	27	104
a24	100	10	0	25.0	162	6 700	6 862

Table 3. Qualitative scale of measurement of the "Impact over welfare"

Value	Description
Very negative	The initiative produces very negative impacts in welfare or affects a significant number of persons
Negative	The initiative has few negative impacts or has a negative effect over a small number of persons
Neutral	The initiative does not affect the welfare of people
Positive	The initiative has few positive impacts or has a positive effect over a small number of persons
Very positive	The initiative has very positive impacts or has a positive impact over a large number of persons
Excelent	The initiative has very positive impacts over a large number of persons

scale. Our approach consisted in querying a set of individuals, with a strong knowledge in the field, for their evaluations according to the scales provided for each criterion. One example of such a scale is shown in Table 3 for the *impact over welfare* defined as "effects of EEff initiatives on the welfare of people, excluding consequences already considered as the effects of pollution". Examples include comfort at home and at the workplace, capacity of enjoying energy services unavailable before (e.g. due to high energy bills), time or space inconveniences, aesthetics, etc.

To note that although the original data for the selected initiatives indicate which ones were implemented by "agencies" and which ones were implemented by utilities, our test considered that each one could be implemented by both types of entities, implying that all the performances over the qualitative criteria were measured for each initiative.

Evaluation model parameters

Any multicriteria evaluation model usually needs a set of parameters that represent the preferences of the decision makers and are the basis for producing meaningful results. The ELECTRE TRI method needs, as referred to previously, the definition of the categories in which the initiatives will be classified, by the specification of the associated reference profiles; the definition of the criterion weights; the definition of the cutting level (λ); and a set of indifference (q_j), preference (p_j) and optional veto (v_j) thresholds for each criterion and reference profile.

The first two types of thresholds represent the acceptance of imprecision by considering indifferent two actions when their performances in each criterion j differ less than a specified amount q_j, and by considering that the transition from indifference to preference is not sharp but changes linearly from q_j to p_j.

To reduce the data requirements, the indifference and preference thresholds were fixed as 1% and 10% of the performance ranges for each category (upper bound – lower bound).

The remaining parameters were obtained by querying a set of five experts in EEff, acting as consultants for the potential decision makers.

Since the purpose of the classification is the decision about implementing each initiative, the following categories were defined: "To discard" (No), "To implement" (Yes), and two intermediate categories ("Maybe yes" and "Maybe not").The group of experts was then asked for:

1. The criterion weights. Due to their nature, ELECTRE methods are indifferent to the scales in which each criterion is measured, hence the setting of weights is easier than for other kinds of methods. The query asked for a distribution of 100 "votes" among the different criteria.
2. The optional veto thresholds. The respondents were asked whether there are unacceptable performances in any criterion that should prevent any initiative of being classified as "to implement" or that should force it "to be discarded", independently of all the other criteria (i.e., even if it is very good in all the other criteria).
3. Values for the reference profiles, namely the lower bound for the category "Yes" and the upper bound for the category "No".

The results of this query were aggregated, resulting in the definition of three reference profiles, defining the four categories, with the reference profile that separates the two intermediate categories being the mean of the other two. The weights were not aggregated, keeping the five sets of weights provided by the respondents. The software package IRIS allows the introduction of uncertainty in the weights (as well as in the cutting level). This feature reduces the data requirements and increases the confidence in the results, as explained in the following section.

Main results

The evaluation process started with the introduction of the performance data for the 24 initiatives according to the different criteria, the aggregated reference profiles and associated thresholds, and the weights, in the IRIS software. The cutting level was constrained to the interval [0.51, 0.67], these bounds corresponding to a simple majority requirement and a two thirds majority. The process was repeated for each set of weights and for each perspective of evaluation (Agency, Regulator, Distribution utilities, Competitive supply companies).

The results of this first step were aggregated, presenting the central estimate provided by IRIS (the classification that results from the central combination of admissible values for the parameters) for the different sets of weights for each perspective, as illustrated in Figure 3 for the case of the Energy Agency. In this figure, the different grades of shade represent the degree of agreement among the respondents, from white (none) to black (complete), also represented by the numbers inside. The categories are represented by the columns: C1 – No; C2 – Maybe not; C3 – Maybe yes; C4 – Yes.

The second step was to reproduce these results with IRIS, allowing the weights to vary between the minimum and the maximum values obtained in the querying process for each criterion, and introducing constraints to the resulting classifications. The result of this process is a set of weights and a cutting level which satisfies all the constraints, representing the aggregated view of the group of experts, and which can be used for further analysis.

	Categories			
Initiatives	C1	C2	C3	C4
a1				
a2			1	4
a3		1	4	
a4			2	3
a5		1	3	1
a6		1	4	
a7		1	4	
a8			4	1
a9			1	4
a10			4	1
a11			3	2
a12		3	2	
a13				
a14				
a15				
a16				
a17			4	1
a18				
a19			2	3
a20				
a21				
a22			2	3
a23			2	3
a24		1	4	

Figure 3. *Results of the use of different weights: Perspective of the Energy Agency.*

Figure 4 illustrates the introduction of constraints to the classifications according to the level of agreement of results shown in Figure 3. For instance, action *a1* is restricted to category 2, since all sets of weights led to that result. Action a_2 is restricted to category 3 or 4 since all sets of weights led to this interval of categories. The constraints are show in the *Elow* and *Ehigh* cells on the left side. The darker cells on the right side represent the proposed classification by IRIS, corresponding to the central combination of parameters shown at the bottom right. The grey cells on the right side represent the other possible classifications, corresponding to admissible combinations of parameters given the constraints considered.

The final step in the evaluation process was to conduct an analysis of the robustness of conclusions, by evaluating two extreme scenarios. These scenarios are constructed with the extremes of the estimates for the performances of each initiative, given the uncertainties in measurements, with the combination of parameters obtained before. Due to the experimental nature of this data set, these uncertainties were artificially fixed at ±10% for all quantitative criteria, and ±1 level in the qualitative scales. Figure 5 illustrates the results of this final step, after aggregating the results for the original data with the results for the extreme scenarios. Again, the shades of grey represent the agreement of the results of the three scenarios, from white (none) to black (complete), with the intermediate degrees of coincidence expressed as numbers in grades of grey. A dark cell indicates a robust conclusion.

An interesting analysis can be performed by a simultaneous view of the results on the four perspectives. In this case

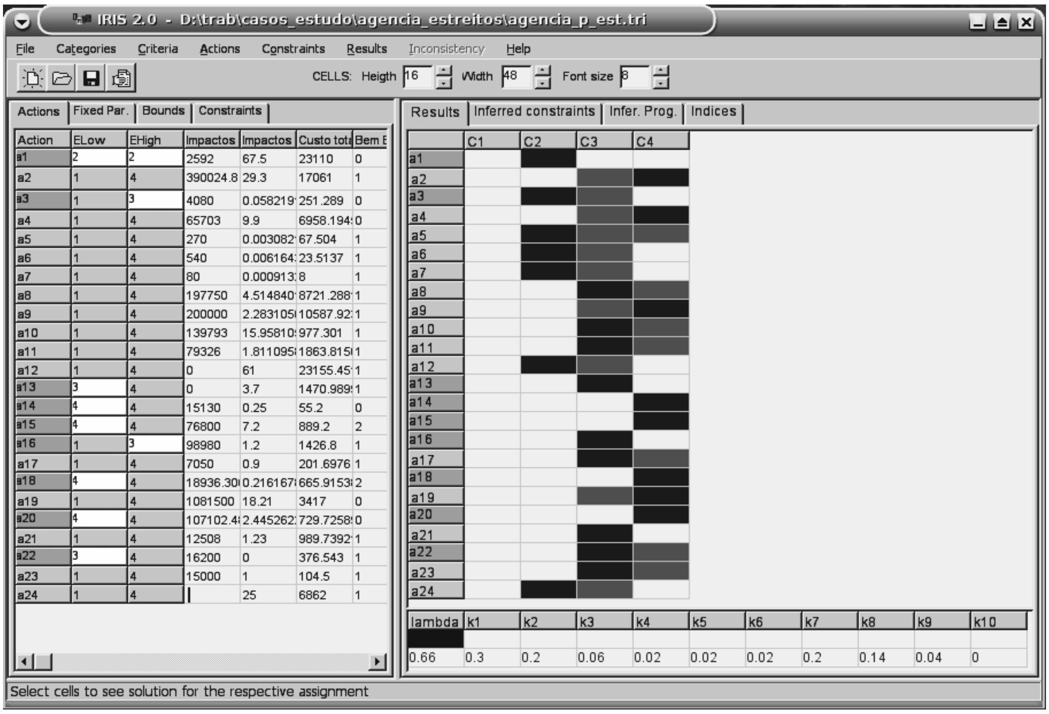

Figure 4. *Introduction of constraints to the classification: Perspective of the Energy Agency.*

it is possible to realise if one initiative is attractive to all the actors or just some of them. In Figure 6, the four axes represent the four perspectives, and are scaled from 1 (Category "No") in the centre to 4 (Category "Yes") in the extremes, and the inner circle represents the boundary between the two intermediate categories. The example illustrated in this figure shows a case where the initiative has low interest for the public entities (the lines for the base case and the pessimistic scenarios are completely inside the circle, meaning they have a result of "probably not" or worse), but a high interest for the utilities.

Concluding remarks

This paper presents a proposal for a multicriteria evaluation of initiatives, avoiding the need for converting all the impacts of the initiative to currency units, and incorporating the actual preferences of decision makers in the analysis.

The first advantage refers to the inclusion of impacts usually not considered due to the difficulty or impossibility of being measured in monetary units. The second one deals with enabling the decision maker to base his/her decision on his/her own values, instead of using the conversion rules hidden in the monetisation formulae. These advantages provide more confidence in the decision suggested, also due to the absence of compensation effects (a good performance in one criterion does not hide a poor performance in another) and to the possibility of conducting an analysis to assess the robustness of the decisions regarding the uncertainty of the input data.

A process of dealing with multiple views for the parameter data was also outlined, making use of the possibilities offered by the IRIS software, namely the capability of accepting imprecision in the input data.

For illustrative purposes, if the California cost-benefit tests (CPUC, 2001) had been used, their results could be the ones expressed in Table 4 (depending on the values used for marginal costs and externalities). A true comparison cannot be made due to the different foundations of both approaches, but there are a few remarks that can be expressed.

- The first remark regards the difficulty in finding the equivalent perspective. The Agency and the Regulator address the societal perspective, but the former has its own constraints and objectives not addressed in the Societal Cost test. The Regulator must also consider the impact on rates expressed through the Ratepayer Impact Measure (RIM) test and usually is more concerned with the Total Resource Cost than with its societal variant. The distribution companies have to deal also with two different perspectives, the reduction in costs vs. the impact on rates. The Supply companies, being unable to recover costs through rates, need to consider the RIM test as a measure of their costs and also the Participant test (not shown), indicating the attractiveness of the initatives as a marketing tool. The combination of different B/C or VAL results is not clear and the lack of consideration of several impacts, due to the impossibility of measuring them in monetary units results in a poor decision aid.
- There are several contradictions between the results, as in initiatives a4, a9, a12 and a24 for the Agency and the societal cost-benefit test, or initiative a6 on the Distribution utility perspective and the Utility Cost Test. As an example, for the perspective of the Agency, initiative a12 is robustly classified in the category "Maybe not", however, its cost-benefit results in the societal perspective contradict this classification, indicating both the Benefit/

Agency

Initiatives	Categories C1	C2	C3	C4
a1		[illegible]		
a2			4	5
a3		8	1	
a4			4	5
a5		8		1
a6		8	1	
a7		8	1	
a8			5	4
a9			2	7
a10			6	3
a11			5	4
a12		8	1	
a13		3	6	
a14			3	6
a15			3	6
a16			7	2
a17		1	7	1
a18			3	6
a19			4	5
a20			3	6
a21		1	6	2
a22		1	4	4
a23		1	4	4
a24		8	1	

Regulator

Initiatives	Categories C1	C2	C3	C4
a1		6	3	
a2		1	5	3
a3		5	1	3
a4			5	4
a5		3	3	3
a6		5	1	3
a7		5	2	2
a8		3	2	4
a9			5	4
a10			5	4
a11			6	3
a12		6	1	2
a13		1	8	
a14			3	6
a15			5	4
a16		1	6	2
a17		1	4	4
a18		1	4	4
a19		1	8	
a20			5	4
a21		1	4	4
a22		1	4	4
a23		1	4	4
a24		3	6	

Distribution utilities

Initiatives	Categories C1	C2	C3	C4
a1		2	3	4
a2		1	4	4
a3	1	3	5	
a4		2	3	4
a5	2	4	3	
a6	4	2	3	
a7	4	3	2	
a8	1	3	3	2
a9		1	4	4
a10		3	3	3
a11		1	6	2
a12		1	3	5
a13		3	3	3
a14	1	6	2	
a15		1	4	4
a16		3	6	
a17	1	6	2	
a18		6	3	
a19		2	3	4
a20		1	4	4
a21		6	3	
a22		6	3	
a23	3	6		
a24		4	2	3

Supply companies

Initiatives	Categories C1	C2	C3	C4
a1	3	3	3	
a2		4	5	
a3	3	2	4	
a4	3	3	3	
a5		3	3	3
a6		4	5	
a7		5	4	
a8	1	3	5	
a9		5	4	
a10	3	3	3	
a11		5	4	
a12		3	3	3
a13	3	2	4	
a14	3	3	3	
a15		5	4	
a16		4	5	
a17		5	4	
a18		4	5	
a19	3	3	3	
a20	3	2	4	
a21		4	5	
a22		3	6	
a23	4	2	3	
a24	3	3	3	

Figure 5. *Robustness of results: presentation of the three scenarios.*

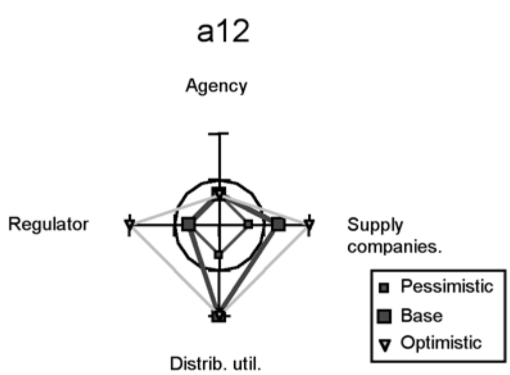

Figure 6. *Simultaneous view of the results on all the perspectives, for one initiative.*

Cost ratio and the Net Present Value of benefits that its benefits outweight its costs by a considerable amount. These contradictions may result from one of the major differences of both approaches: Cost-Benefit analysis has compensation effects; ELECTRE TRI has veto effects, hence a bad performance in one criterion may impose a veto to any good classification even if the performances in all the other criteria are excellent. It may also result from the impacts which are not considered in the cost-benefit approach.

- The uniqueness of the results of the cost-benefit analysis may lead to a false confidence. The opacity of the calculations gives no place for questioning. The multicriteria approach has the capability of capturing the natural uncertainty associated with the decision maker's preferences. Therefore, the knowledge of the admissible outputs

Table 4. Results from the application of the California tests of cost-benefit analysis.

	Societal Cost	
Ref	B/C	NPV (kEuro)
a1	0,75	-5 798,17
a2	1,56	9 616,87
a3	0,88	-31,14
a4	0,83	-1 200,31
a5	0,21	-53,41
a6	1,2	4,66
a7	0,52	-3,83
a8	1,29	2 507,66
a9	0,99	-151,58
a10	11,21	9 973,68
a11	2,42	2 640,6
a12	1,37	8 654,29
a13	1,94	1 378,63
a14	14,66	753,98
a15	6,32	4 728,13
a16	3,63	3 755,99
a17	2,86	374,82
a18	1,48	322,21
a19	16,95	54 510,42
a20	8,09	5 170,32
a21	0,91	-93,37
a22	2,27	477,38
a23	9,02	838,33
a24	1,94	6 447,6

	Total Resource Cost	
Ref	B/C	NPV (kEuro)
a1	0,75	-5 857,55
a2	1,04	682,38
a3	0,49	-127,78
a4	0,61	-2 705,4
a5	0,12	-59,6
a6	0,67	-7,71
a7	0,29	-5,66
a8	0,72	-2 421,79
a9	0,55	-4 733,08
a10	7,93	6 771,38
a11	1,36	663,18
a12	1,37	8 654,29
a13	1,94	1 378,63
a14	8,38	407,39
a15	4,34	2 968,84
a16	2,04	1 488,61
a17	2,06	213,32
a18	0,83	-111,57
a19	9,7	29 735,97
a20	4,72	2 716,87
a21	0,61	-389,65
a22	1,21	80,4
a23	5,44	464,42
a24	1,94	6 447,6

	Utility	
Ref	B/C	NPV (kEuro)
a1	1,74	23 047,07
a2	6,7	25 787,68
a3	0,86	154,86
a4	2,11	5 845,32
a5	0,21	2,94
a6	3,66	21,23
a7	0,51	2,28
a8	5,41	9 177,96
a9	2,17	7 991,94
a10	13,98	11 868,19
a11	2,41	3 761,01
a12	11,47	58 202,29
a13	4,3	5 380,88
a14	14,59	685,33
a15	18,46	5 671,59
a16	7,87	4 075,22
a17	14,5	639,82
a18	4,96	753,06
a19	76,94	49 974,74
a20	23,92	5 038,42
a21	2,31	859,24
a22	13,26	628,66
a23	37,33	840,59
a24	3,93	18 746,84

	Ratepayer Impact Measure	
Ref	B/C	NPV (k€)
a1	0,5	-31 173,95
a2	0,73	-11 477,17
a3	0,44	-271,97
a4	0,57	-5 701,19
a5	0,16	-71,85
a6	0,55	-22,05
a7	0,29	-10,16
a8	0,7	-4 747,79
a9	0,59	-7 137,43
a10	0,96	-527,32
a11	0,78	-1 275,96
a12	1,72	26 385,36
a13	0,84	-1 198,63
a14	0,85	-144,08
a15	0,77	-2 069,07
a16	0,64	-2 802,65
a17	1	0,15
a18	0,58	-704,53
a19	0,94	-3550
a20	0,78	-1 668,79
a21	0,66	-555,06
a22	0,58	-594,9
a23	0,73	-369,33
a24	0,44	-33 706,1

as a result of imprecise inputs contributes to creating confidence and making the results understandable.

The application of the proposed methodology to a set of initiatives, for testing purposes allowed us also to propose ways of dealing with the need for a considerable amount of data, for setting the parameters of the decision models. The definition of a decision maker's preferences is usually not an easy process, and many would prefer relying on others' values as a way of avoiding this step. However, the capability of using imprecision in inputs and the analysis of the robustness of decisions are certainly useful aids for making this process less painful and creating confidence in the results. The use of different views, using for instance a group of experts, is a practical way for obtaining the parameters needed.

In opposition to the cost-benefit approach in which the decision makers usually have no intervention in the definition of the technical parameters, our approach offers them all the information, encourages their involvement in the whole process, improves the knowledge about the EEff initiatives and their own preferences for making sounder decisions, and provides a sense of ownership of the evaluation model.

Developments currently underway include: – the measurement of the impacts that in this work were mostly assessed using qualitative scales; – the interaction with multiple decision makers and the aggregation of their information; – a specific software tool to include the procedures of aggregation of multiple preference information and the analysis of the robustness of conclusions.

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