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Societal objectives as drivers in the search for criteria weights when ranking energy efficiency measures

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HIGHLIGHTS

- We address a Portuguese energy efficiency fostering tender mechanism.
- We used a genetic algorithm to search for sets of criteria weights.
- We used societal objectives to guide the selection of energy efficiency measures.
- Flexibility in the weights can help finding the best possible use of public money.

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ABSTRACT

In this paper we address a ranking problem from a tender mechanism established by the Portuguese energy regulator to promote energy efficiency measures in electricity consumption. Measures candidates to this tender are subjected to previously known assessment rules, and weighted criteria. Our proposal has explicitly taken avoided consumption and cost of saved kWh as decision variables for defining two societal objectives. In order to define ranges for the weights of the criteria and reference performance values, the search for the most suitable sets of weights is done by an evolutionary algorithm. Measures were used that applied for funding in previous tender calls. The results demonstrate that in face of different sets of measures, the range of weights for each criterion may vary significantly. The proposal, besides helping to obtain a more suitable set of criteria weights, can also assist in the very process of formulating the criteria, in view of the regulator's societal objectives, since it was found that some of the used criteria actually lack the ability to discriminate between candidate measures. After a post-processing analysis, the DM is presented with a set of criteria weights from which he can select the one that better reflects his preferences.

1. Introduction

In a ranking problem every alternative is evaluated according to a set of criteria, where each criterion represents a fundamental point of view and should be valued against the attractiveness it represents to the decision maker (DM). Behind the definition of criteria, as well as of their weights, are DM preferences and objectives. Consider the case when criteria and their weights should be set before the alternatives are known. Even when weights reflect DM preferences, in the presence of the alternatives to which they will be applied, a new set of weights could result in a more interesting outcome to the DM, even maintaining his preferences.

The Portuguese energy regulator (ERSE) has developed a tender mechanism to promote energy efficiency in electricity consumption (PPEC), with a track record of four calls for proposals. This tender mechanism, an actual market transformation instrument, is subject to an annual budget (funds come from electricity tariffs paid by all electricity consumers). Selected measures, to be implemented by the promoters, are partly financed by this budget and must contribute to increasing energy efficiency in electricity end-use. Among promoters are electricity suppliers, network operators, and consumer organizations, targeting different consumer segments (industrial, agricultural, residential, commerce and services). For the sake of transparency in the ranking and selection of measures, the regulator ensures that rules, criteria and their weights are known in advance.

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The data used in this work pertains to the last three PPEC calls. This work addresses only tangible ("hard") measures, whose effects are accountable for. Additionally, there are intangible ("soft") measures, of which good examples are information campaigns. Some of the measures candidates to those calls were not included in the work. This is, for example, the case of measures that address reactive power compensation. Those measures were very common in the first and even in the second calls, but are now highly discouraged. Therefore it was the authors' opinion that this type of measures should not be considered in their work. In Tables A1, A2 and A3, in Appendix A, the measures included in the study are presented, separated according to the consumer segment they address. One relevant characteristic of the sets of measures is that there is always a great number of them directed at lighting. In the 1st data set, of all 38 measures, 17 of them are related to improving efficiency in lighting. The 2nd set of data contains 40 measures, 20 of them regarding lighting. In the 3rd data set, 30 of the 53 measures are also addressing energy efficiency improvements in lighting. Another very common type of measures regards energy efficiency improvements in motors, such as installation of high efficiency motors, installation of variable speed drives, and even more efficient gears.

An alternative approach to the ranking of the measures is developed in the paper, based on the definition of societal objectives that are an intrinsic part of the regulator's mission. This alternative preserves simultaneously the essential method of assessing and ranking energy efficiency measures presented by the applicant promoters. Although maintaining the weighted sum of values assigned to each measure according to the regulator's criteria, the proposed methodology aims at improving the capability of the DM to express his preferences and obtain a ranking of measures that better suits societal objectives of energy efficiency fostering. This is accomplished by an improved definition of the weights in the weighted sum, based on the accumulated experience of previous PPEC editions, whose results are publicly available. Since PPEC funds derive from electricity tariffs paid by all electric energy customers, it is important to assure that all of them have the opportunity to benefit from measures financed by PPEC. Avoided consumption and cost of each saved kWh were the selected variables for defining the societal objectives addressed in the paper. Reducing consumption has the well-known impact of reducing GHG emissions, attenuating the depletion of resources, reducing the supply dependence from third party countries, as well as avoiding some more expensive energy production options. Reducing the cost of each saved kWh has an important impact on the economy. Besides, reducing the cost of each saved kWh highlights the advantages of using energy efficiency as an alternative to invest in more generation of electricity.

A brief context of the present work is made in Section 2. In Section 3 we make a brief description of the case study, highlighting the main differences between the approach followed by the regulator and our proposal. In Section 4 we present the proposed methodological approach. The application of the methodology and its results are presented in Section 5. In Section 6, some considerations regarding the results obtained and a post-processing analysis of the results regarding the selection of measures, are presented. The paper ends with some conclusions where some advantages of the proposed methodology are highlighted.

2. Contextual setting

The proximity to the energy consumer, the access to information regarding electricity consumption amounts and pattern, the knowledge to target conservation efforts, the possession of "know-how", of human, and of financial resources, are arguments in favor of engaging utilities in energy efficiency fostering policies (Jollands et al., 2010). Under the Tariff Code of the electricity sector, the Portuguese energy regulator (ERSE) developed PPEC to stimulate utilities, and other market players, to participate in the promotion of energy efficiency on the demand side.

Together with the promotion of energy efficiency, the increase of the share of renewable energy sources in the generation of electricity are pointed out as means to reduce GHG emissions, reduce dependence over fossil fuels, and reduce dependence over third-party countries. Portugal signed the Kyoto Protocol and, as a member of the EC, must improve its energy consumption regarding the above mentioned aspects. Besides the promotion of energy efficiency in the consumption of electricity, renewable energy sources for the production of electricity (RES) have also been capturing attention and incentives. Special support systems are given to RES, due to relatively high costs of energy production of electricity through RES, at least until they become competitive in the market (Meyer, 2003). Some experiments suggest that feed-in tariffs are the most effective way of stimulating the market for a sustainable development of RES (Couture and Gagnon, 2010). In Portugal, in order to reduce the amount of GHG emissions and to diversify the sources of electricity generation, an extra value is paid for each MWh generated by the special regime (Apolinário et al., 2009). Comparing the part of the costs of each saved kWh allocated to the PPEC budget (CSk_{PPEC}), both the one that resulted of the first PPEC edition (2007) and the ones that are expected of the last three PPEC editions, to the additional costs incurred in paying renewable kWh above market costs in order to stimulate RES (AMCRE), we can see that saving energy is much less expensive (Table 1). The values paid for each saved kWh of renewable source was between 2.3 and 6.25 times more expensive than investing in saving it.

3. Main differences between PPEC's approach and our own

The aim of this work is to help setting criteria weights that are used to value alternatives, using an additive value function. The case study used in this work is a mechanism managed by the Portuguese energy regulator to promote the implementation of energy efficiency measures in the consumption side of the electricity sector. The selected measures are the best performing, according to a set of criteria with previously fixed weights, set by the regulator.

The rank value is obtained according to the following 8 criteria (in brackets is the weight given to each criterion by the regulator in the most recent calls for proposals): *A*—benefit-cost analysis (60 points), *B*—scale risk (10 points), *C*—weight of the investment in equipment in the total cost of the measure (10 points), *D*—quality of presentation (7 points), *E*—ability to overcome market barriers and spill over effect (5 points), *F*—equity (4 points), *G*—innovation (2 points), and *H*—promoter experience in similar programs (2 points). Benefit-cost analysis is also

Table 1
Avoided consumption values, avoided emissions, CSk_{PPEC}, and AMCRE, reported by ERSE (Apolinário, et al., 2007; Apolinário, et al., 2009; ERSE, 2009, 2010, 2011).

PPEC editions	Avoided Consumption (GWh)	Avoided Emissions (thousand ton CO_2)	CSk_{PPEC} (€/kWh)	AMCRE (€/kWh)
2007	390	144	0.0127	0.0294
2008	878	325	0.0092	0.0416
2009	3004	1111	0.0054	0.0281
2011	2244	830	0.0080	0.0500