BEHAVIOURAL FACTORS' INFLUENCE ON ENERGY SAVINGS

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ABSTRACT

Energy consumption depends on various factors, such as equipment's energy efficiency, comfort level, consumer's behaviour and income. Equipment's efficiency and consumer's behaviour are crucial to achieve energy savings.

The present paper focuses on the relation between energy savings and consumer's behaviour.

For the majority of demand side management measures, energy savings obtained are affected by behavioural factors, introduced by the consumers.

The Portuguese Energy Services Regulatory Authority (ERSE) has developed a competitive mechanism for promoting efficiency in electricity consumption called PPEC (Demand-side Electricity Efficiency Plan). In this plan, energy efficiency measures, promoted by suppliers, network operators, consumers and energy agencies, etc, are evaluated and ranked by merit order. The merit of each measure is defined by a cost-benefit analysis.

A methodology to consider the behavioural factors in the merit analysis of energy efficiency measures is presented in the paper.

INTRODUCTION

The present paper presents a methodology to consider the behavioural factors in the usage conditions of certain electrical equipment in order to estimate electricity savings. This methodology is presented and applied to a set of measures designed to promote energy efficiency in the context of PPEC (Demand-side Electricity Efficiency Plan). It discusses several hypotheses for evaluating the behavioural factor (BF) on savings and the results in the ranking of energy efficiency measures.

Some conclusions about the influence of behavioural factors can be obtained.

PPEC - DEMAND-SIDE ELECTRICITY EFFICIENCY PLAN

ERSE has developed a competitive mechanism for promoting efficiency in electricity consumption called PPEC by which eligible promoters (suppliers, network operators, consumer associations, energy agencies, etc.) submit initiatives to improve electricity efficiency in the industrial, commercial and residential sectors. The annual budget of the program is supported by the Global Use of System regulated tariff, paid by all consumers and included in third party access tariffs.

In this plan, energy efficiency measures are evaluated and ranked by merit order, based on a technical and economical analysis [1]. The evaluation process is based on a metrical criteria related with the amount of energy savings deemed achievable through a given measure. These energy savings depend on the efficiency measure tangibility. Thus, energy efficiency measures are classified in two categories: tangible and intangible measures [2].

A tangible measure is usually associated with the installation of physical equipment with a level of efficiency superior to standard equipment available on the market, therefore producing measurable consumption reductions.

An intangible measure is associated with disseminating information or technical skills on energy efficient practices in order to promote a change in behaviours. Some examples of this sort of measures are energy audits, information campaigns, seminars and conferences.

The ranking process for tangible measures is run separately for each consumer segment: industry, services and households, thus allowing for the funds to be distributed by all segments.

Intangible measures cannot be evaluated by metrical criteria. Consequently, non-metrical criteria have to be applied, e.g. the ability to address and suppress relevant market barriers, equity on the access of the general public to the measure's benefits, risk of scale or innovation level [4].

The results obtained with demand side management programs, like PPEC, have proven to be cost effective when compared to other measures intended to lower carbon emissions (as green generation for example). Evidently both approaches have different virtues but it is clear that their consideration in energy policy instruments should be made in parallel.

BEHAVIOURAL FACTORS

The energy consumption level is influenced by equipment's energy efficiency, by consumer's behaviour, their comfort and income levels. The last two items are correlated. The efficiency level of equipment is mostly determined by technological issues. Energy consumption resulting from the use of certain equipment depends on this efficiency level but also on the intensity of use (for example, a heating device will consume more energy

The authors alone are accountable for the comments and conclusions presented in this paper.

with the hours it is running or the necessary heating power). This intensity of use is related to the utility level required by the consumer. Finally, and without reducing this utility level (or intended output), consumer behaviour can affect the energy consumption resulting from using a given technology (e.g. leaving the room light on when there is nobody there).
The consumer behaviour is likely to affect energy savings in some cases more than others. When savings are more dependent on behavioural aspects they are less likely to materialize. Thus, the expected energy savings resulting from a given energy efficiency promotion measure should be riskier (therefore, lower), in the case of higher dependence on consumer participation (behaviour). A behavioural factor is used for each efficiency measure to characterize the likelihood of its energy savings (taking values from 0 to 1). If there is great dependence between energy savings and consumer behaviour, then the behavioural factor is high, penalizing the efficiency measure. On the other hand, the behavioural factor is low for measures whose results do not depend too much from consumer actions.
The next figure resumes these statements.

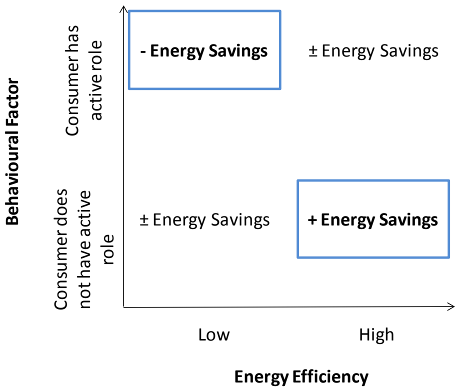

Figure 1. Behavioural factor and energy efficiency contribution to energy savings

An example of great dependence between achieved energy savings and consumer deliberate action is a power strip with a switch. This equipment provides a simple way of reducing stand-by energy consumptions but in order for savings to happen the consumer must deliberately switch on and off the power strip. Otherwise, the power strip is just like a plug which does not avoid stand-by consumption by itself.

Behavioural factors application model

A model was designed to apply behavioural factors to energy savings estimation in the context of PPEC's evaluation and ranking process. It was also analysed the influence of these behavioural factors in the ranking results.
Behavioural factors were only applied to tangible efficiency measures, affecting the metrical evaluation criteria.
Some hypotheses were drawn to determine the behavioural factor for each efficiency measure. It was set that the behavioural factor would depend on the consumer's role in the installation and utilization of the equipment (Hypothesis 1), on the consumer's share of the overall cost of the new equipment (Hypothesis 2) and on the type of consumer (industrial, commercial or residential). For efficiency measures addressing the household segment, an additional hypothesis was considered, which is whether it targets or not consumer segments with special needs (Hypothesis 3). Each hypothesis is described in more detail in the next paragraphs.
Generally, energy savings can be determined by the expression:

$$W_{Savings} = W_{Potential\ savings} \times BF$$

Where:
W_{Savings} are the expected energy savings after taking into account the behavioural factor BF; $W_{\text{Potential savings}}$ are the total potential energy savings which can result from the efficiency measure when the consumer fully and correctly uses the efficient equipment.

Hypothesis 1

In this hypothesis, the behavioural factor is determined by the expression:

$$BF = BF_1 = BF_{1A} \times BF_{1B}$$

Where BF_{1A} and BF_{1B} are settled according to Table 1.
In one hand, if the consumer plays a big role in installing or in using certain equipment, the BF should be low, meaning that there is a higher risk that the measure is not correctly installed or used, thus not producing the expected results in respect to energy savings.
Additionally, the higher the energy consumption level of a given consumer, the more important can be expected to be for him the energy savings resulting from the efficiency measure. That importance can be translated into a more skilled and professional look into energy efficiency measures. Thus, the value of BF has been set higher for consumer segments with higher energy consumption.

Question	Answer	BF_1 Household	BF_1 Services	BF_1 Industrial
BF_{1A} - Do energy savings depend of the consumer installing the equipment?	No	1	1	1
	Yes	0,9	0,95	0,975
	Yes and other alternatives with low saving performance exist.	0,2	0,6	0,8
BF_{1B} - Is the energy savings dependent on the consumer's equipment utilization?	No	1	1	1
	Yes	0,5	0,75	0,875

Table 1. Behavioural Factor for Hypothesis 1 (BF_{1A} and BF_{1B})

Hypothesis 2

This second hypothesis considers an additional question in determining the BF: what is the consumer's share in paying for the efficiency measure? The higher is this share the more probable is that energy savings are obtained, once the consumer is more personally committed to them. The share of consumer's participation in the costs of the efficiency measure is given by:

$$Cons_{share} = \frac{Cost\ payed\ by\ the\ consumer}{Total\ cost\ of\ the\ measure}$$

The BF_2 parameter was determined stepwise according to this share and intervals considered (0-10%, 10-30% and 30-100%) as shown in Table 2.

In this case, the BF to be applied to the energy savings is determined by:

$$BF = BF_1 \times BF_2$$

Question	Answer	BF_2 Household	BF_2 Services	BF_2 Industrial
What is the share of consumer participation in the costs of the efficiency measure?	0-10%	0,9	0,9	0,95
	10-30%	0,95	0,95	0,95
	30-100%	1	1	1

Table 2. Behavioural Factor for Hypothesis 2 (BF_2)

Hypothesis 3

The last hypothesis in determining the BF takes into account whether the consumer targeted by the efficiency measure belongs to any consumer group economically fragile. For consumers with economic difficulties, there should be greater awareness of the energy costs, thus stronger commitment to obtain energy savings provided by an efficiency measure. The identification of such consumer groups can rely on the location where the measure is implemented (for instance in social districts or old neighbourhoods), or other means.

This hypothesis was only applied to measures implemented in the residential sector. The BF is determined using the BF_3 value, as described in Table 3, as well as the following expression:

$$BF = BF_1 \times BF_2 \times BF_3$$

Question	Answer	BF_3 Household	BF_3 Services	BF_3 Industrial
Does the measure target economically fragile consumer groups?	Yes	1	-	-
	No	0,95	-	-

Table 3. Behavioural Factor for Hypothesis 3 (BF_3)

Results of BF application to energy efficiency measures

The behavioural factor model described was applied to a set of energy efficiency measures that were submitted for approval in the PPEC for 2008. Figure 2 shows the BF applied according to the hypothesis described.

The technologies included in the case study were: compact fluorescent lamps (CFL), LED lamps (LED), Power Strips (with a switcher), cooling (COOL), solar heating (SOLHEAT) and heating pump (HPUMP).

In PPEC 2008 analysis, only POWER STRIPS energy savings were affected by a risk factor of 0,25 because of its clear dependence on consumer's behaviour.

With the hypotheses presented in above, SOLHEAT, HPUMP and COOL measures were not affected by the behavioural factor since equipment installation is usually done by professionals and the efficiency performance of the equipment is not affected by the way consumers use the equipment. On the contrary, POWER STRIPS measures are the most influenced by the behavioural factor.

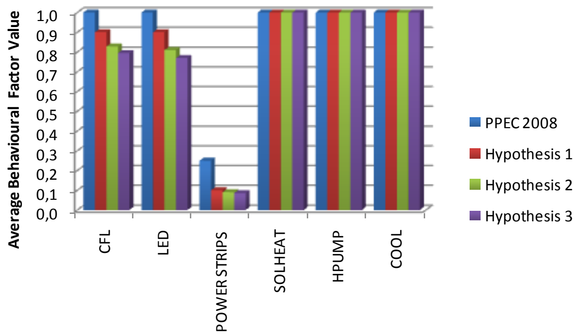

Figure 2. Behavioural Factor application to energy efficiency measures

Some conclusions can be drawn from the application of the BF to energy savings evaluation.

The BF's influence on the evaluation of the efficiency measures is such that it can change the merit order resulting from the ranking process. Figure 3 shows an example of the way this ranking can be affected by the application of BF. It also shows that, for the particular set of measures analysed, the use of additional criteria for BF determination (Hypothesis 2 and Hypothesis 3) does not influence the relative ranking of different technologies.

Some types of measures change their ranking positions depending on the use of BF. SOLHEAT and HPUMP measures raised their ranking position, while POWER STRIPS measures decreased notably their rank. In a competitive mechanism like PPEC, which assigns financing resources to the best efficiency promotion measures, changing the merit order of a measure can make the difference between achieving the financing approval or not.

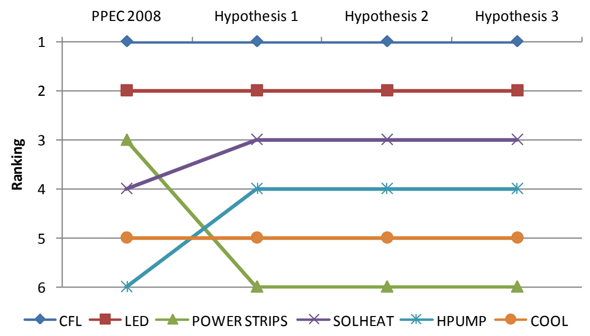

Figure 3. Ranking of efficiency measures by technology considering the BF

In Figure 3, it was considered an average ranking position for each technology. It is also important to analyse the influence of BF in different measures of similar technologies. Figure 4 presents the influence of BF on the ranking results of CFL measures among the measures for the residential customers. The 5 CFL measures were submitted to PPEC by promoters and, although they address the same technology, they present several differences respecting the way they are delivered to the public, the consumer groups targeted and share of consumer participation in the cost of the lamps. This results in different ranking positions. Nevertheless, 4 out of 5 measures are in the top 5 efficiency measures for the residential sector, showing that CFL is a very cost-effective energy saving solution.

When comparing different measures that target the same efficient technology, the results of applying BF can be observed and can even be more visible because the global evaluation of the measures is similar. It shows that the ranking changes with every option taken in respect to the BF determination.

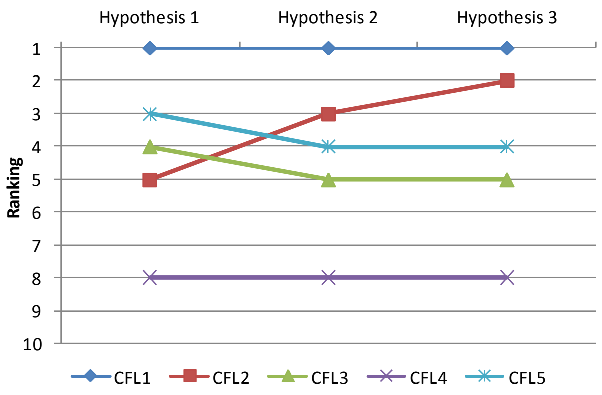

Figure 4. Ranking of CFL measures considering the BF

CONCLUSIONS

In the context of a regulatory instrument for energy efficiency promotion, which attributes financing resources to measures upon a competitive mechanism, a methodology to take into consideration the relation between the energy savings and consumer behaviour is developed. Energy savings credited to efficiency measures that rely much on the consumer role can be discounted compared to other measures which presumably can produce results without having to account on the consumer good practices.

The use of such methodology is more important when a primary objective of the regulatory instrument is to maximize real energy savings as these behavioural factors affect the set of approved efficiency measures. This is the case of Demand-side Electricity Efficiency Plan (PPEC).

The methodology presented in this paper is currently being used in the evaluation of energy efficiency measures for the PPEC, thus impacting in the approval of these measures. In the paper several hypotheses for evaluating the behavioural factors on savings are presented and the corresponding results on the merit order of several typical energy efficiency measures are shown.

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