Evaluation of an energy efficiency program for low-income households

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Abstract

This paper addresses the evaluation of an energy efficiency program for low-income households. The so-called 'éco-social' program was launched by the local utility of Geneva-Switzerland at the end of 2009. By the end of 2013 it had reached more than 5000 households through eight campaigns and attained its initial objective of 2 GWh/year of electricity savings before the end of the program.

The aim of éco-social is to favor the implementation of energy efficient technologies in low-income households. All of the inefficient lighting are replaced by energy efficient lighting devices, outlet power strips with external switch are installed, electric kettle boilers are offered and rebate vouchers are given to replace existing refrigerators by energy efficient ones.

Different types of data collection and methods are used to estimate the savings generated by the program: simple engineering ex-ante estimates (based on the information collected on the replaced and installed devices; enhanced ex-post engineering estimates (based on measurement of the energy consumption before and after the implementation). The ex-post methods were intended to calibrate the ex-ante methods that are used at present time to evaluate the savings during a given campaign. The methodologies and main results obtained are detailed in this paper. In addition, three topics are discussed: problems with the reference group for one of the saving estimation methods, the evolution of the stock of inefficient light bulbs in households, and the development of a software tool to estimate the savings.

One of the methods used to estimate the savings is based on the comparison of participant and non-participant households. Since the first campaign, the program had a great success concerning the willingness of targeted households to participate. This complicated the task of evaluators who intended to use non-participants as a reference group and had to slightly change the way saving estimations were made.

Data collected during the campaigns allow to follow the evolution of the stock of inefficient light bulbs in households. While a shift from incandescent light bulbs to compact fluorescent light bulbs (CFLs) was expected after the ban of incandescent light bulbs, it is rather observed a shift towards halogen bulbs. Statistics of the evolution of the average power of inefficient light bulbs, which are replaced during the campaigns, are also given in the paper.

Using the calibrated ex-ante methodology presented in this paper, the program operator is able to estimate the savings generated by each campaign with relatively good accuracy. This has been introduced in the software tool that is used by program implementers to manage the campaigns and allows to have a picture of the energy savings generated almost in real time.

The experience gained by the program and implementers allowed to redesign a new program for 2014-2015 with a more ambitious objective than the previous one. A similar objective (2 GWh/year) is targeted within a shorter time frame.

The program

éco21 and éco-social

The local utility SIG[1] (Geneva – Switzerland) launched an energy efficiency program in 2008, named éco21, for the electricity sector. The program started with a set of subprograms addressing different customer segments. One of these subprograms, named éco-social, was designed to address specifically low-income households. After a period of preparation, éco-social launched its first campaign at the end of 2009. By the end of 2013, eight campaigns have been implemented with the participation of 5288 households.

The program éco21 was initially intending to reach an objective of 150 GWh/year at the end of 2013. The sub-program éco-social was supposed to contribute to this objective by reducing the electricity consumption for a group of low-income households by 1.8 GWh/year (i.e. 1.2% of the global objective). At the end of 2013, éco-social obtained, through the eight campaigns, 2 GWh/year of savings, exceeding its initial objective by 11%.

Several factors prevented éco21 to reach the global objective of 150 GWh/year at the end of 2013 and the program was redesigned in order to obtain a more realistic objective: 125 GWh/year by 2015. As éco-social obtained its own first objective at the end of 2013, a new objective of 4 GWh/year (2 GWh/year in addition) is being targeted at the end of 2015, increasing the contribution of this subprogram to éco21 from 1.2% to 3.2 %.

While the contribution of éco-social to the global goal of éco21 is relatively small compared with the other subprograms, it gives a lot of visibility to the program itself and the utility SIG. The program appears frequently in the local newspapers and the SFOE[2] (Swiss Federal Office of Energy) awarded the program in 2011 with the "Watt d'Or", an award that recognizes significant and exemplary energy projects in Switzerland.

More details about éco-social

Several programs around the world address the problem of energy efficiency in low-income households in different ways (Blavier). The aim of éco-social is to favor the implementation of energy efficient technologies in low-income households in Geneva. To achieve this, most of the inefficient lighting (i.e. incandescent and halogen light bulbs) are replaced by energy efficient lighting devices (i.e. compact fluorescent lamps and LED); outlet power strips with external switch are installed, electric kettle boilers[3] are offered to families who do not own one, and rebate vouchers[4] are offered to replace existing refrigerators by energy efficient ones (A++ or A+++). The replacement of some bulbs by LEDs and the installation of electric kettle boilers started at the third campaign.

In order to put in place a given campaign, éco-social coordinates with a local municipality to select a group of buildings that will participate to the program, proceed to recruit the energy ambassadors and put in place the management and logistics for the campaign. The energy ambassadors are, in general, recruited among young people of the community who are unemployed. The energy ambassadors are trained before the campaign by a local association in charge of the coordination and management of the campaign. The municipality provides the

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[1] SIG (Services Industriels de Genève) is a public owned local utility that provides electricity, natural gas, water and sewage to the canton of Geneva (www.sig-ge.ch).

[2] The Swiss Federal Office of Energy (SFOE) is the Swiss competence center for issues relating to energy supply and energy use at the Federal Department of the Environment, Transport, Energy and Communications (DETEC).

[3] Electric kettle boilers were introduced since the second campaign.

[4] A rebate voucher had a value of 400 Swiss Francs for some campaigns and 500 Swiss Francs for the rest. It covers between 20 to 50% of the total price depending on the type of refrigerator. The sellers offer usually an additional rebate. The final amount that participants paid per refrigerator ranges from 290 to 530 Swiss Francs.

necessary space to store the material during the campaign and helps during the communication process in order to increase the participation rate among the selected households. In general, every campaign goes for two weeks.

Few days before the campaign, an intensive recruitment campaign among targeted households is carried out. Those who agreed to participate, arrange an appointment to receive a visit from an energy ambassador. During the visit, the participants receive, free of charge, a CFL or LED bulb in exchange of every inefficient bulb installed at home. The replacement is made by the ambassadors. The replaced bulbs are collected and discarded lately by the association in charge of the management of the campaign. The ambassadors identify appliances with high stand-by consumption and, if agreed upon by the participant, install an outlet power strip with external switch and inform the participant about its use. Finally, rebate vouchers, valid for three months, are distributed to those participants who own a refrigerator older than two years.

As described in the previous section, the first objective of éco-social was to achieve 1.8 GWh/year of electrical savings at the end of 2013. To achieve this, 4500 households were targeted with an expected saving of 407 kWh/year per household. The estimation of the expected savings per household was based on the hypothesis that a significant number of incandescent bulbs of 100 and 75 W would be replaced. A study of the first pilot project showed that the savings were close to 350 kWh/year per household, 14% lower than expected. The main reason identified was that the more commonly bulbs used were those of 60 W and 40 W instead the incandescent bulbs of 100 W and 75 W as initially supposed.

In order to reach the objective, the program increased the number of participants and introduced LEDs (to replace bulbs that could not be replaced by CFLs) and electrical kettle boilers. The total number of participants amounted 5288 at the end of 2013 instead of the 4500 initially planned. The energy savings per household increased slightly. The average estimated savings for the eight campaigns is close to 380 kWh/year per household.

In 2013, éco21 merged with another program intended to reduce carbon emissions. In order to contribute to carbon reduction, starting January 2014, éco-social introduced low-flow showerheads to replace inefficient ones and the installation of aerators in faucets. The purpose of these actions is to reduce the use of hot water that is produced using fuel oil or natural gas. The first results for these new actions are under analysis and are not presented in this paper.

Counting the energy savings / methods used for the evaluation

The program éco21 requested the University of Geneva in 2009 to take care for the evaluation of the program. A methodology was developed for each of the subprograms, data collection, and transfer protocols were organized and reports and results are followed by the evaluators in a bi-yearly basis. The general methodology for the evaluation of savings and the particular methods used for éco-social were described previously (Cabrera et al). The adopted evaluation methods are based mainly on the work already done by Intelligent Energy for Europe (Ecofys, Broc). The EVO IPMVP protocol inspired also the methodology (EVO).

The development of the evaluation methodology for éco-social started in parallel with the first pilot campaign. It was decided to use a bottom-up approach and whenever possible, to use an ex-post evaluation based on measurements before and after the campaign. More specifically, three types of methods were proposed: 1) a simple engineering ex-ante estimation based on the information collected during the implementation of a given project; 2) enhanced engineering ex-post estimates based on extraordinary measurement with two variants and; 3) ex-post analysis of billing readings. We describe briefly the first two methods[5] below in the present section and detail the pertinent particularities that are useful to better illustrate the contents of the following section where we present some results and discuss some lessons learned.

Simple engineering ex-ante estimation (method 1)

This method is based on the information collected during the implementation of each campaign. The following information is collected by the ambassadors for every household they visit: 1) power for each replaced bulb; 2) number and age of the fridge-freezer, 3) type of kitchen (gas or electrical); 4) power of each new bulb installed; 5) number of water kettle boilers installed (1 or 0) and; 6) number of power-strips installed. The first three are used to establish the baseline consumption, and the following three to estimate the ex-ante savings.

Let’s note that, except for the power of replaced bulbs, the rest of the information has to be recorded anyway for administrative purposes. Then, the additional effort to complete the information needed for the ex-ante calculations is marginal.

The forms used during the first two campaigns allowed the ambassadors to write manually the power of bulbs. The information written by the ambassadors was not always easy to understand and errors were easily produced during the transcription of data to an electronic format.

The project manager decided to improve the data collection process and introduced a new form that facilitates the recording process. With this new form, the ambassadors just fill in a field to record the power of the replaced bulb. The forms contain a barcode that helps to transfer the data from the forms to a digital database. The error for transfering the information is then drastically reduced. However, in order to optimize the available space in the form, only the following fields were introduced (25 W, 40 W, 60 W, 75 W, 100 W for incandescent bulbs; 20W, 35 W and 50 W for halogen bulbs, and 300 W for linear halogen bulbs). An additional field allows to record other powers provided that there are only few of them. With the introduction in the market of new “efficient” halogen bulbs that are similar in shape as the old incandescent bulbs, there now exists a wide range of powers. The ambassadors then check the checkbox with the closest power for halogen bulbs with a power that does not match exactly one of the available cases in the form. This introduces some error for every individual bulb that statistically is reduced for a large number of them. Some results concerning the analysis of the database containing the replaced bulbs are detailed in the next section.

The estimated age of refrigerators is recorded. The ambassadors can fill one of the following options (less than two years; between two and ten years and; older than ten years). They usually give a rebate voucher per fridge-freezer only for those that are older than two years. The ambassadors record also the number of power strips that they install and the boiler that was offered, if any.

The advantage of this method is that it is relatively cheaper and it allows for saving estimations in a very short period of time. The disadvantage is that, if not calibrated and supported by ex-post methods, can give wrong (or biased) saving estimations. This method has been applied for all the eight campaigns, retroactively for the two first campaigns. At present time, it has been introduced in the software that is used to manage the campaigns.

Enhanced engineering ex-post estimations (method 2)

[5] Billing analysis is not discussed in this paper. Analysis will be carried out at the end of the summer 2014, when data will be available for five campaigns.

This method is based on different types of measurements performed during three time intervals[6]. The first interval falls shortly before the campaign, the second interval just after the campaign and the third interval occurs after the replacement of fridges-freezers (i.e. between three to six months later). The duration of the interval used was a multiple of a week (two in general[7]) in order to avoid the imbalance that can arise due to difference in energy consumption between labor days and weekend.

The aim with this method is to evaluate the savings shortly after the campaign implementation and to calibrate the ex-ante method as early as possible. It has been applied to the first two projects and then at least to one project per year. It will be applied in the next two years for at least one project per year with the purpose of consolidating the ex-ante estimates or, failing that, to correct the parameters used for the estimations.

Two types of measurements were used, method 2a and method 2b, described here below.

The first method (method 2a) consists of three sets[8] or extraordinary readings of the electric utility meters (including date, hour and kWh). The extraordinary readings are performed by the personal on charge of electric meter readings at SIG. The meters are read the same day of the week at the same hour (± 1 hour). The data are collected for all the households targeted by a given campaign (i.e. participants and non-participants). Our intention was to use the data collected from non-participants as a reference.

The second method (method 2b) consists of two or three load profiles (usually at 15 minutes intervals) recorded by electricity loggers that are installed expressly to measure the savings. The loggers are installed at the main power electrical switchboard and then measure the power for a group of households that are located in the same building. The disadvantage of this method is that the individual information for each household is lost. The advantage is that load profiles allow to check at what time of the day the savings are more important. Let's note however that the program is not looking for peak reduction.

The first two campaigns beneficiated of method 2a and 2b and the third campaign beneficiated only of method 2a. Later, method 2b has been preferred. The reasons that pushed the evaluators to drop-out method 2a in favor of method 2b are detailed in the next section.

Two main problems arise with the enhanced engineering ex-post estimations: first, the extraordinary measurements have usually a relatively high cost when compared with the ex-ante method or the billing analysis method; and second, an error is introduced when extrapolating this data to a yearly consumption. The advantage, as stipulated before, is that it allows for a saving evaluation based on measurements, shortly after the implementation of the campaign.

Summary of methods

Three types of methods are used to evaluate the savings: 1) a simple engineering ex ante estimation based on the information collected during the implementation of a given campaign; 2) enhanced engineering ex-post estimates based on extraordinary measurement with two variants and; 3) ex post analysis of billing readings. The aim was to drop the enhanced engineering ex post estimates in favor of the improved simple engineering estimations that are more efficient in time and cost. However, due to the dynamic observed in the energy efficiency

[6] However, only two time intervals were used for two campaigns in order to reduce costs.
[7] For one campaign, we obtained measurements for three weeks.
[8] In some cases we obtained only two to reduce measurement costs.

field and the requirement of additionality that the program has to fulfill, lead us to propose rather to use an ex ante method that has to be recalibrated periodically by ex post measurements.

The information collected during the campaigns provides valuable information to the evaluators. The information gathered allows not only determining with satisfactory precision the savings obtained by éco-social, but it is also helpful for the evaluation of other programs addressing the residential sector (see paper presented by Bertholet in this conference) and the effect of federal energy efficiency policies.

Lessons learned and main results

This section presents some lessons learned and results obtained from the analysis of data collected for the evaluation of energy savings. We describe here some issues concerning the reference group in method 2a, the evolution of type and power of bulbs used in households and the usefulness of the evaluation as a monitoring tool.

The problem with the reference group

It is useful to have a reference group to which participants can be compared. It made sense to take the non-participants of the targeted households as a reference group. Two factors impeded to proceed further this way: the high participation rate and the biases observed.

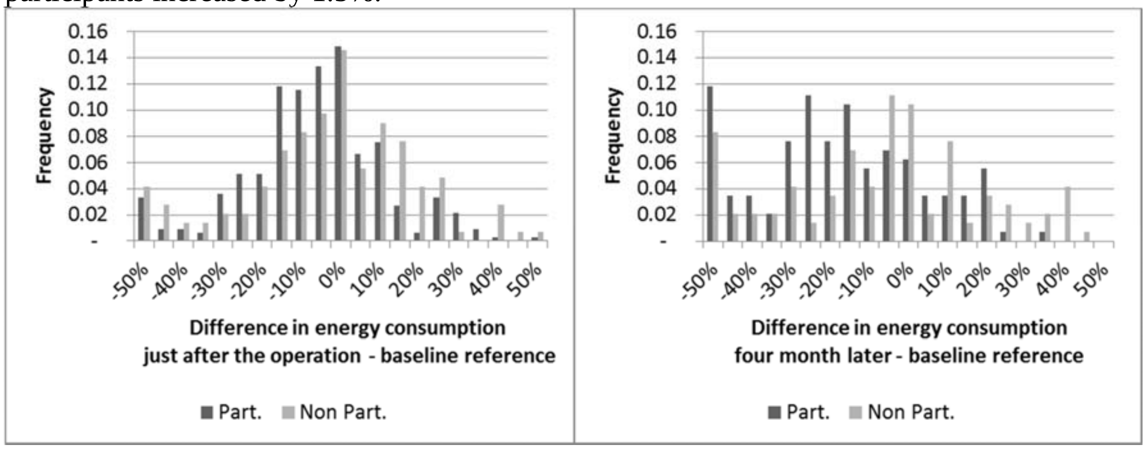
The first campaign had already, from our point of view, a successful response from households willing to participate to the program. The program managers obtained a high rate of participants (336 households representing 67% of the target), and left a reasonable number of non-participants (168 households representing 33% of the target) for the comparative analysis. Starting at the second campaign, éco-social has had a very high participation rate among the targeted households, higher than 87% in all the cases, leaving less than 13% of households for the reference group. **Table 1** provides a summary of targeted households and participation rate for the eight campaigns.

Table 1. Number of target households, participants recruited and participation rate for the eight campaigns. The participation rate has been, from our point of view, very successful.

Campaign	Targeted households	Participants	Participation rate
1	504	336	67%
2	580	502	87%
3	787	688	87%
4	1070	930	87%
5	795	716	90%
6	1072	939	88%
7	619	591	95%
8	639	586	92%
Total	6066	5288	87%

For the first campaign, the non-participants (33%)[9] were used as a reference group to calibrate the savings (see **Figure 1** below). Households participating in the project reduced their electric consumption by approximately 12%, whereas the consumption of the households that did not take part in the program increased by 1.5%. The average energy savings for the participating households can be then estimated to 13.5% (12% - (-1.5%)). However, we noticed that non-participants had in average a lower yearly consumption than participants but not further investigation was carried out at this stage.

Figure 1. Distribution of the difference in energy consumption just after implementation (left) and 4 months later (right) for both groups (participants and non-participants). The participants reduced their electric consumption by approximately 12%, whereas the consumption of non-participants increased by 1.5%.



For the second and third campaign, the excellent recruitment process obtained a higher participation rate and left a small number of households (13%) for the non-participant group. We noticed again that non participants had in average lower yearly energy consumption than participants. After investigation, it was found that several non-participants were in general people who were not frequently at home and could not be contacted during the recruitment campaign. Then, not only the reference group became too small, but also the non-participants households were not really representative and our results could be biased if this group continued to be used as a reference. As the high participation rate for the following campaigns was expected to be as successful as the previous ones (indeed it has been the case, achieving 95% during the seventh campaign), we decided to drop out non-participants of the targeted buildings to be part of the reference group. We decided then, starting the fifth campaign, to privilege load profile measurements (method 2b) instead individual extraordinary meter readings (method 2a) for the following projects where measurements of method 2 type were selected. However, the problem of the lack of a reference group persisted. Finally, for the eighth campaign, a group of buildings not included in the target, but with similar characteristics, has been selected as reference. For this last campaign, load profile measurements were used. The measurements were made for a group of buildings participating in the campaign and a group of buildings not participating in the campaign. In this way, the reference group is not anymore affected by the success of the recruitment campaign.

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[9] Actually, the number in both groups was a little bit smaller. We noticed some data concerning households showing almost zero consumption at one of the three periods (some households were empty due to a building renovation). These households were removed to avoid biases.

Table 2 presents the methods that were used for the eight campaigns to evaluate the energy savings, the availability of a reference group, and the biases of the reference group.

Table 2. Methods used for the estimation of energy savings for each one of the campaigns

Campaign	simple engineering ex-ante	enhanced engineering ex-post individual meter readings	enhanced engineering ex-post load profiles	availability of reference group	biased
1	x	x	x	yes	yes
2	x	x	x	yes	yes
3	x	x		yes	yes
4	x			no	-
5	x		x	no	-
6	x			no	-
7	x			no	-
8	x		x	yes	no

Analysis of replaced bulbs

As stated early, the information concerning the power of replaced bulbs is important to establish correctly the baseline for the simple engineering estimations (method 1). It was expected that this baseline would move as the interdiction of incandescent light bulbs started in Switzerland in 2009. It has been the main reason to record the power of replaced bulbs. The ambassadors recorded this information for each household visited. The numbers of bulbs recorded during four years is close to 40'000. **Table 3** gives a summary of the number of bulbs for each campaign and type of power.

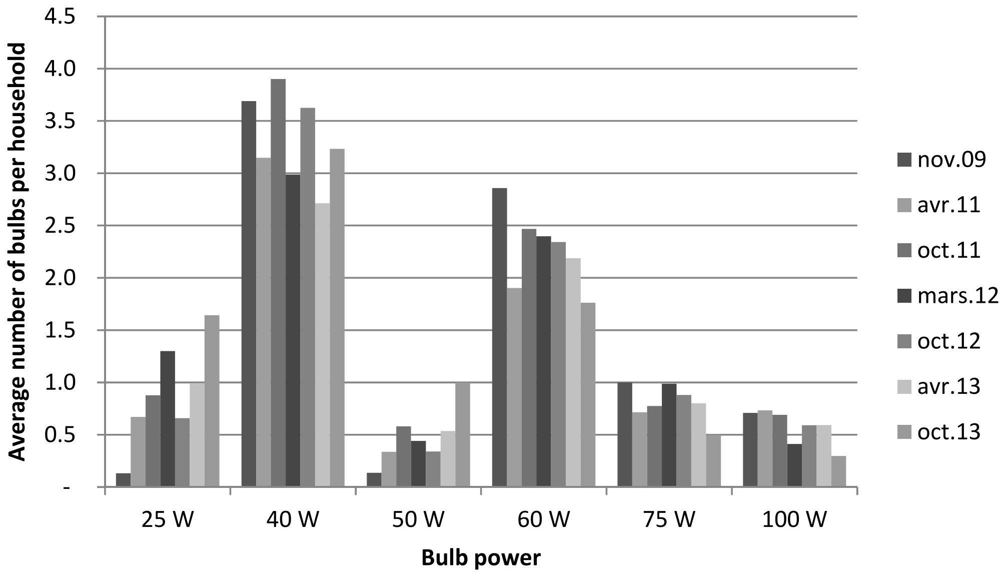
Table 3. Number of bulbs /and %) of a given power replaced during the éco-social campaigns

W/Camp	1		3		4		5		6		7		8		Total
25	22	2%	462	9%	815	9%	930	15%	594	8%	584	13%	962	19%	4369
40	620	43%	2165	42%	3627	42%	2139	35%	3274	43%	1600	35%	1895	38%	15320
50	23	2%	232	4%	539	6%	315	5%	307	4%	316	7%	585	12%	2317
60	480	34%	1309	25%	2294	27%	1717	28%	2115	28%	1291	28%	1032	21%	10238
75	168	12%	491	10%	720	8%	706	12%	795	10%	472	10%	291	6%	3643
100	119	8%	504	10%	641	7%	295	5%	533	7%	349	8%	174	4%	2615
Total	1432		5163		8636		6102		7618		4612		4939		38502

Let's note that the rate of incandescent bulbs of 100W and 75W is relatively small. Bulbs of these powers account together for less than 15% of the replaced bulbs. This was one of the important findings at the first campaign as one of the premises was to replace this type of bulbs.

Figure 2 presents the distribution of bulbs of different powers for seven of the eight campaigns. We observe a decreasing tendency for bulbs with the powers of 100W, 75W, 60W and 40W. Those powers corresponded for the first campaign to incandescent bulbs, but at present time we noticed an important share of halogen bulbs, especially for the 60W and 40W. Concerning the bulbs of 25W and 50W, a large part of them are halogen and its number is increasing.

Figure 2. Distribution of bulbs of different powers for seven éco-social campaigns.



Due to the ban of incandescent bulbs, it was expected that, at a given moment, few inefficient bulbs will be found in households. We expected that this would occur before the end of 2013, the initial date for the finalization of the program. As savings obtained with the replacement of bulbs is the largest part of the savings generated by the program, there was a risk that lower savings could potentially impact the achievement of the objective. The number of incandescent bulbs has reduced; however, there are still a large number of incandescent bulbs operating in households. The average power of bulbs has indeed reduced, but surprisingly for us not at the expected rate. Additionally, instead of the replacement of incandescent bulbs by energy saving technologies (like CFLs or LED), we have observed a shift towards the new type of halogens, those that have a shape similar to the incandescent bulbs. The replacement of inefficient bulbs still plays a role for éco-social.

A Negawatthour meter

The ex-ante estimation method is systematically applied for each campaign. The information gathered by the ambassadors is recorded firstly in forms and then transferred to a database using barcodes.

The results from the measurements and calculations made following the ex-post methods allowed for a calibration of the ex-ante method that is fairly accurate.

At present time, the information recorded in the forms by the ambassadors is introduced few hours later in the software that is used to monitor the campaign and an estimation of the savings is made immediately after.

As the database is available on-line, the program manager can follow the saving estimates almost in real time (as soon as the information is digitally recorded). It allows also to communicate the results of each campaign, shortly after its finalization, with satisfactory accuracy.

Conclusions

The selection of a reference group is not an easy task. The success of the program introduced a bias for the reference group that was composed of non-participants. This forced the evaluators to look for other alternatives for the selection of the reference group. It has been useful in this case to have alternative ex-post methods to estimate the savings and the flexibility to modify them accordingly to our needs.

The average power of inefficient bulbs in households is reducing thanks to the policies introduced in 2009 (phase-out of incandescent bulbs). However, instead of the replacement of incandescent bulbs by energy saving technologies (like CFLs or LED), we have observed a shift towards mainly the new type of halogens, those that have a shape similar to the incandescent bulbs. Then, the replacement of inefficient bulbs still plays a role for programs addressing the residential lighting sector.

The methods used for the evaluation of savings allowed to build an ex-ante estimation method that was introduced in the software used for the managers during the implementation of the campaigns. It is possible at present time to follow almost in real time the savings produced by the program and to communicate shortly after the implementation fairly accurate results.

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