When can we trust ex-ante energy savings estimates?

Cabrera Daniel, University of Geneva, Geneva-Switzerland
Bertholet Jean-Luc, University of Geneva, Geneva-Switzerland
Lachal Bernard, University of Geneva, Geneva-Switzerland

Abstract

The cost of ex-ante savings estimates is in general significantly lower than ex-post (enhanced engineering measurements and billing analysis). For this reason, the former ones are frequently used to assess the energy savings generated by programs promoting energy efficiency. However, sometimes the errors arising from ex-ante estimates can be relatively important and provide misleading information to program managers. Under what conditions may we expect to have a good accuracy of ex-ante savings estimates? Is it enough to have trained and experienced professionals in charge of the ex-ante estimations? Can we consider other characteristics inherent to the energy saving projects that could help to give some elements that allow assessing under what conditions ex-ante estimates can be trusted? This paper presents an analysis based on the monitoring of several hundred of lighting projects for which ex-ante and ex-post estimates are available and shows some particularities among those with a relatively low/high error rate. These findings can be exploited to elaborate some criteria that can be used to decide under what conditions ex-ante estimates can be used and improve the cost efficiency of the impact evaluation without sacrificing accuracy.

Introduction

Ex-ante estimations are often used in energy efficiency programs for its impact evaluation. There are some advantages to use them: they are less costly than ex-post, the results are available as soon as a given Energy Efficiency Action (EEA) has been implemented and; they can in general be carried out by personnel requiring only a basic training. However, it is indisputable the disadvantage that they could have in accuracy when compared with ex-post estimations.

Our study is focused on the results obtained through the evaluation of an energy efficiency program in Geneva-Switzerland. The program, named éco21, has several subprograms organized to address different customer sectors (Reynaud et al. 2014). The impact evaluation of the program has a strong component of bottom-up and ex-post analysis providing the evaluators with some detailed information at project level (Cabrera et al. 2012).

To better illustrate our purpose in the present study, the savings estimates of light retrofit projects from two sub-programs are analyzed. While the ex-ante estimates for one of the sub-programs was found initially to have a good accuracy, it was not the case for the second sub-program. This difference in accuracy of ex-ante calculations between the two subprograms inspired the authors of this paper to analyze the assumptions used in the ex-ante calculations for both sub-programs in more detail.

Ex-ante vs. ex-post

Estimates of savings from efficiency measures are typically made both prior to program implementation (i.e., ex-ante) and after program implementation (i.e., ex-post). Ex-post estimates of cost and savings are generally considered a more accurate representation of actual cost and savings, particularly after they have been reviewed and analyzed by an independent, third-party evaluator, in which case they can be called evaluated, ex post estimates (Schiller et al 2011).

Let's have, first of all, a discussion of the advantages and disadvantages of ex-ante under the consideration of the following points: cost; availability in time; availability of human resources; and accuracy.

The cost for ex-ante estimates is in general cheaper than for ex-post estimates as for the formers it is not required to make measurements in addition to the calculations. For example, for a project consisting to replace a group of light fixtures of the same characteristics, the ex-ante calculations require only to know: the number of fixtures, the required power and the operating time (before and after the EEA). However, for an ex-post estimation, it is necessary to measure the energy consumption before and after the retrofit to account for the savings. If lighting accounts for only part of the total electricity consumption, as it is often the case, the billing meter will not be enough to measure accurately the savings and it will be necessary to make specific measurements. With this purpose, the electrical panel that feeds the light fixtures addressed by the EEA, and the respective electrical conductors, have to be identified, a measurement device has to be installed (and later removed), and finally the data has to be extracted and analyzed to calculate the savings1.

The prompt availability of savings estimates, characteristic of the ex-ante estimations, is an actual advantage for program managers as they can follow almost in « real time » the progress of the program. Actually, the results can be even available for program managers before the EEA has been implemented (if changes are not made during the implementation phase). In contrast, ex-post estimates require a given period of time in order to evaluate the energy consumption after the EEA has been implemented. When the seasonality has to be taken into account, sometimes several months are required in order to collect the necessary data. The analysis of the gathered data and preparation of the respective report may also take some time. This long waiting period can be counterproductive for a program manager who needs a prompt feedback to monitor the progress of the program.

Due to the fact that ex-ante estimates for several types of EEA are based on simple calculations, professionals with a very basic training can take care of it. If program managers provide appropriate training to stockholders, the quality and the precision of the ex-ante estimates can be improved significantly. In addition, software tools can help to facilitate the task of the estimates and guide the user to avoid mistakes when making the calculations. In contrast, the measurements needed for ex-post estimations, require frequently skilled professionals that in general will need a given certification to install the meters, make the calculations and develop the measurement and verification report.

The Achilles heel of the ex-ante estimates is the inaccuracy that could arise if the hypothesis taken for the calculations does not reflect reality. If this is the case, all the advantages described in the previous paragraphs will fade.

A particular form of ex-ante estimates are the deemed savings. In this case, it is not even necessary to make any calculation. One example is the white certificates scheme used in France (Bertoldi et al 2010) where an amount of kWh cumac (cumulated and actualized over the life expectancy of the product) is associated with a given action. The amount of savings is associated to a given EEA like for example replacing an existing light bulb - incandescent or halogen - by a more efficient one - CFL or LED or replacing an old refrigerator by a new efficient A+++ one. In this case, it is enough to know the number of replaced bulbs and refrigerators to deduce the savings. Deemed estimates could be even less costly, be available as soon as the EEA has been carried out and it is not

1 There can be of course some exceptions concerning the cost of ex-ante estimates. This is the case when savings arose from a complex EEA where rather complex models and/or software tools are necessary to make accurate calculations. One example is the comprehensive retrofit of a building envelope. Here, it is required for an ex-ante estimation to obtain data concerning the area and thermal characteristics for all the elements of the envelope (walls, roof, windows); the optical characteristics and orientation for the transparent components (windows); identify the thermal bridges and finally proceed to make simulations that need in addition meteorological data for the city where the building is located. Getting all this information and introducing into a software tool to model the thermal behavior of the building has an inherent cost that usually is not negligible. For the ex-post estimations of the same EEA, the annual (or monthly) energy consumption (that can be obtained from the billing meter) adjusted or corrected by meteorological conditions would be sufficient for the energy saving calculations.

even necessary to train professionals to estimate the savings. However, the results, in particular at project level, can potentially deviate significantly from the reality.

Description of the ex-ante calculations of our study case

As stated before, projects from two sub-programs, both of them belonging to a large program, form part of the present study.

For projects of both programs, the professionals in charge of the project perform a basic energy audit addressing the lighting system and estimate the present energy consumption and the future energy consumption with the proposed efficient light fixtures. The calculation is based on the number of fixtures, the individual power of light bulbs or light fixtures (including the ballast) and an estimation of the operating hours.

Once the project is finalized, the electrician in charge of the project (or the owner of the building) sends a copy of the bill of the project (with the cost of the equipment and the installation) to the program manager, who validates the estimation and send back a financial incentive2. The financial incentive is proportional to the ex-ante estimated savings, additional reason to look for accurate estimations at project level.

In order to better illustrate the analysis that is given later in this paper, we describe first the two sub-programs, given some details of the projects and the inherent characteristics of the hypothesis taken in consideration for the ex-ante calculations.

The Communal Areas of Buildings sub-program

The first sub-program is addressing the communal areas of buildings, in particular residential ones. Within this program, the lighting system in the entrance hall, corridors, stairwells and parking of buildings are retrofitted. There is a particular characteristic of lighting systems of communal areas of buildings in Geneva: before 2005, it was mandatory to insure that light was always on. Then, light fixtures in closed spaces were installed to run 24 hours per day (i.e. connected directly to an electrical panel without a switch to prevent that lights could be turned off) and light fixtures in spaces where natural light was available were connected to a clock (or equivalent system) to turn on the lights automatically for the entire night, operating in this way 12 hours per day on average. Consequently, the electricity consumption for lighting represents an important part of the total consumption of communal areas of buildings. Most of the lighting projects were carried out in multifamily buildings. An analysis of a small sample of them showed that lighting accounts for almost fifty percent of the electricity consumption (households excluded). The rest is distributed among elevators, ventilation fans, heating distribution pumps and laundry equipment.

Until 2008, when the program started, practically all the buildings constructed before 2005 kept the same type of system. The electricians, partners of the program, promoted at the beginning more efficient fluorescent light fixtures (electronic ballast and 28W T8 fluorescent tubes) as a standard to replace the existing light fixtures and are promoting at present time the installation of more efficient light fixtures (in general LEDs with a power close to 20W). Concerning the replaced light fixtures, most of them consist of 36W T8 fluorescent tubes with ferromagnetic ballasts. The new light fixtures include a sensor to turn on the light when an occupant is detected. When nobody is present, the light intensity is reduced to 10%.

For some of the first projects, ex-post analysis with on-site measurements addressing specifically light fixtures were performed and for almost all of the projects the ex-ante savings at the program level are confirmed by an analysis of the electrical bills. More than two thousand buildings

2 A comprehensive macroeconomic analysis for the Communal Areas subprogram can be found in (Yushchenko et al 2016).

have participated at present time to the program and this number allows for robust statistical analysis. The billing analysis shows that on the program level the average of deviations is compensated and there is a good concordance between the ex-ante and ex-post estimates. Actually, the ex-ante estimates are slightly smaller than the ex-post that left the evaluators believe in the good accuracy and a rather conservative estimation of the savings. At individual level we can find of course significant differences[3], but at the program level the errors compensate in average and the difference is rather small. It was pleasant for the evaluation team to find that the difference between ex-ante and ex-post estimations at the program level were close (see Table 1)[4].

Table 1. Ex-ante and Ex-post savings (in MWh/year) for the Communal Areas sub-program

		Ex-ante		**Ex-post**		**Realization Rate [5]**
Year	**Projects**	**Savings (mean)**	**Savings (total)**	**Savings (mean)**	**Savings (total)**	**Ex-post / Ex-ante**
2008	4	-5.3	-21	-6.1	-24	1.14
2009	103	-7.3	-751	-6.4	-657	0.87
2010	262	-6.5	-1'694	-8.6	-2'266	1.34
2011	304	-7.2	-2'184	-7.8	-2'383	1.09
2012	540	-8.8	-4'765	-11.2	-6'045	1.27
2013	581	-8.3	-4'813	-8.7	-5'036	1.05
2014	386	-9.2	-3'569	#N/A	#N/A	#NA

The Optiwatt sub-program

The second sub-program addresses middle customers, those with annual electricity consumption between 30 MWh/y and 1000 MWh/y [6]. Among the customers who already participated to the program, we find restaurants, office buildings, small hotels, etc. Projects in this program are then more heterogeneous than the previous one. This sub-program started four years later than the previous one for the communal areas of buildings that has been described in the previous section.

An energy audit addressing lighting is financed by the program and if the proposed retrofit is executed, the energy audit is used as the ex-ante estimation for the energy savings. Once the project has been executed, an additional financial incentive, based on the amount of savings, is offered to the customer.

As several projects consist to change only light bulbs (for example a restaurant where halogen bulbs are replaced by LED ones), it is not required to have a trained technician to execute the project and new energy auditors, with basic training, started to be in charge the ex-ante calculations and the implementation of the Optiwatt projects.

A first analysis of some projects of the Optiwatt sub-program showed some bias between the projected and the real savings. The difference between ex-ante and ex-post estimates were more

---

3 It is possible to observe also a given tendency depending on the professional (or the company) in charge of the calculations. While some of them tend to be conservative with their estimations, some others tend to be rather optimistic.
4 More detailed information about the impact evaluation of this program can be found in Bertholet 2016.
5 The realization rate corresponds to the evaluated (ex-post) gross savings divided by the claimed (ex-ante) gross savings.
6 Let's note however that, at present time, most of the customers who have participated to the program are below 100 MWh/y.

important than what we found for the Communal Areas subprogram and in general overestimating the savings. What was more surprising is that, not only the new auditors, but also the same professionals that were involved with the Communal Areas projects and doing accurate savings estimations didn't have the same accuracy for Optiwatt projects. This difference in accuracy between the two programs inspired the authors of this paper to analyze the assumptions used in the ex-ante calculations in more detail. The details and result of this analysis are presented in the following section.

Analysis of ex-ante calculations

Previous works have addressed the discrepancy that can arise between claimed savings from energy programs and their verified savings. The discrepancy at a project level can be due to a number of factors like for example eligibility requirements, changes in operating hours, or the applicable baseline (Lutz 2014).

For our study case, the calculation of savings is based on the estimation of the electricity consumption before and after the retrofit, each one based on the estimation of the power and operating hours of light fixtures, information that is available for the evaluation team and allow for deeper analysis. We present here our analysis over the hypothesis taken to make the ex-ante calculations for projects of both programs.

Let's note that collecting the detailed data from thousand energy audits can be cumbersome. However, this task can be optimized if auditors use an informatics tool for their calculation as it is the case for most of the audits with the two sub-programs of the present study. The audit tool has been put in place by the program and a specific training is offered to auditors that join the program.

Communal Areas of Buildings

Concerning the estimation of the situation before retrofit, the evaluation team found that the estimation of the power had a good accuracy. The imprecision came mainly from the estimation of the power drained by the ballast (most of them ferromagnetic). The total power of light fixtures was in general slightly underestimated. For the operating hours of light fixtures, the precision was very accurate. This is not surprising given the fact that most of light fixtures operate either 12 or 24 hours per day. There are of course burned light tubes that are not consuming electricity but its number is considered to be in general insignificant.

Concerning the hypothesis taken for the estimation of the electricity consumption after retrofit, we found a couple of bias. The power of light fixtures when operating at 100% was estimated correctly (the power of the entire light fixture, included the electronic ballast is really close to 28 W). However, the power during stand-by was considered to be 10% of the nominal power while electrical measurement showed that the actual power was 30% of the nominal one. On the other side, the operating hours at 100% were overestimated by more than twice the actual value (underestimating in this way the stand-by time). A few on-site measurements in multifamily buildings[7] showed that the time people stay in corridors and stairways is very short: just the elapsed time between the moment they open the door to leave the flat, go to the elevator and wait for it (or the reverse). It was found that, for all inhabitants combined, light fixtures on a given corridor stay on for close than one hour per day. Electricians were considering in their calculations between two to three hours, overestimating in this way the electricity consumption and overcompensating the error arising from the wrong value used for the power during the stand-by operation.

---

7 These measurements were made with loggers equipped with occupancy and light sensors installed close to light fixtures.

The electricity consumption for the situation before and after retrofit are underestimated. However, due to the fact that the difference in electricity consumption between the two situations (before and after the retrofit) is important, the impact on the calculation of the savings has a small impact.

Optiwatt

Concerning the hypothesis taken for the sub-program Optiwatt, the estimation of the power of light bulbs is in general good. However, it was found that it is not the case for the operating hours. The estimation of the power is not very problematic for the auditors. In general, the light bulb or light fixture has a label indicating the power. Some errors can arise for old light fixtures when the power of the ballast is unknown or if the light fixture in question has a dimmer, but this is marginal. However, the estimation of the operating hours is more complicated. The auditors base in general their estimation of the operating hours on the occupancy hours and a factor for the time the lights are turned on, information that is in general provided by the occupants or found in standards. For example, if an office operates 8 hours per day, this is the base that is primarily used to estimate the operating hours. The problem is that apparently the occupants and then auditors get anchored[8] by the occupancy hours. Due to the fact that the actual hours of operation can be significantly different than the building occupancy hours, it has as a consequence to introduce an error for the reference base, the situation after retrofit and of course also the energy savings.

A campaign of on-site measurements, using light on-off loggers, was put in place to get a better picture about the actual operating hours. The analysis of these measurements showed that indeed the hypothesis taken by the auditors were biased and almost systematically overestimated. It was found, for example, that the operating hours in office rooms depends on the number of occupants. The time that lights are turned on is considerably lower in office rooms with one or two occupants than open-plan offices. The auditors have overestimated in general (and by a large amount) the energy consumption in office rooms with few occupants and underestimated (slightly) in open office work spaces.

Other studies have shown the same kind of problem. The analysis of many projects of various types that were evaluated through California's Investor Owned Utility (IOU) sponsored energy efficiency programs from 2006 through 2008, indicates that operating hours were a large cause of the realization rate gap (Lutz 2012).

Intermediate summary

First, let's recap the facts, the problem and the main results of the analysis.

The ex-ante estimations for the projects of the first sub-program (Communal Areas) were presenting a small underestimation and in general in agreement with the actual savings.

The ex-ante estimations for the projects for the second sub-program (Optiwatt) didn't present the same level of accuracy and were in general overestimating the savings.

A large group of professionals were involved in both programs, so what are the reasons that allow a good estimation of savings in one case and a rather bad one in the second case?

The analysis of the assumptions taken for the ex-ante calculations for projects of the Optiwatt subprogram shows that the problem arises mainly from the difficulty to estimate the actual time of operation of light fixtures (and bulbs).

---

8 This term is borrowed from the seminal paper concerning Judgment under Uncertainty: Heuristics and Biases (Tversky et al 1974).

The same problem appears with the ex-ante calculations for projects of the Communal Areas subprogram where the time after retrofit is not estimated correctly. However, while in the case of Optiwatt this can introduce a bias, it has a smaller impact in the case for the Communal Areas because the error is compensated by the error introduced with the power during stand-by operation after retrofit). The fact that the amount of savings is much larger than the electricity consumption after the retrofit, makes also the error relatively small and then negligible.

Collect the data used at project level can be cumbersome. However, if energy auditing tools working online are available for auditors, data collection can be simplified.

Conclusions

A simple comparison between ex-ante and ex-post energy savings should not be enough to validate the accuracy of ex-ante estimations. The fact that savings estimations match with the actual savings doesn't mean that the assumptions taken for the calculations are correct.

The analysis of the energy audits used for the ex-ante calculation shows that the estimation of the operating hours is the major issue that needs to be addressed, followed by the actual power consumption in stand-by mode.

It can be useful for evaluators and program managers to have a look at the hypothesis that are used to calculate the energy savings and trust the ex-ante savings only if each one and all of the independent variables (i.e. power and time after and before an EEA) have an acceptable accuracy. However, in order to check for the consistency of data, some additional information needs to be collected during the audit, like the type of building (restaurant, hotel, etc.), the surface, occupancy hours per days, days per week, week per years, etc.

In order to get the detailed data used for the audits, online IT tools can be very useful as they allow to collect all the information from the auditors in a centralized and structured database.

The information contained in the audit database can be linked to information from other databases like those containing the electricity bills, a catalog of light fixtures and the operating hours for the sample that has benefited of specific measurements.

The total consumption before retrofit estimated by the auditors can be, for example, compared with the total electricity consumption (obtained from the electrical bills). The power of light fixtures can be checked/matched with those of the existing light fixtures, and operating hours can be individually assessed to see that it corresponds with the sample that has been measured.

If all the data is validated then the ex-ante estimate can be accepted and if it is not the case, the program manager can check with the energy auditor for the potential errors, request a second audit, or eventually request to validate the estimates with an ex-post measurement and verification.

Acknowledgements

We would like to express our gratitude to the program éco21 (Pascale Le Strat and Gilles Garazi) to trust the University of Geneva for the evaluation of their program and the program managers (Frédérik Chappuis, Olivier Grand and Caroline Cacheiro). We would like also to thanks the utility SIG for the data provided concerning the electricity bills. Thanks to the reviewers who suggested very pertinent remarks. Finally, we would like to thanks Hadia Khimda who made the measurements and analyzed the TOU of lighting equipment for projects carried out under the program Optiwatt.

References

Bertholet, J.L., Cabrera, D., Lachal, B., Energy Savings in Common Areas of Buildings. IEPPEC, Amsterdam 2016.

Bertoldi, P., Rezessy, S., Lees, E., Baudry, P., Jeandel, A. and Labanca, N. 2010. "Energy supplier obligations and white certificate schemes: comparative analysis of experiences in the European Union", Energy Policy, 38 (3): 1455–1469.

Cabrera, D., Seal, T., Bertholet, J.L., Lachal, B., Jeanneret, C., 2012. Evaluation of energy efficiency program in Geneva. Energy Efficiency. February 2012, Volume 5, Issue 1, pp 87-96.

Lutz, A. Pagada, P. 2014. "Discrepancy, What Discrepancy? Reasons for the Difference between Claimed and Evaluated Savings". 2014 ACEEE Summer Study on Energy Efficiency in Buildings.

Lutz, A., and Tirumalashetty, V. 2012. "Measure by Measure – the real reasons for Gaps in Claimed and Evaluated Savings" 2012 ACEEE Summer Study for Energy Efficiency in Buildings. Pacific Grove, CA. American Council for an Energy-Efficient Economy.

Reynaud B., Garazi G., Jeanneret C., 2014. Energy and Non-Energy Impacts of a Demand-Side Management Program: Case Study of the Program éco21, Geneva, Switzerland. IEPPEC, Berlin 2014.

Steven R. Schiller. Charles A. Goldman. Elsia Galawish. 2011. National Energy Efficiency Evaluation, Measurement and Verification (EM&V) Standard: Scoping Study of Issues and Implementation Requirements. ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY LBNL-4265E.

Tversky, A.; Kahneman, D. 1974. Judgment under Uncertainty: Heuristics and Biases. Science, New Series, Vol. 185, No. 4157. (Sep. 27, 1974), pp. 1124-1131.

Yushchenko A., Patel M., 2016. "Contributing to a green energy economy? A macroeconomic analysis of an energy efficiency program operated by a Swiss utility". Applied Energy.