THE IMPACT OF MEASUREMENT AND VERIFICATION OPTION CHOICE ON FINANCIAL RETURNS FOR CLIENTS IN ENERGY PERFORMANCE CONTRACTS

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ABSTRACT

Energy Performance Contracts (EPCs) differ from traditional energy efficiency upgrades due to the degree of performance risk transferred to the supplier (ESCO) for the level of energy savings delivered. While there are many different forms of EPC a fundamental component of all is the need to agree how savings will be measured and verified, in order to determine if the guaranteed level has been achieved. The choice of Measurement and Verification (M&V) strategy is typically approached as a trade-off between the cost and complexity of the measurement method and the need for accuracy. However, different M&V strategies imply different measurement boundaries for energy savings and thus the level of savings covered by the guarantee can vary significantly. While many commentators have pointed to the importance of robust M&V arrangements, there has been almost no discussion of the commercial implications of the choice of strategy. In this study, stochastic modelling is used to take account of the large number of uncertainties inherent in any building retrofit project when exploring the consequences of the choice of measurement boundary for a lighting upgrade project. The results highlight the need for a more sophisticated understanding of the impacts of the trade-off between cost of monitoring and accuracy of results. Without this the ESCO industry risks a loss of trust as a result of a sizeable proportion of clients receiving lower than expected savings with no recourse under the guarantee.

INTRODUCTION

Energy efficiency is a fundamental part of India's strategy for addressing the interconnected challenges of energy security and reducing carbon dioxide emissions (Delio et al., 2010) with an estimated potential for 33% improvement in energy efficiency in buildings by 2030 (Klessmann et al., 2007). Both internationally and in India, EPCs have been widely promoted as a mechanism for increasing uptake of energy efficiency investments by transferring the performance risk for the energy saving measure to the contractor responsible for its installation (Prasad Painuly, 2009).

Whether EPCs should be viewed as heralding the shift from the industrialised economy to a performance based economy as suggested by Steinberger et al. (2009) or more prosaically, as a mechanism for unlocking energy efficiency investments, they have received considerable attention as part of the solution to deliver significant and rapid reductions in carbon dioxide emissions to address climate change goals (Fang and Miller, 2013; Fang et al., 2012).

In line with Duplessis et al. (2012) the definition of Energy Performance Contract used in this study is taken from EU directive 2006/32/EC:

“A contractual arrangement between the beneficiary and the provider (...) of an energy improvement measure, where investments in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement.”(article 3j The European Parliament and The Council of the European Union, 2006)

Literature relating to EPCs was identified from the Scopus database for journal articles published between 2005 and 2017, using the following search terms:

- energy performance contract
- energy service company
- energy service companies

The terms ‘ESCO’ and ‘EPC’ were not used in the search as these abbreviations were found to be used in various unrelated fields. A total of 377 papers were identified and the 100 most cited were selected for inclusion in the review. Paper abstracts were then reviewed to ensure that only papers which referred to

EPCs as defined above were included. This resulted in 67 papers for review. More detailed review of the full text of the remaining 67 articles and book chapters identified a further 15 items which did not directly relate to EPCs and these were also removed. Two items were excluded as only the abstract was in English, access was not available to one item and one item had been withdrawn leaving a total of 48 items.

DEVELOPMENT OF EPC MARKETS

While the literature indicates that the market for EPCs is large and growing and EPCs offer some demonstrable benefits, many commentators have identified barriers which may prevent it reaching its full potential (Bertoldi et al., 2006; Dobes, 2013; Hansen, 2011; Marino et al., 2011). Reasons for this apparent lag and/or proposals for supporting market growth are explicitly addressed in a large proportion of the literature, in all 24 unique accounts were found in the 48 papers reviewed and a number of recurring themes were identified:

Awareness and incentives to invest

For an EPC to be a possibility there must first be a desire to improve energy efficiency and an awareness of the potential solution offered by an EPC, (2011) suggests a global lack of awareness, a view borne out by the range of commentators sharing it. Commenting on the EU ESCO market (2006) report a lack of awareness or understanding on the part of potential clients in some member states of the importance of energy efficiency or how EPCs could be used to increase it. This finding is mirrored in analyses of other markets (Aasen et al., 2016; Jensen et al., 2013; Kostka and Shin, 2013; Pätäri and Sinkkonen, 2014; Soroye and Nilsson, 2010; Suhonen and Okkonen, 2013). Nolden and Sorrell (2015) note that even in jurisdictions where awareness of the need for energy efficiency might be expected to be high, energy efficiency investments must compete for scarce capital resources. The development and implementation of energy efficiency ratings schemes has a key role to play in this (Delio et al., 2010).

Cultural barriers

The need to adapt to local market and cultural norms is discussed by many authors (Fang and Miller, 2013; Marino et al., 2010; Patlitzianas and Psarras, 2007; Patlitzianas et al., 2006; Soroye and Nilsson, 2010), Yuan et al. (2016) note that even within a single country, in their case China, there is a need to take account of regional differences. Some cultural barriers are particularly challenging to market development, for example, a moral objection to a third party profiting from public sector actions in some Nordic countries (Jensen et al., 2013; Pätäri and Sinkkonen, 2014; Suhonen and Okkonen, 2013).

Government support

Development of EPC markets relies on government action in three key guises: firstly for the establishment of the appropriate legal and regulatory framework which allows EPCs to be undertaken (Hansen, 2011; Soroye and Nilsson, 2010; Vine, 2005). The need for legislative change to financial markets in Turkey to allow access to risk capital is a good example of this (Okay et al., 2008). Secondly, governments can influence market activity through the availability of subsidies for energy efficiency investments (Patlitzianas and Psarras, 2007) or tax incentives (Zhang et al., 2008). Thirdly, governments also have an important role to play as clients, leading by example (Bertoldi et al., 2006). Delio et al. (2010) highlight the risk that policies intended to support development of the EPC market could be counterproductive in some cases, citing the example of the impact of price subsidies for electricity for the agricultural sector in India (Modi et al., 2010).

Access to finance

Access to finance is cited by many authors as a potential barrier to market development. In the Indian market, access to finance appears to be a concern for smaller ESCOs but not for the largest companies (Delio et al., 2010). Specific initiatives have been developed to address this barrier, such as the German development bank, KfW's partnership with the Small Industries Development Bank of India (Panev et al., 2014).

Transaction costs

High transaction costs are identified by a wide range of authors as a barrier to market expansion in locations as diverse as China, Finland, India and Denmark (Jensen et al., 2013; Kostka and Shin, 2013; Prasad Painuly, 2009; Suhonen and Okkonen, 2013), these findings echo earlier conclusions by Sorrell (2007) that transaction costs would be a determining factor in deciding governance structures for procuring energy efficiency projects.

Uncertainty

Backlung and Eidenskog (2013) and Suhonen and Okkonen (2013), Marino et al. (2011), Mills et al. (2006) and Vine (2005) all expressly discuss the potential for actual savings and hence financial returns to vary from the expected values. Standardisation of contracts and measurement and verification procedures is seen as a key strategy for addressing these risks (Bertoldi et al., 2006; Larsen et al., 2012; Vine et al., 1998; Zhang et al., 2008). A separate dimension of uncertainty is related to the long-term nature of these contracts with Nolden and Sorrell(2015), Pätäri and Sinkkonen (2014) and Jensen et al. (2013) all highlighting the potential unwillingness of clients to enter into long term contracts which might either restrict their ability to respond to future business demands or realise much lower than anticipated returns due to changes in estates strategies.

A more detailed exploration of the approach to risk in the EPC literature was undertaken by relaxing the ranking requirement and including the term 'risk' in the original search. This resulted in the addition of 31 articles. Relaxing the ranking criterion meant that less heavily cited studies were included, in many cases the lack of citations is likely to be due to the relative recentness of the articles the oldest of which dated from 2014. It was necessary to exclude a further 9 articles due to a lack of access. Review of the abstracts resulted in the identification of a further 3 articles which did not relate to EPCs as defined above.

The studies that remained could be thematically divided into four main categories: studies which use expert opinion to identify risks (Berghorn and Syal, 2016; Garbuzova-Schlifter and Madlener, 2016), case studies which include discussion of risks in particular contexts (Betz et al., 2016; Bustos et al., 2016; Deng et al., 2015; Joubert et al., 2016; Lee et al., 2016; Zhang et al., 2015), consideration of risk allocation as a result of sharing mechanisms typically modelled using game theory approaches (Huang et al., 2014; Iimi, 2016; Qian and Guo, 2014; Shang et al., 2015; Wang et al., 2017) and discussions of the implications of measurement and verification strategy (Meijsen et al., 2015; Shonder and Avina, 2016)

The risk identification studies cited two key sources of risk and uncertainty which were also explicitly identified in a number of case study examples: the variability of energy savings and the uncertainty around energy prices. Mills et al. (2006) suggested a list of possible causes for these uncertainties:

- Inadequate time or methodology to establish an accurate volumetric consumption baseline
- Inability to monitor behavioural changes that could result in greater consumption of energy when new equipment is installed
- Inability to monitor and mitigate actions that could decrease asset efficiency, such as poor maintenance
- Volatility in future energy rates, currency exchange rates, interest rates, etc.

They concluded that "Quantitative risk analysis is essential to correctly value energy-efficiency projects in the context of investment decision-making" (p. 198 Mills et al., 2006).

While a number of the studies reviewed here did not explicitly evaluate risks and provided more general explorations of particular projects, others provided a more detailed consideration of how risk and uncertainty can be approached. Some suggestions for best practice for the treatment of risk and uncertainty can be drawn from this:

- probabilistic simulation of energy savings using building energy simulation is important and the computational load can be reduced through the application of parameter screening
- probabilistic simulation of energy price volatility is also required
- variability of the performance of energy conservation measures over time should be considered
- variation in weather over time should also be considered.

The significance of measurement and verification in risk allocation

Many commentators identify standardised Measurement & Verification (M&V) processes as a key market enabler (or, its absence as a key market barrier). Only two of these commentators take a slightly different view, with Jensen et al. (2013) placing a higher emphasis on trust in the context of Danish municipalities and Sarkar and Singh (2010) cautioning against over-complex M&V arrangements as a potential market barrier in developing countries. In addition, a variety of US based studies quoted in Kats et al. (1997) provide evidence of greater savings in projects with robust M&V arrangements.

Wang et al. (2017) draw an important distinction between four categories of savings:

- expected - the savings which are expected to be made

- guaranteed - the level of savings which the ESCO is comfortable with guaranteeing
- verified - the measured savings
- actual - the total savings

The distinction between the final two categories is important and frequently missed, since the scope of verified savings will be defined by what is practical and cost-effective to measure and may well not be the same as the actual savings. The test of whether or not energy savings have been achieved is more precisely a test of whether or not the verified savings exceed the guaranteed savings.

Shonder and Avina (2016) highlight the potential for different measurement and verification approaches to result in different risk allocations for clients and ESCOs and different values for measured savings as a result. This difference in measured energy savings between the different IPMVP options is also reported by Ginestet and Marchio (2010).

The most commonly used approach for measuring and verifying savings is the International Performance Measurement and Verification Protocol (IPMVP) which grew out the US EPC industry standards (Efficiency Valuation Organization, 2012), with ten Donkelaar et al. (2013) reporting its use in just under 50% of 100 European projects surveyed. However, it is important to note that IPMVP does not present a detailed process for measuring savings but a framework that can be adapted to fit a wide range of circumstances. In particular, IPMVP contains 4 distinct options for measuring savings each with different measurement boundaries, since many ECMs may affect other building systems across these measurement boundaries, the total savings measured and thus guaranteed, may vary depending on the option selected.

For the EPC market to achieve its aim of increasing energy efficiency investments, it is essential that clients have confidence in the level of guarantee offered under the contract since otherwise the risks of investment will not be considered to be reduced. The potential for differing levels of savings depending on the measurement boundary selected leads to a risk that clients and contractors may have very different expectations of energy savings as a result of the investment in an EPC with important consequences at an industry level as a result of a lack of confidence in future energy savings guarantees. To date, the literature has sought to explore the market level impacts of standardised M&V approaches as discussed above but only one study was found which considered the differences in outcomes for different M&V approaches. Ginestet and Marchio (2010) compared the costs and results of each of the 4 IPMVP M&V options for an AHU upgrade. The study was undertaken using a pair of identical lecture theatres with the AHU in one upgraded and the other used for a baseline comparison. Ginestet and Marchio's results indicated that option A was only useful when operational patterns were well understood. Their results echoed Shonder and Avina's (2016) assessment of the relative costs of each option with A and C being the cheapest options and B and D the most expensive.

The choice of M&V strategy is thus related to concerns about transaction costs, with the cost of more detailed monitoring having the potential to affect the financial viability of a project. The development of specialised monitoring tools and extended period of monitoring required for the Ginestet and Marchio study is likely to be impractical in many commercial settings. This study seeks explore the implications of M&V option choice as Ginestet and Marchio did but to do so in the context of limited information which applies in many competitive procurements. The theoretical case of a lighting retrofit in an archetypal UK school is modelled to understand the consequences of alternative measurement options under IPMVP when only limited data about the context and setting is available. While thermal energy demands are very different in India and the UK, the principles of the impact of measurement boundaries on electricity consumption are valid in both contexts.

SIMULATION

A typical UK primary school (420 pupils aged between 4 and 11 years old, taught in classes of 30) was modelled in EnergyPlus (US Department of Energy, 2015). A fundamental complication of measurement and verification of energy savings is that since the energy savings are an absence of consumption they cannot be measured directly. It follows from this that establishing the baseline condition, the energy consumption which would have taken place if no energy efficiency measure had been installed is critical. Moreover, the literature on the energy performance gap has repeatedly demonstrated the difficulty in accurately calculating the energy performance of buildings in use, even where detailed design information is available. Where such information is no longer available and buildings may have been incrementally modified over the years with limited record keeping this situation is compounded.

Whilst in theory, much of this missing information could be obtained from detailed surveys, in practice, the cost of obtaining this information and the time needed to do so mean that only limited survey work is undertaken. To capture this uncertainty surrounding the baseline condition of the archetypal school the probabilistic approach identified in the literature review is required.

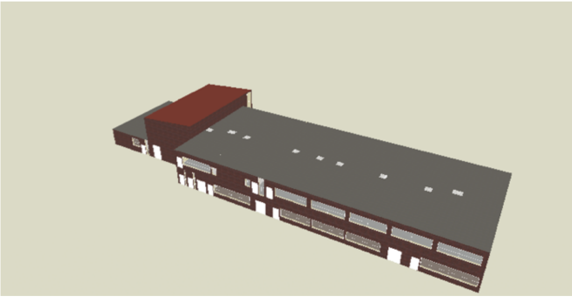

Figure 1: Archetypal UK primary school modelled in EnergyPlus

Screening

A literature review coupled with the lumped parameter approach proposed by Garcia Sanchez et al. (2014) was used to identify 91 variable input parameters, covering building fabric, systems, settings and occupant behaviour. Capturing the full range of variation over this large input space is time-prohibitive as the individual models are relatively time-consuming to run (approximately 3.5 minutes for parallel simulation of 8 primary school models). Consequently, a screening approach was necessary to select the most influential parameters which can be permuted in subsequent model runs with values for the un-influential parameters being fixed. Global Sensitivity Analysis (GSA) considers variations across the full input space and is appropriate for a complex, non-linear model such as a building simulation model where interactions between input parameters are expected to be important (Saltelli et al., 2008). The screening approach used in this study has been described in Fennell et al. (2017).

Testing the effects of different measurement boundaries

The impact of different measurement boundaries was explored for a single ECM, a lighting upgrade comprising 2 parts: relamping, modelled as a reduction in lighting gains and lighting controls, modelled as a change in the lighting hours. Difficulties of data collection mean that very little data exists detailing lighting practices in UK schools (Drosou et al., 2015). In Drosou et al. (2016) a study of lighting behaviour in 4 UK classrooms suggested that lights were used for most of the time that classrooms were in use. Since Drosou et al.'s data related to 2 secondary schools and the current study is based on a primary school where classrooms are in continuous use a simplified profile was used for the lighting schedules, with a single on and off time. A single occupancy schedule is used for the whole building which was considered to be appropriate for a primary school where occupancy density is high and most spaces will be in continuous use. Diversity was introduced in the sample by treating the on and off times as variables sampled stochastically from symmetric triangular distributions. The lower bounds for on time and off time are based on a typical UK school day of approximately 9am to 3pm (Qualifications and Curriculum Authority, 2002). Upper bounds for on and off time are estimated based on potential for early morning cleaning schedules and evidence in Taajamo et al. (2014) of an average 51 hour working week for UK teachers. The resulting lighting schedules are shown in figure 2.

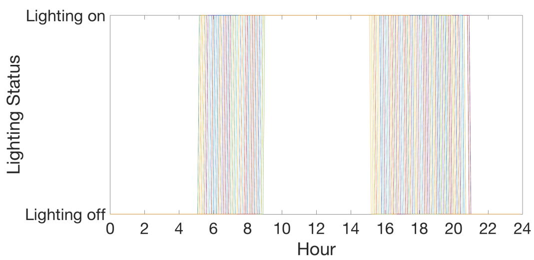

Figure 2: Lighting schedules prior to retrofit

Following retrofit, lighting hours are matched with occupancy hours to reflect the installation of occupancy sensors. Lighting fraction is introduced as a variable to allow for a proportion of lights to be switched off during the day. One of the very few sources of data for lighting use in schools is Drosou et al. (2016) where the authors report lights being used in a secondary school classroom for 60% of the school day in a building with occupancy sensing. This was taken as the lower bound for the lighting fraction as the space utilisation rate in primary schools is typically higher than in secondary schools in the UK.

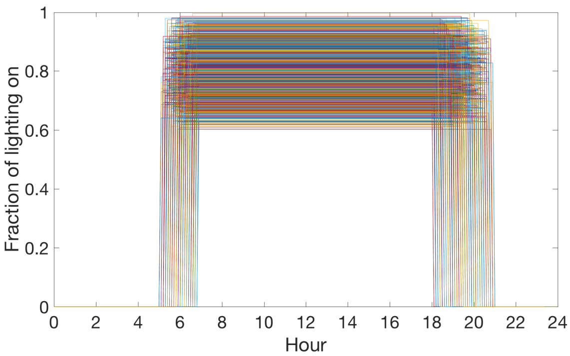

Figure 3: Lighting schedules post retrofit

Table 1: lighting gain values

	PRE-RETROFIT	POST-RETROFIT
Distribution of samples	symmetric triangular	normal
Classroom	12-21 W/m^2	4.4 W/m^2 (SD 0.22)
Office	12-14 W/m^2	5.4 W/m^2 (SD 0.27)
Hall	12-13 W/m^2	5.7 W/m^2 (SD 0.27)
Ancillary	8 - 10 W/m^2	3.1 W/m^2 (SD 0.16)

IPMVP, (Efficiency Valuation Organization, 2012) sets out 4 different approaches to measuring energy savings:

- Option A: Field measurements of specified key performance parameters and estimates for other parameters are used in engineering calculations. The measurement boundary is defined by the calculation undertaken and so may not encompass all aspects of the ECM
- Option B: Field measurements are taken of the energy use of the ECM-affected system. Measurements can be short term or continuous and would normally also cover the period prior to installation to establish a baseline level of consumption. The measurement boundary is the system considered. Other systems which might be affected are not included within the boundary.
- Option C: Energy use is measured at the whole or sub-facility level. Savings are calculated from analysis of the whole facility energy use pre and post ECM installation and regression analysis is typically used for routine adjustments.
- Option D: Savings are determined through a calibrated simulation model of the energy use of the whole facility or sub-facility. Measurement boundaries for options and C and D are conceptually the same and so option D is excluded from this analysis.

Savings were calculated pre and post-retrofit for using 3 different methods:

- Option A savings were calculated by assuming a baseline figure of 2000 annual lighting hours with the exception of offices which are assumed to have a baseline of 2500 annual lighting hours, (Philips, 2010). 2000 hours per annum equates to 10 hours of lighting per day. Post retrofit, a 20% reduction in lighting hours is assumed as a conservative estimate based on manufacturers' claims, (Guo et al., 2010). No allowance is made for uncertainty in these estimates to reflect standard practices identified in interviews undertaken by the authors as part of a broader study.
- Option B results are based on the lighting energy consumption calculated by Energyplus.
- Option C results are based on the whole facility electricity and gas consumption calculated by Energyplus.

RESULTS AND DISCUSSION

The reduced model was based on a total of 19 influential parameters following the screening process documented in Fennell et al. (2017)

6 parameters had a significant effect on electricity consumption ($S_i \geq 0.05$): classroom equipment gains, classroom lighting gains, general equipment on-time, general equipment off-time, general lighting on-time, general lighting off-time.

13 parameters had a significant effect on gas consumption ($S_i \geq 0.05$): intermittent heating set point, regular heating set point, intermittent heating set back band, regular heating set back band, general full occupancy end-time, general heating on-time, ventilation temperature, infiltration rate, boiler part load ratio, boiler efficiency, domestic hot water loop exit temperature, fibreboard thermal conductivity, classroom ventilation rate. Of these 13, 3 had a much greater effect: regular heating set point, ventilation temperature and infiltration rate.

As discussed earlier, post-retrofit lighting hours are linked to occupancy and so occupancy parameters were included in the list of variable parameters. An additional variable was included post-retrofit to model the percentage of lighting in use. 1200 runs were undertaken for the pre-retrofit condition with the non-influential parameters fixed at their mean value. Sample values for the parameters which were influential but unchanged by the lighting upgrade were reused in the post-retrofit condition.

Figure 4 shows in blue the annual electricity savings calculated on a whole building basis and in red, the lighting energy saving, reflecting the option C and B savings calculations respectively. The annual electricity saving calculated using the option A method is 1.6 x 10^{11} J, this is shown as a broken line. These results indicate that there is good agreement between the option B and C calculations. It is also clear that the energy savings are closely linked to the number of lighting hours pre-retrofit. In the majority of the cases modelled here, lighting savings will be in excess of the option A predicted value. However, for the lower quartile of lighting users, savings will be lower than the value predicted as their original consumption was lower than estimated, in these cases, the performance guarantee offers no protection since the savings are deemed to have been met based on the engineering calculation. This is a concern since the inclusion of a performance guarantee typically adds cost to a procurement either directly or by limiting the range of potential suppliers to those who have the covenant strength to provide a guarantee. In these cases a client has incurred an additional cost, in excess of the underlying installation cost for a guarantee which offers them no protection.

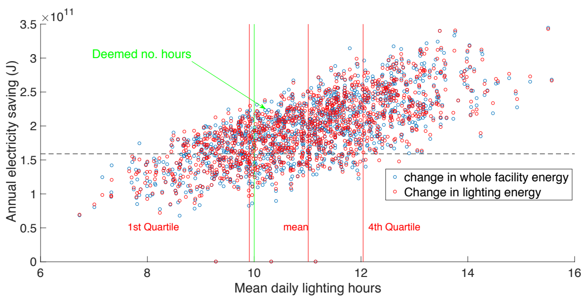

Figure 4: Distribution of annual electricity saving

Although these results might suggest that choosing a whole building approach to measuring and verifying energy savings is always in the client's interests, ESCOs may not be willing to accept the additional risks that this approach imposes on them. In particular, ESCOs are exposed to the wide ranging impacts of occupant behaviour which are outside their control. While some commentators have raised concerns relating to over-burdensome requirements for establishing baselines in Indian public sector projects (Yang, 2016), others have noted a tendency to over-simplify measurement (International Finance Corporation, 2011) and the need for greater measurement rigour (Alliance for an Energy Efficient Economy, 2017a). As Stetz et al. (2001) note, "Since the purpose of M&V is to provide assurance that project savings exist, improper and excessive reliance on stipulations may effectively nullify savings guarantees." While research on the Indian EPC market is not yet extensive, as the market expands and encompasses commodification and standardisation of projects, pressures to simplify M&V approaches are likely to increase. In the Indian market, where lack of trust is cited as the root cause of many of the barriers to growth (Alliance for an Energy Efficient Economy, 2017b), ensuring that energy savings guarantees provide the protection that clients expect is fundamental to market growth

CONCLUSIONS

Lighting retrofit projects offer the opportunity to significantly reduce the electricity consumption of existing buildings. Greater attention needs to be paid to the impact of measurement boundaries and M&V strategy on the actual value of the guarantee for clients. Choosing a low-cost option in the presence of significant uncertainty about the baseline position may lead to a sizeable proportion of clients receiving lower than expected savings with no recourse under the guarantee. EPCs rely on a guarantee of savings to create an incentive for investment in energy efficiency but clients may see savings fall short of expectations even though the guaranteed saving has technically been achieved. This effect will be greater for clients with lower overall hours of lighting use and underlines the danger of using an option A approach where patterns of use are not well understood, a concern raised by Ginestet and Marchio (2010) in relation to an AHU upgrade. It is likely that these results would apply to other energy efficiency retrofits as well and if this risk is not clearly explained to clients it is likely to lead to a loss of confidence in the concept of energy performance contracts as a whole.

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