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Predicting Energy Savings for Energy Performance Contracting: the Impact of the Energy Performance Gap

Dave Baas[#*1], Wim Maassen[#*2], Rik Maaijen[*3], Wim Zeiler[#4]

[#]*Department of the Built Environment, Eindhoven University of Technology*
P.O. Box 513, 5600MB Eindhoven, The Netherlands

[1]t.j.baas@student.tue.nl

[4]w.zeiler@tue.nl

[*]*Royal HaskoningDHV*
P.O. Box 8520, 3009AM Rotterdam, The Netherlands

[2]wim.maassen@rhdhv.com

[3]rik.maaijen@rhdhv.com

Abstract

The building industry faces a significant mismatch between predicted- and measured energy consumption of buildings, known as the performance gap. This gap can have a large impact on the profitability of business-cases for energy performance contracting. A risk assessment is employed to determine the most important risks for energy performance contracting, including the risks on energy performance. A building performance evaluation on five office buildings is set up to quantify the current gap in the Dutch industry and the impact this has for a typical energy performance contracting business-case. The risk assessment shows that performance contracting includes a widely distributed risk profile, of which the gap in energy performance is one. Results of the performance evaluation show that on average, the offices use 1.5 times more energy than predicted. For a typical performance contracting project, this decreases the profitability from 13 to 6% for the Energy Service Company. Better quantification of the uncertainty of energy predictions in current practice risk management is thus needed to ensure sound business-cases for all stakeholders.

Keywords – energy performance gap; energy performance contracting; energy prediction; risk assessment.

1. Introduction

Over the past decades, the building industry has come aware of a recurring mismatch between predicted- and in-use energy consumption of buildings, often referred to as the ‘energy performance gap’. Evidence on the magnitude of the gap is adding up fast, suggesting buildings tend to use 1.5 to 2.5 times more energy than predicted in their design [1,2]. Causes for this gap are arising in all different stages of the building process, from poor assumptions and model inadequacy in the design stage to deviant occupant behaviour in the operational stage [3]. The gap due to poor assumptions in the design stage however, can generally not be redressed or reduced after building completion. This makes improving predictions even more important in reducing the energy performance gap.

Energy Performance Contracting (EPC) has shown to be successful towards a low-carbon economy, realizing significant energy savings in the existing building stock of most European countries [4]. EPC can be a powerful approach in reducing the performance gap, but the gap is also attributed as a significant barrier for large scale implementation of EPC. This study investigated the consequences that the gap in energy performance has for conducting energy performance contracts. The paper is organized as follows: the methodology is described in the next section. Thereafter, the results are shown in section 3. The results are then discussed in section 4 and conclusions are drawn in section 5. Finally, recommendations for future work are given in section 6.

2. Methodology

A risk assessment is employed to identify and quantify the risk profile of EPC-projects for the Energy Service Company (ESCO). By conducting a building performance evaluation, this study evaluates the industry's current ability of predicting building energy performance and the impact this can have for performance contracting.

Performance based projects typically involve an increase in project risks, when compared to fixed-fee projects. This increase in risks is experienced as one of the major barriers for further development of the EPC-industry [4]. Risk management is therefore one of the core elements in performance based contracting. The main starting point for a typical risk management framework is the process of identification, analysis and evaluation of the risks, often called 'risk assessment'. To evaluate how urgent the risks on energy performance are, a risk assessment is made for EPC-projects. The risk assessment is based on the RISMAN method [5], a common risk management framework in the Dutch industry. First, a risk breakdown structure is employed to identify the general risks involved in EPC. The risks are identified and structured based on the main actor (ESCO, customer or external) and their type (e.g. economical, technical etc.). Then the risks are quantified by calculating the risk score for each individual risk. The risk score is defined as the product of the probability and impact of an event ($risk\ score = P \times I$), in here the probability and impact are defined as respectively the likelihood of occurrence and the impact of the risk when it occurs. RISMAN further defines the impact as the sum of several individual impacts, for this study, impacts on money, time and quality were considered. Each risk can then be assessed as: $risk\ score = P \times (Imoney + Itime + Iquality)$. After quantifying the risks, they can be ranked based on their risk score, which helps one to decide which risks should be given highest priority.

For the building performance evaluation, five projects of the engineering consultancy Royal HaskoningDHV are taken as case study. All five projects are focusing on a single building, of which the main characteristics can be found in table 1. These buildings are evaluated based on their annual thermal energy demand, comparing monitoring data with the predictions from the design. Depending on the availability per case, 3 to 10 years of monitoring data is used for the comparison. Weather fluctuations are taken into account by degree-day normalization.

Table 1. Main characteristics of the case buildings

	Project year	Project type	Function	Gross floor area [m²]
Building A	2002	New built	Office	17.000
Building B	2004	New built	Office	38.600
Building C	2000	Retrofit	Office	21.500
Building D	2005	New built	Office	74.500
Building E	2004	Retrofit	Office	26.000

Investment decision makers generally use appraisal tools as basis for their decisions. The most common approaches for investment appraisal are Net Present Value (NPV) and Internal Rate of Return (IRR). The latter approach, IRR, is a relative measure of worth often employed in real estate and investment performance measurement. In short, the IRR is defined as the percentage of discount rate, for which the NPV is zero. The higher the IRR of an investment, the more attractive it is for the investor. Often a minimum IRR, the Required Rate of Return (RRR), is defined by investors as the necessary expected rate of return to consider investing. EPC-projects are typically long-term contracts and are based on third party financing, a typical RRR which can be considered for EPC business-cases is 9%.

The business-model for EPC is to a large extent based on the predicted rate of energy savings. Given the figures on the performance gap, it is important to know how sensitive the profitability of EPC projects is to the accuracy of energy predictions. Hence, a typical EPC business-case of Royal HaskoningDHV is evaluated. The evaluation is based on the IRR as measure for the profitability and the energy prediction as source of uncertainty.

3. Results

With the risk breakdown structure, 27 different risks were identified for a typical EPC-project. All 27 project risks were quantified by calculating their risk score. Figure 1 shows the results of this risk assesment in a pareto diagram. The risks are ranked based on their relative risk score. The cumulative in the diagram shows the risks are widely spread. The risk due to a mismatch in energy performance is ranked as nr. 4, with a risk score of 32% (highlighted in black in figure 1).

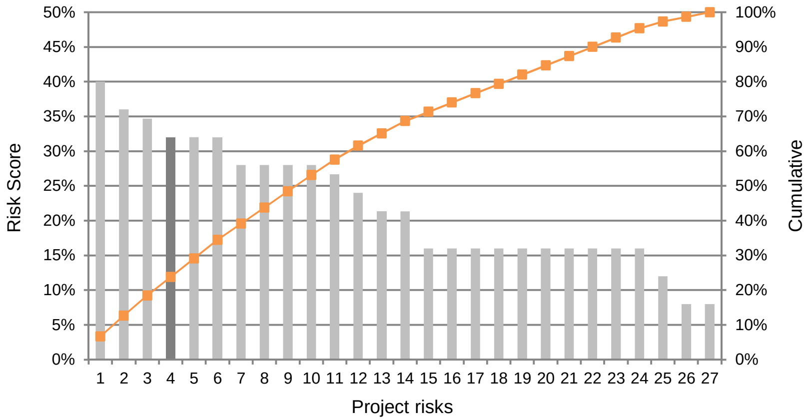

Fig. 1 Pareto diagram risk assessment for EPC-projects

To get insight in the distribution of the most important risks, the 6 risks with the highest risk score are summarized in table 2. From these 6 highest risks, 2 risks are related to the building energy demand (risk 4 and 6). Looking at table 2, no particular dominance can be recognized in the type or the main actor of the risks. In other words, EPC-projects are characterized by a widely distributed risk profile, in which one risk is formed by the performance gap.

Table 2. Top 6 highest project risks for EPC

Risk nr.	Risk score	Actor	Type	Description
1	40%	Customer	Economical	Bankruptcy of customer
2	36%	ESCO	Economical	Bankruptcy of ESCO partner
3	35%	Customer	Other	Building-/systems demolishing (e.g. by fire)
4	32%	ESCO	Technical	Energy savings are lower than expected
5	32%	Customer	Contractual	Hidden defects from customer
6	32%	Customer	Technical	Change in energy consumption pattern customer

Figure 2 shows a comparison of the predicted- and measured heating demand for the five office buildings. The boxes in the figure indicate the distribution of annual measurement data for respectively building A to E. Figure 3 shows a similar comparison, but for the annual building cooling demand. The average annual heating demand shows to be 40% above predicted and the cooling demand 50% above predicted.

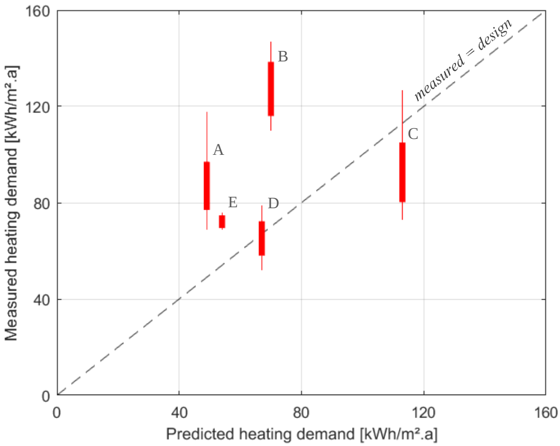

Fig. 2 Comparison of predicted- and measured annual heating demand for the case buildings

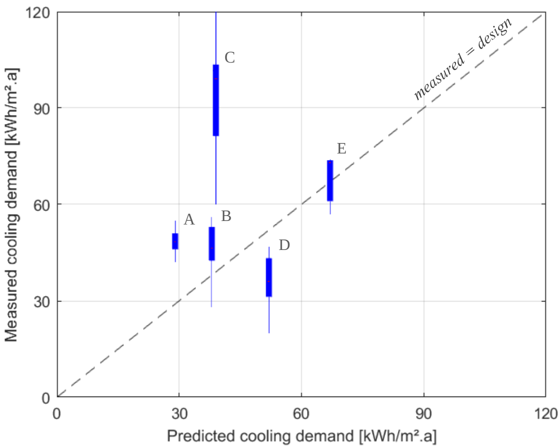

Fig. 3 Comparison of predicted- and measured annual cooling demand for the case buildings

The results on the performance gap suggest that predictions on energy performance get accompanied by significant uncertainty. However, the predicted energy consumption of all case-buildings was given as point estimate, suggesting there is no uncertainty at all. This incomplete representation of energy predictions is illustrated in figure 4, showing the given point estimate with the disregarded uncertainty range.

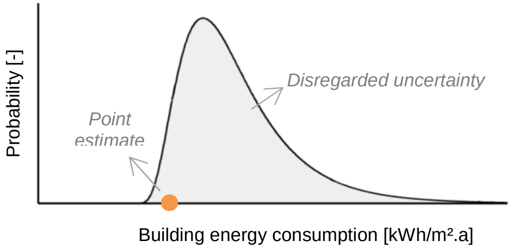

Fig. 4 The incomplete representation of energy performance predictions

The performance evaluation shows that the thermal energy demand of office buildings tends to be 1.5 times higher than predicted in its design. This indication for the magnitude of the performance gap is therefore used for further analysis on the consequences for EPC. Table 3 shows the impact a mismatch of 50% would have on the profitability of a typical EPC-project. When realizing energy savings as expected, an IRR of 13% would be achieved. This is a reasonable result for a typical investment in energy saving measures. However, a deviation of 50% from predicted energy savings will either increase the IRR to 20% or decrease to a marginal 6%. The decrease to 6% would be critical for the ESCO, since it is below the RRR of 9%.

Table 3. Effect of energy savings on IRR of a typical EPC-project

Energy savings	IRR
50% less than predicted	6.0%
Predicted savings	13.4%
50% more than predicted	20.0%

4. Discussion

For the building performance evaluation, five different projects are analyzed. Due to the limited availability of data, the projects could only be evaluated based on thermal energy demand. Performance gaps in e.g. energy generation and occupant related energy consumption were therefore left out of quantification. For building A however, an analysis on the performance gap at the level of energy generation was possible. This analysis found indications of a performance gap at the level of energy generation too. So although the total performance gap is not quantified for the five buildings, it can be assumed that the gap is also present at the other levels of energy performance, and the total energy performance gap for the buildings is probably even larger than the gap of 50% quantified in this study.

The case study presented in this paper is made up of five case-buildings. This is a limited amount of buildings, especially when looking at the spread in outcome for the thermal energy demand. Although the findings are in line with results from other work on the performance gap, further research is needed.

5. Conclusion

It is shown that EPC-projects are characterized by a widely distributed risk profile. This profile is composed of various types of risks, of which as well technical- as economical- and contractual risks are amongst the most important risks.

The building performance evaluation on 5 office buildings shows the thermal energy demand tends to be 1.5 times higher than predicted in their design. These findings are in line with other work on the performance gap.

Results on the case study show the impact of uncertainty in the energy performance prediction can be significant for EPC-projects, decreasing the internal rate of return from 13 to 6% for a deviation of 50% in energy savings. Integrating the risk on energy performance into current practice risk management for EPC-projects is thus required to ensure sound business-cases for all stakeholders.

Reducing the energy performance gap is a very important and major challenge for the building industry. Improving predictions is therefore essential, since the part of the gap due to poor assumptions in the design stage can generally not be redressed or reduced by building monitoring or –commissioning.

Based on the findings of the mismatch in thermal energy demand, it can be concluded that energy performance predictions get accompanied by significant uncertainties. Despite these uncertainties, energy predictions are generally given as point-estimates, suggesting there is no uncertainty at all. Quantifying uncertainties in standard practice energy predictions is needed to provide any valuable input for decision making.

6. Future work

Further research is needed on quantifying the energy performance gap, preferably based on a larger set of buildings. Allocating the shares of the performance gap to the different stages in the building process is necessary to increase commitment of the industry in reducing the gap in energy performance.

It is shown that the mismatch in energy performance has a large influence on the profitability of energy conservation investments. Decision making for these investments is generally based on point estimations for energy consumption. Future work should include the development of a framework on defining accurate uncertainty profiles for input parameters and propagation of this uncertainty to the model's output. Next, the added value of propagating this uncertainty should be determined for decision making.

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