Predicting energy savings for energy performance contracting

– the impact of the energy performance gap

DAVE BAAS
Royal HaskoningDHV
The Netherlands
dave.baas@rhdhv.com

RIK MAAIJEN
Royal HaskoningDHV
The Netherlands
rik.maaijen@rhdhv.com

WIM MAASSEN
Eindhoven University of Technology
The Netherlands
wim.maassen@rhdhv.com

WIM ZEILER
Eindhoven University of Technology
The Netherlands
w.zeiler@tue.nl

The building industry faces a significant mismatch between predicted- and measured energy consumption of buildings, known as the energy performance gap. This study assesses the magnitude of the performance gap and the impact it has on the profitability of business cases for investments in energy conservation and energy performance contracting.

Keywords: energy performance contracting; energy prediction; EPC; performance gap; risk assessment.

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]. This mismatch in energy performance also holds for hospital buildings, using even 2 to 3 times more energy than predicted in their design. Causes for the performance 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.

Investments in energy conservation measures and nZEB building design are key drivers to realise a low-carbon building stock. Energy Performance Contracting (EPC) has shown to be a successful tool to accelerate energy conservation, achieving significant energy savings in the 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 investigates the consequences that the gap in energy performance has for investments in energy conservation and conducting energy performance contracts.

Risk assessment

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.

Building performance evaluation

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. Due to a limited availability of data, the buildings could not be evaluated on energy consumption for e.g. energy generation or plugloads. 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 [m^2]
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 appraisal

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 becomes 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.

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 assessment 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**).

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.

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.

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

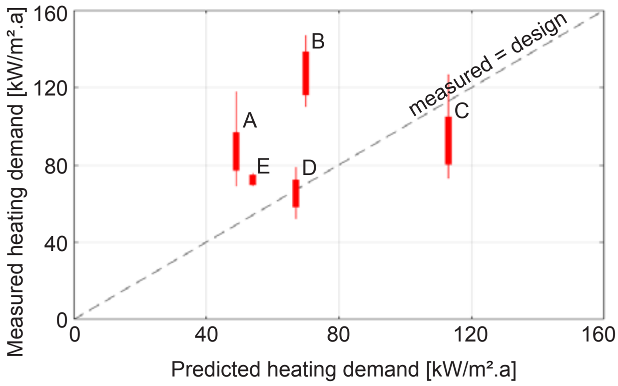

Figure 2. Comparison of predicted- and measured annual heating demand for the case buildings.

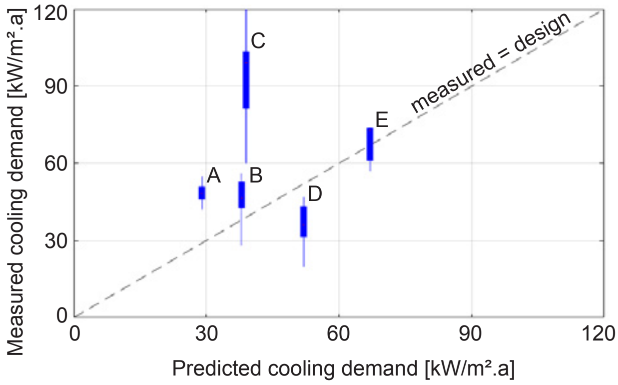

Figure 3. Comparison of predicted- and measured annual cooling demand for the case buildings.

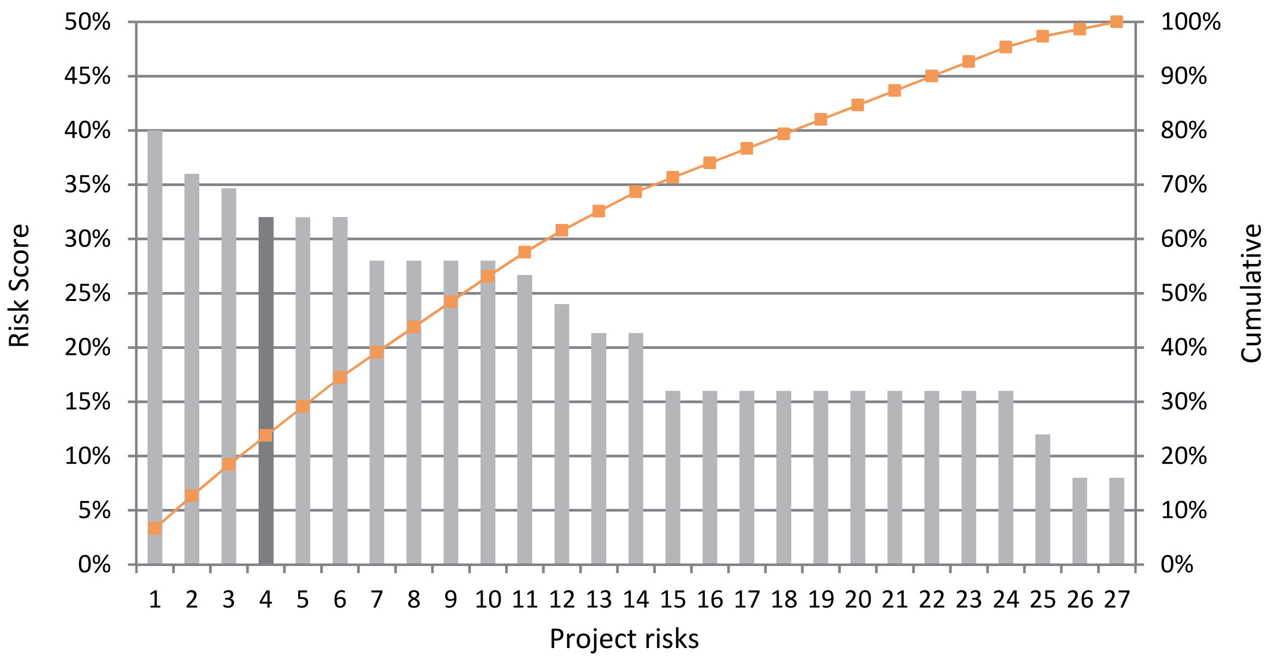

Figure 1. Pareto diagram risk assessment for EPC-projects.

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.

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. **Figure 5** 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%.

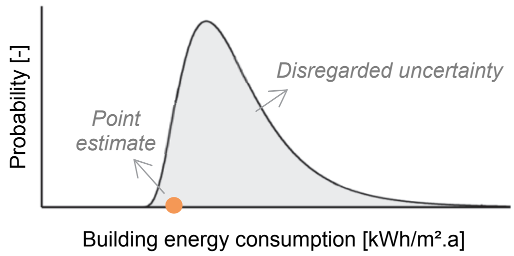

Figure 4. The incomplete representation of energy performance predictions.

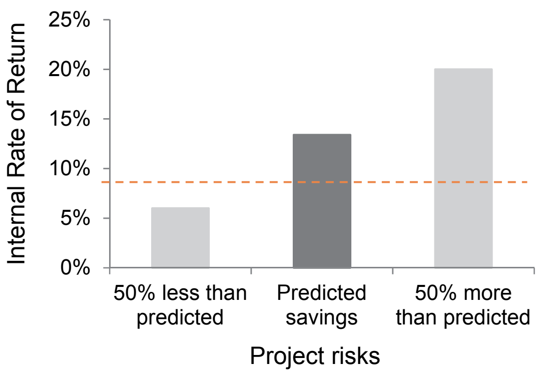

Figure 5. Effect of energy savings on IRR of a typical EPC-project.

Discussion & Conclusion

Evaluation of five case buildings shows that the thermal energy demand of the five buildings tends to be 1.5 times higher than was predicted in their design. These findings are in line with other work on the performance gap, confirming that the performance gap is also present in the Dutch building industry.

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, especially in the need to design and deliver (nearly) zero energy buildings. Improving the energy performance predictions is essential in reducing the performance gap, 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. ■

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