Chapter

Risk Mitigation in Energy Efficiency Retrofit Projects Using Automated Performance Control

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Abstract

Performance gap concerns limit investment in the building energy efficiency retrofit market. In particular, the ability of projects to deliver on promised energy savings is commonly drawn into question. Performance risk mitigation mainly occurs through energy saving performance guarantees. Contractual stipulations arrange the conditions of the guarantee, and ceteris paribus, a higher energy saving guarantee should reduce project performance risk. Therefore, methods that yield a higher energy saving guarantee could help accelerate the market. We review the ability of "smart," automated, and connected technologies to: (a) intelligently monitor and control the performance of energy-consuming devices to reduce performance variations, (b) provide additional degrees of control over the project's performance, and, by doing so, (c) motivate the energy services company (ESCO) to raise the energy saving guarantee. Our analysis finds that use of such automated performance control could significantly raise the energy saving guarantee, making projects more likely to succeed.

Keywords: derisking energy investments, energy efficiency, performance gap, energy savings guarantee, building controls, Monte Carlo analysis, monitoring and verification

1. Introduction

Energy efficiency investment is the most cost-effective pathway to reduce carbon dioxide (CO_2) emissions [1, 2]. Yet, the 2014 $5.3 billion U.S. energy efficiency market can be contrasted against an estimated $92 to $333 billion overall potential [3–5]. Nominal revenue stagnation in guaranteed savings contracts for buildings between 2011 and 2014 [4] raises concerns about a seeming incapability to successfully unlock the rest of the market.

Explicit consideration of investment barriers is required to unlock energy efficiency retrofit project investment at scale [6, 7]. In particular, a critical barrier surrounds operational performance uncertainty, widely captured in the literature under the energy saving "credibility gap" or "performance gap" [8–10]. For example, expected or experienced performance risk leads project clients to emphasize concern "about [energy service companies' (ESCO's)] guaranteed savings not being achieved, causing problems to third party financing" as a top worry [11]. In a similar vein, "uncertainty of payments based on energy savings" is seen as a key market and financial barrier according to industry experts [12].

Evaluations of performance contracting projects also find over-performance. For example, an evaluation of 8541 buildings in Greece found that realized savings exceeded expectations, on average, by 44% [13]. Similarly, review of a National Association for Energy Service Companies (NAESCO) database found that 72% of projects (517 projects) experienced greater savings than were guaranteed by the ESCO, some by as much as 50% more [14]. Analysis of a Department of Energy (DOE) Super Energy Savings Performance Contract (Super ESPC) Program found that, for the aggregate of 102 projects, the value of annual cost savings exceeded the cost savings guarantee by 19% [15].

In this regard, performance contracts raise conflicting concerns: over-performance or under-performance of the guarantee? Our research question is whether risk management under a guaranteed savings contract can be improved so as to reduce ESCO tendencies to shift project risks to other parties; and can we manage risk around the guarantee in a manner that reduces the credibility gap harbored by potential clients? Our focus is on "smart controls" as one tool to address these twin problems [16, 17].

Responsible for up to 40% of CO_2 emissions, the building sector represents an especially salient target for climate change mitigation and investment [18, 19] and there is a general consensus in the literature that building controls can improve energy saving performance profiles of energy efficiency projects [20]. Control of building operations could save up to 60% of energy consumption, with most reported savings in the 10–30% range [20, 21]. Examples of commonly operational issues that result in low performance in the building sector that "smart" controls could address include continued system operation beyond necessary hours, improper technology set-points, and inadequate economizer operations [22].

The use of automated control technology options represents an emerging paradigm for monitoring and verification of project performance that can measure and control building operations in real-time [23–25]. In general, technologies within this paradigm rely on "web-based analysis software, data acquisition hardware, and communication systems (...) to store, analyze, and display whole-building, system-level, or equipment-level energy use" and typically provide sub-hourly interval meter data with graphical and analytic capabilities and assessment [26, 27]. The use of such techniques is currently largely in the pilot stage and used primarily for program targeting and opportunity identification [24]. The available technology platforms are mostly used in commercial and industrial applications [23, 24, 28–30] but "cloud computing platform[s] for real-time energy performance [monitoring and verification are] applicable to any industry and energy conservation measure" or ECM [31]. Automated building control techniques can therefore yield actionable value by monitoring and correcting, in real-time, the energy performance profile of the building [26, 27].

We review the relationship between, on the one hand, the energy efficiency sector's currently dominant risk mitigation method in the form of energy savings guarantees and, on the other hand, smart, automated building controls. In particular, we evaluate the ability of these controls to improve the monetary value of the energy savings guarantee by reducing the project's risk profile, making energy efficiency retrofit projects more likely to succeed. To that end, Section 2.0 first covers common risk conditions associated with energy efficiency retrofit projects in the built environment. Next, Section 3.0 discusses the dynamics associated with the energy savings guarantee setting process and introduces the modeling approach used to test the interaction effects between energy saving guarantees and smart, automated building controls. Section 4.0 provides the results of the analysis.

We find that building controls represent a credible mechanism for performance risk mitigation that could motivate a significant increase in the energy savings guarantee. Section 5.0 concludes the chapter.

2. Conventional energy performance contracting risk mitigation

Inherent risks accompany energy performance contracting and clear risk allocation is critical to avoid dispute or litigation [11, 32–34]. As a prominent risk mitigation option, contractual agreements are used and, principally, performance contracts between ESCO and client can be formulated as either so-called shared savings contracts or guaranteed savings contracts.[1] Shared savings contracts allow the ESCO to take a share of the savings above a target level and, in this model, ESCOs typically provide project financing [11]. Under the guaranteed savings model, the ESCO guarantees a level of performance sufficient to pay back installation and financing costs if proposed energy conservation measures (ECMs) are implemented and monitored and verified according to protocol guidelines. When actual savings fall short of the guarantee, the ESCO compensates the shortfall to the client or otherwise makes the client whole. The ESCO does not benefit from performance levels that are above the guarantee. The ESCO market now mostly uses the guaranteed savings model [14, 35].

Under the guaranteed energy savings model, project clients are typically responsible for obtaining financing either from internal funds or from external third-party investors (e.g. a bank or financial institution) [11, 36, 37]. A range of factors can cause energy savings uncertainty, including monitoring and verification risk, financing risk, and technology risk (**Table 1**). These factors complicate risk assessment, limiting the usefulness of conventional risk screening tools such as simple payback [38].

Table 1 shows also that energy savings guarantee contract design options typically include specific stipulations for these risk categories. The actual value of the guaranteed energy savings stands out as a key contributor to the project's overall viability that is easily communicated to project client and potential third-party investor. In this, ESCOs face a double-edged incentive. On the one hand, the ESCO can be inclined to set the guarantee below the expected savings of the project to lower downside risk (e.g. lower risk of dispute with the client, lower risk of needing to deliver shortfall compensation, etc.). On the other hand, a higher guarantee

Category	Manifestation	Causes	EPC contract design
Financial	Payment default	Insufficient savings	Guaranteed savings
Technology	Equipment fault	Poor maintenance	Diagnostics
Operational	Unexpected use	Baseline changes	IPMVP[a]
Monitoring and verification	Modeling errors	Incorrect assumptions	IPMVP[a]
Economic	Fuel cost increases	Price volatility	Price escalator

For further discussion on the topic, see Refs. [11, 32, 39, 40].
[a]*International Performance Measurement and Verification Protocol.*

Table 1.
Examples of relevant risks.

[1] Other contractual agreement forms, such as first out or chauffage, are also available but are not evaluated here.

makes the ESCO more competitive and more likely to win the project bidding process. No 'rule of thumb' can be clearly identified for setting the guaranteed savings value [41] although some argue that ESCOs typically set the savings value of the guarantee *below* predicted performance using ESCO-specific risk tolerances on individual energy conservation measures [42–44].

At around 15 terawatt-hours in 2012 electricity savings, the public/institutional sector dominates the 34 terawatt-hour U.S. energy efficiency market [4, 45]. This market segment is especially relevant as clients in this sector often finance up to 100% of project costs [35]. The guaranteed savings model is compelling for public/institutional property owners as they operate in a capital deficient, maintenance-deferred environment [46]. The guarantee, supported by a creditworthy ESCO, represents a financial commitment that addresses downside risk, making it easier for these property owners to attract the capital needed for the project. However, energy savings guarantees come at a cost:

- The ESCO embeds their profit directives into the value of the guarantee.
- Contractors will not typically assume risks that cannot be managed in a direct fashion. Technologies that have a proven track record of managing additional risks, therefore, could convince the ESCO to embed the dimension into the guarantee.
- Any remaining unbounded risks (any risks not captured in the guarantee) is transferred to the other parties (i.e. the client and any potential investors).
- Savings guarantees are commonly set (well) below the achievable savings in order to build-in risk protection for the ESCO.

A benchmarking database of about 6100 projects maintained by Lawrence Berkeley National Laboratory (LBNL) in partnership with NAESCO appears to

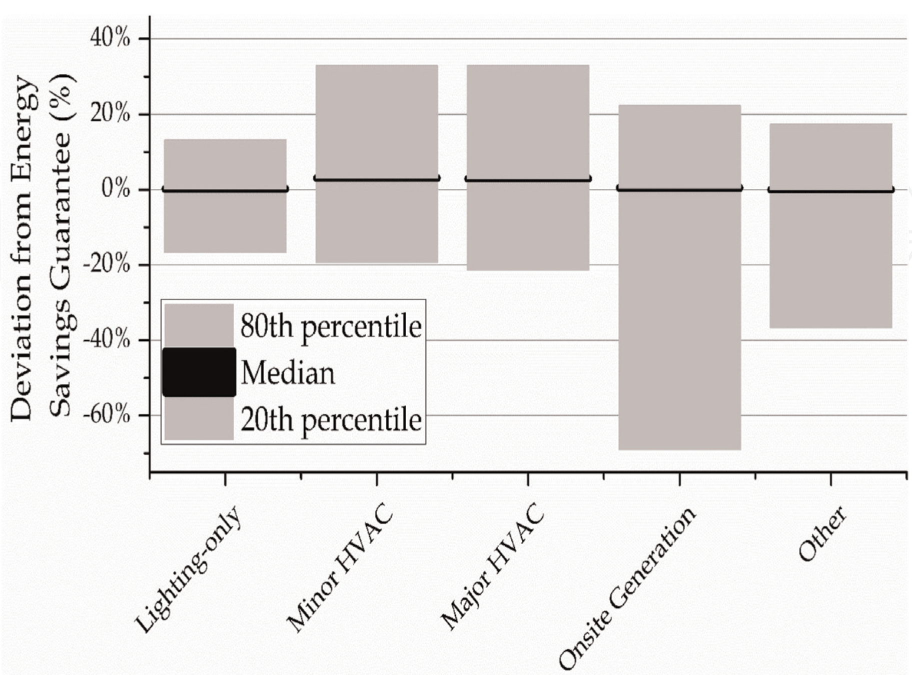

Figure 1.
Realized energy savings against guarantee at public properties (1990–2017). Note: Presented here is the 20th percentile (lower end), median (black horizontal bar), and the 80th percentile (high end) (n = 1652). Source: https://eprojectbuilder.lbl.gov/home/#/benchmark.

underscore the importance of getting the guarantee right: realized savings often deviate from the guarantee in both ways, sometimes significantly so (see **Figure 1**). Discrepancies between predicted and actual metered building energy use found in evaluations resulted in the introduction of the 'credibility gap' [8–10, 13, 47–50]. Risk mitigation in guaranteed savings projects, therefore, could deliver substantial energy performance improvements and attractive financial arrangements for, especially, public sector clients.

3. Strategic implementation of automated controls

A 2018 market analysis by a leading industry actor found that building control improvements are "the most popular investment for the next 12 months among U.S. organizations" as 68% of survey respondents indicated plans to invest in (additional) controls [51]. A 2014 estimate by McKinsey Company suggested the intelligent building control market could reach an annual $59 billion (in 2009 dollars) by 2019 [52]. Clients that have used such technology suites indicate a high level of satisfaction: 19 out of 21 cases evaluated in one assessment reported automated measurement, verification, and control as critical in achieving energy savings [27]. Trust-building and other benefits accrue from use of automated performance control options. Many of these benefits can be connected to the risks identified in **Table 1**.

3.1 Benefits of automated controls

Implementation of automated building controls could help prevent project under-performance. The potential for this technology option is substantial. For example, an assessment by the U.S. Energy Information Administration (EIA) documented in 2012 that over 85% of commercial buildings in the United States have inadequate control infrastructure in place ([53], as quoted by [54]). In addition, it has been broadly established that advanced control measures can improve performance and save 10–30% of energy consumption [20, 54–58]. For lighting, for instance, a combination of improved lighting devices and controls can reduce commercial lighting energy use by 81% [59]. A meta-analysis looking at the savings generated by lighting controls in commercial buildings by isolating the control function found savings ranging from 28 to 40% with combined operation of sophisticated controls achieving higher saving rates [60].

Whole-building energy management systems integrate a variety of end-uses (including services beyond energy such as security). A survey of zero net-energy buildings that use building controls found that 91% of the commercial buildings surveyed in North America relied on control systems that integrate multiple end-uses with 67% using a fully integrated controls architecture capable of controlling all end-uses centrally [61]. Many of these systems do often still rely on the occupant for some part of the successful operation of the controls: 74% of the buildings surveyed have integrated controls system sequences that are not fully responsible for driving performance, relying instead on the occupant [61].

Relative to the potential, significant under-adoption of the technology suites can be observed and this is often attributed to the high cost associated with whole-building applications [27]. The suite of technologies is typically deployed as software as a service (so-called SaaS) offerings, delivering capabilities on a subscription-type basis [27]. In other words, up-front expenditures for items such as licensing and system configuration are accompanied by recurring subscription fees which spread out the cost of the entire system over its lifetime. Nevertheless, up-front cost estimates range from $10 to $3400 per point with most in the $100 to $500 per point range [27]. In addition, the recurring costs range from $5 to $3100 per point [27]. Put together, 5-year ownership estimates ranged from $140 to $16,000 per point [27]. A point is a single datum that is trended, stored, and available for normalization and data analysis across use cases and comprehensive, whole-building systems can have thousands of points. For example, a use cases overview of a major controls company shows how a project involving three federal office buildings contained 18,000 points [62]. Therefore, at the median 5-year ownership costs found by Ref. [27] of $1800 per point, a fully integrated energy management system could cost as much as $32 million for the three federal office buildings.

Strategic design and selection of automated control technologies at the end-use level might overcome this barrier. Versions of partial integration deployment strategies can be observed in the market: the survey of zero net-energy buildings found that partial integration of end-uses occurred in 24% of the buildings while 9% had no whole-building controls architecture at all but, instead, used controls only at the end-use level [61]. At this level of operation, there is an expectation of significant cost reduction to the point where control technology cost can be brought down from an estimated $150–$300 per node to $1–$10 per node using low-cost, self-operated, and wirelessly connected end-use level devices [63]. Lower costs opens the door for automated controls to fulfill performance control functions for key ECMs.

Coordinated implementation of end-use level automation could enable projects to reap additional benefits:

- *Operational and engineering risk* reductions include time efficiency, improved accuracy, and possibilities for standardization and certification. For instance, automated performance control accelerates whole-building assessment from a typical 4 days to 1 day and reduces time needed for custom engineering calculations from 6 days to 1 day [64]. Automated analysis yields actionable data within the first project month [57]. Analysis of 537 projects further shows that industry standard predictive accuracy can be achieved with only 6 months of training data [65, 66]. When assessed as part of a portfolio of buildings, predictive accuracy improves further leading to the conclusion that these models are "compellingly accurate" [64]. Automated data analysis enabled by automated control enables attribution of consumption pattern variation, standardization and certification—a key need of the sector to develop investor-ready program design [7].

- *Monitoring and verification risk* reductions include portfolio level analysis, benchmarking, improved sampling, and fast anomaly and fault detection. Real-time and high-resolution automated control of performance makes even small or portfolios of projects capable of processing "big data". Further, scalability and precision allows larger sample sizes, retrieving feedback on the performance of diverse aspects of the retrofit project. Real-time data collection and control enables faster anomaly or fault detection and interface options such as online dashboards empower clients and ESCOs to mitigate under-performance.

- *Economic risk* reduction benefits from automated control include real-time utility tariff and energy consumption analysis to validate utility bills through, among others, (a) continuous monitoring and management of peak load consumption; (b) streamlining of utility-related processes to, for example, minimize personnel requirements; and (c) identification of metering or billing errors by automatically crosschecking consumption patterns with utility bills.

- *Financial risk* reduction is achieved through uncertainty mitigation and improved project finance-ability. Strategic use of automated control can deliver investor-ready program design and enhance the energy savings guarantee. Data generated by automated control can improve project finance-ability as it supports, among others, (a) accurate savings estimates, (b) risk management of operational and performance uncertainty, and (c) quick remediation of potential energy saving shortfalls.

3.2 Modeling the contribution of automated controls in the energy savings guarantee setting process for building retrofit projects

The level of savings that an ESCO will guarantee is principally influenced by: (a) the project's ability to confidently deliver savings and (b) the risk tolerance of the ESCO. A simplified interaction dynamic between project host and ESCO is provided in **Figure 2**. For a hypothetical project, **Figure 2** shows that the project's savings can exceed a low guarantee but will likely fall short when a (very) high guarantee is used. Under a guaranteed savings structure, savings above the guarantee are awarded to the project host while savings that fall short of the guarantee negatively impact the ESCO. This is illustrated in **Figure 2** by the green and red areas, respectively. From the perspective of the project host, savings that exceed the guarantee are welcome but, critically, these savings are not guaranteed and, therefore, are not available to underwrite the initial investment. However, savings that fail to reach the level of the guarantee prompt the project host to argue for compensation that

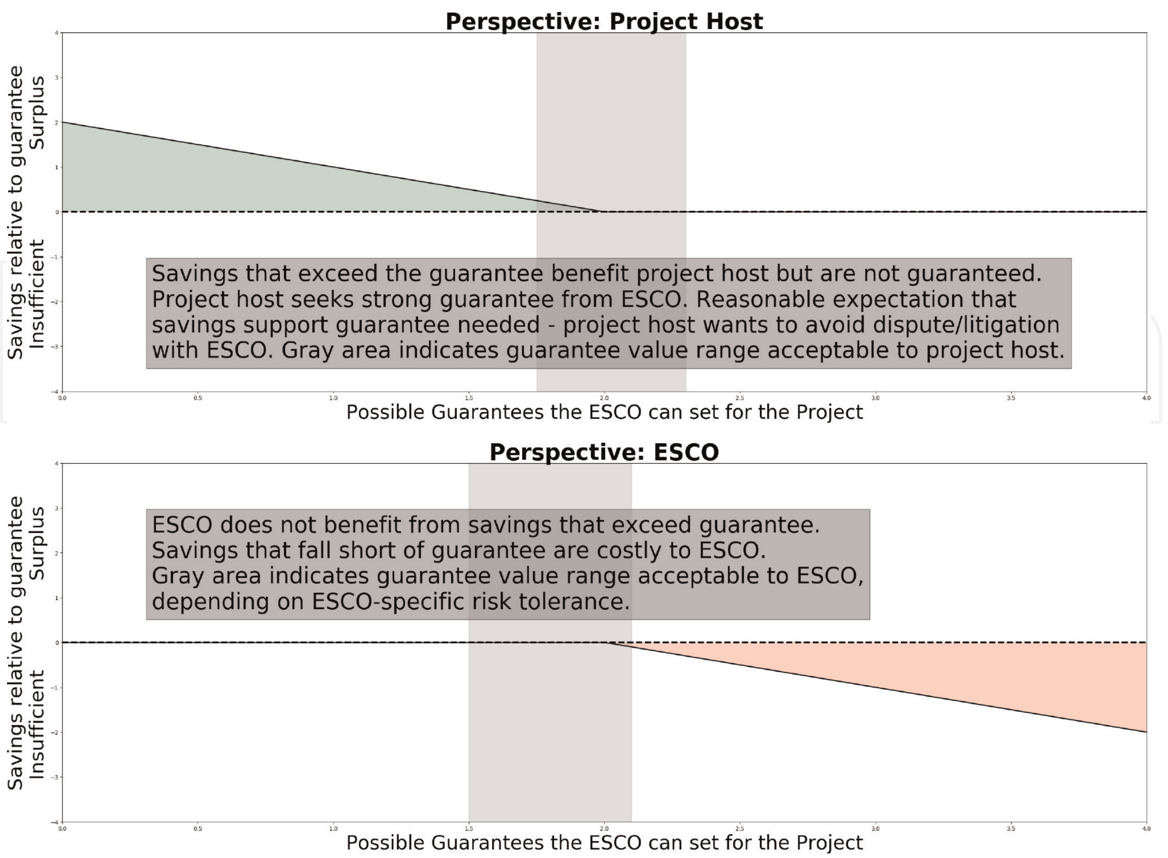

Figure 2.
Hypothetical interaction for setting the energy savings guarantee between project host and ESCO. The gray area provides an indication of agreeable guarantee levels under the modeled conditions.

could be disputed by the ESCO. This can be an arduous process. The project host, overall, is interested in a high guarantee but concerned about disputes with the ESCO [11, 12].

Surplus savings above the guarantee occur when the project over-performed relative to the guarantee. In this case, the ESCO is not at risk of claims for compensation. While this sounds appealing, it also means that the project bid by the ESCO could have been more competitive. Insufficient savings to cover the guarantee lower the overall return on the project and could even represent a net-loss for the ESCO. From the perspective of the ESCO, this should be avoided whenever possible. As illustrated in **Figure 2**, a hypothetical range of possible guarantee values that are acceptable to the ESCO can be identified. In general, the ESCO is incentivized to place the guarantee below expected savings but is hesitant to place it too low.

So far, we have established that energy efficiency savings performance can be uncertain. One way to consider this uncertainty is to reflect on energy savings performance as a stochastic distribution of possible savings. A broad distribution of energy savings i.e. a higher probability for adverse circumstances as listed in **Table 1** presents a higher risk for the ESCO that performance levels will be below the guarantee (e.g. [67]) and, ceteris paribus, is accompanied by a lower guarantee. To estimate these considerations, we follow the model proposed by Deng et al. [41]. This approach calculates, from the perspective of the ESCO, the annual and total profit for a series of possible guarantees against a Monte Carlo analysis-derived savings profile. We use the approach to calculate the guarantee level where, for a given risk tolerance, the ESCO will is unlikely to experience losses due to insufficient savings and resulting claims for compensation by the project host. In other words, consider a Monte Carlo simulation of a project's performance that results in a stochastic distribution of possible savings. In this case, a 95% risk tolerance would result in a guarantee level where 95% of all the simulated outcomes deliver savings sufficient to cover the guarantee in each year of the project lifetime. Then, the maximum guarantee within the ESCO's risk tolerance is selected as a probable guarantee for the project.

The steps of the analysis are to, first, derive possible performance profiles for pre-retrofit, post-retrofit without controls, and post-retrofit with controls scenarios for each year of the hypothetical project. This step produces three distributions of performance that approximate normal distributions. The contribution of building controls, here, is to substantially narrow the distribution of post-retrofit performance, leading to more secure savings profiles. In addition, controls improve actual building operations, leading to a savings profile with a higher overall average savings. The second step is to take the probabilistic savings profile and compare it against many possible guarantee values to identify the moments where the savings fall short. From the perspective of the ESCO, any moments where the savings exceed the guarantee are set to zero (these savings are awarded to the project host). Finally, within the stated risk tolerance of 95%, the maximum guarantee where savings are sufficient to cover the guarantee is calculated.

3.3 Software stack and data inputs

The primary software element is the U.S. Department of Energy's (DOE) Energy Plus software: a leading building energy simulation tool in the energy efficiency industry [68–70]. Advantages of Energy Plus include first-principles, text input–output work-flow that can be automated [71] and availability of benchmark building model databases (16 building types across 16 locations and three construction periods) [72, 73]. Within Energy Plus, we made use of DOEs prototypical commercial building models that describe typical building layout, geometry, energy consumption, etc. for buildings in the Delaware region constructed before 1980 [73, 74]. In particular, we model the performance of the "large office" building benchmark. The energy performance of the large office benchmark building was simulated using Energy Plus version 8.6.0. This DOE benchmark building reflects a possible building operated by the public sector, the dominant user currently of energy savings guarantee projects.

The large office benchmark building is a 46,320 square meter, 12-story office building (including basement) with total annual baseline consumption of 26,358 GJ of electricity and 7266 GJ of natural gas to fulfill its end-use functions or 725.9 MJ/m^2. Notably, over half of the buildings energy consumption serves interior lighting (9422.03 GJ or 28.1%) or interior equipment (8384 GJ or 25.2%). Heating is third most responsible for annual energy consumption (7265 GJ or 21.6%).

Possible ECMs were identified using research results from Lawrence Berkeley National Laboratory (LBNL), specifically the Commercial Building Energy Saver (CBES) project (http://cbes.lbl.gov/ and Refs. [75–77]). This ECM selection was further supported by data from the Building Component Library and several articles using a similar methodological approach [11, 36, 43, 71]. Finally, our research team had access to guaranteed energy savings agreements (GESAs) provided by ESCOs for other projects in Delaware and across the United States. Data from these GESAs was used to complete ECM profile selection by looking at buildings in those projects that share similarity with the benchmark building. Critically, based on a review of existing control literature, the selected ECMs listed in **Table 2** can be accompanied by automated controls.

Parametric evaluation of the building models was conducted using jEPlus software (version 1.7.2), an open-source parametric analysis tool specifically designed for Energy Plus [71] that provides flexible and structural analysis opportunities and smooth operations [81]. The tool has been used in similar investigations to determine sensitivity or optimize energy systems [82, 83]. This set-up enables Monte Carlo analysis for risk estimation and management of, among others, renewable energy projects, system planning, or system optimization [84, 85] and for energy efficiency projects in general and monitoring and verification efforts specifically [36, 44, 82]. Latin Hypercube Sampling (LHS) was used to run 10,000 simulations per jEPlus model run. LHS is a powerful tool that enables efficient stratification across the uncertain performance range [86]. Parametric evaluation was conducted on Amazon Web Services (AWS) architecture. The data inputs used for the

ECM & name	Energy plus parameter (Unit)	ECM costs
1. LED lighting upgrade	Lighting load (W/m^2)	\$0.63/m^2 [78][b]
2. Appliance upgrade	Plug load (W/m^2)	\$5.29/m^2 [79, 80]
3. Thermostat set-point update	Set-point in Celsius (C)	\$49.10/thermostat [80]
4. Chiller replacement	Reference COP (fraction)[a]	\$439.48/ton [80]
5. Boiler replacement	Nominal thermal efficiency (fraction)	\$34.96/MBH [80]
6. Install high-efficiency fans	Fan total efficiency (fraction)	\$0.176–\$0.390/cfm [80]
7. Water heater replacement	Heater thermal efficiency	\$20.82/gallon [80]

[a]*Coefficient of performance.*
[b]*Typical retail prices for LED packages purchased in quantities of 1000 from major commercial distributors. Using price point estimates for 2020 for cool white LED packages at 218 lumens per Watt.*

Table 2.
Selected ECMs and key parameters.

ECM	Distribution	Input	Pre-retrofit	Post-retrofit	Source
1	Normal	Value:	16.14	6.46	[82]
		σ:	0.565	0.226	
2	Normal	Value:	10.76	8.07	
		σ:	4.549	3.412	[82]
3	Triangular[a]	*Heating*			[82]
		Value 1:	21	20	
		Value 2:	15.6	14.6	
		Min/Max:	±6.52%	±6.52%	
		Cooling			
		Value 1:	24	25	
		Value 2:	26.7	27.7	
		Min/Max:	±6.52%	±6.52%	
	Normal	Value:	5.11	6.2	[82]
		σ:	0.024	0.029	
	Normal	Value:	0.76	0.95	[44]
		σ:	0.011	0.014	
	Normal	Value:	Various	0.65	σ = 5%
		σ:	0.050	0.033	
	Normal	Value:	0.8	0.95	[44]
		σ:	0.012	0.014	

[a]*Two thermostat threshold set-points for heating and two threshold set-points for cooling are included in the model.*

Table 3.
Pre- and post-retrofit performance variation inputs for the large office.

parametric evaluation are provided in **Table 3**. Controls are assumed to be able to reduce performance variation by 90%.

4. Results

The energy efficiency retrofit project of the large office benchmark building represents a total project investment of about $1.23 million. This project investment generates energy savings compared to pre-retrofit conditions. A broad range of possible energy consumption levels exists across the 10,000 simulations modeled here for both the pre-retrofit and the post-retrofit without application of performance control. In terms of energy savings, the post-retrofit scenario provides an average annual consumption level of about 24,057 GJ compared to the pre-retrofit average consumption level of 37,034 GJ an average savings of about 35% (**Figure 3**).

As provided in **Figure 3**, the savings profile is such that, under highly unfavorable circumstances, the project could have annual performance levels that are below pre-retrofit performance. In other words, in the most efficient operation of the pre-retrofit benchmark building and the most inefficient operation of the post-retrofit model, no energy savings would occur. In fact, energy consumption could be *above* the baseline in this case. The savings profile, in short, is relatively uncertain and could benefit from the inclusion of smart performance control.

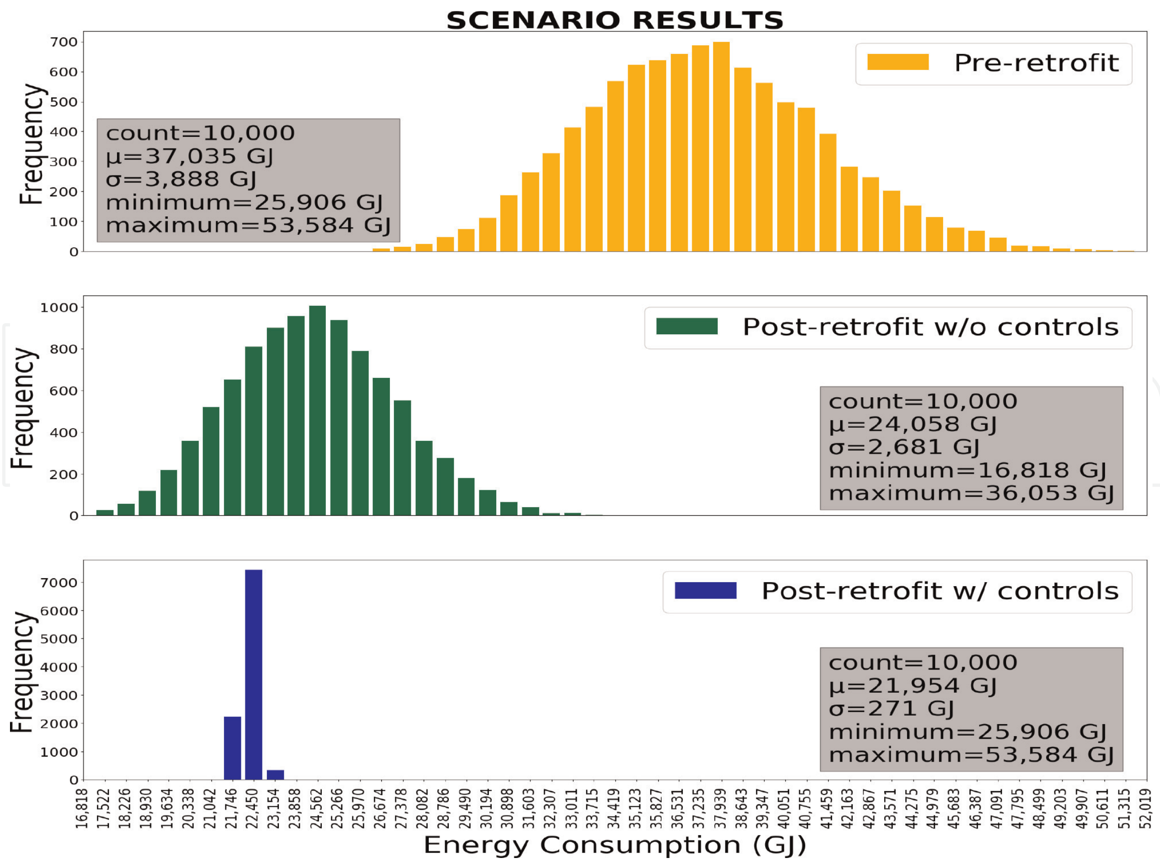

Figure 3.
Monte Carlo analysis results for energy consumption profiles in three scenarios for performance year 1 of a hypothetical project.

Figure 3 illustrates the performance profile of the post-retrofit building when performance control technologies are installed as part of the project. The controls substantially limit performance variation. In addition, the application of performance variation control also improves the overall functioning of the system, leading to higher average savings overall. For example, the average energy consumption in GJ without application of performance variation control technology is 24,058 GJ while the average energy consumption is 21,954 with application of this technology option.

The probability that a certain amount of savings in dollar terms can occur is critical in the calculus of energy savings guarantee placement. We calculate the savings distribution and probability for each year of a 20-year project using similar assumptions as Deng et al. [41] but with natural gas and electricity prices relevant for Delaware as provided by the U.S. EIA. The probability of dollar savings is influenced by the volatility and drift of natural gas prices, the contracted escalator in the price of electricity, inflation, and equipment degradation over time.

Now, we introduce the ESCO‘s perspective by asking the ESCO to guarantee the performance of the project. This guarantee is dependent on the energy efficiency project profile introduced above and importantly on the ESCO‘s tolerance for risk. We assume a highly risk averse ESCO with a risk tolerance of 95%. This means that 95% of the 10,000 simulations of the project need to exceed the guarantee in each year of the 20-year project in present value terms. The ESCO‘s risk for profit losses, therefore, is virtually eliminated by this risk-averse placement of the guarantee. In other words, the ESCO can reasonably expect the energy efficiency project to perform in accordance with the annual savings guarantee.

The cost savings profile of the 20-year project yields a strategic estimate of the guarantee an ESCO might be willing to provide of around $47,500. The use of

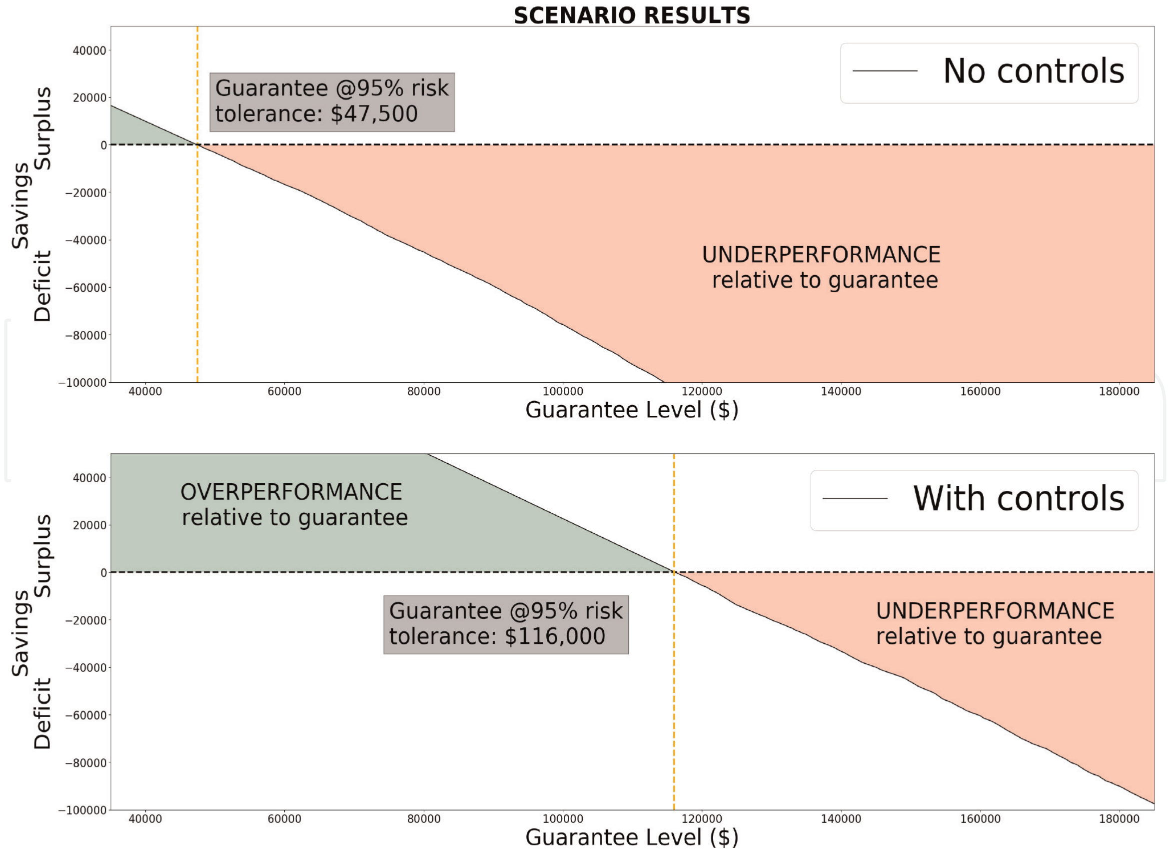

Figure 4.
Energy savings guarantee placement without and with performance control.

performance control technology is proposed as a viable risk mitigation pathway for energy efficiency performance projects. To consider the effect of using these controls, we calculate the upward movement expected in energy savings guarantee placement when the controls improve performance and reduce risk. Effectively, the scenario where controls are applied enables the ESCO to reasonably expect a higher level of performance (see **Figure 4**). The guarantee placement, at 95% risk tolerance, is increased to around $116,000.

The higher guarantee should be attractive to the project client as well as any third-party financier of the project. The ESCO, in turn, can determine the benefits of reaching this higher guarantee by weighing it against the cost of installing the additional controls. Additional research is needed to establish the precise cost profiles of the control technologies. Assuming the price points indicated by Ref [63] of $1–$10 per point are feasible for a 6000 point large office (the use case overview by a major controls company described a three-building project of large office spaces to be around 18,000 points [62]), procurement and installation of end-use and device-level control technologies could cost $6000–$60,000. Additional costs would occur from the operation of the controls. Compared to the costs associated with (a) potentially losing the project bidding process and (b) engaging in (expensive) dispute resolution regarding potential under-performance cases with the client that damages relationships and lowers future project bidding success, the installation and procurement cost of controls could be a small additional price to pay. In addition, the extra performance yields savings that can underwrite the investment, potentially leading to lower costs of financing and other costs associated with project risk.

Overall, the control function modeled here:

1. Improves overall savings by achieving a lower average consumption;

2. Lowers performance risk by achieving a significantly lower standard deviation of the savings distribution; and

3. Doubles the savings guarantee the ESCO can reasonably be expected to provide.

5. Conclusions

The conceptual and modeling approach introduced in this chapter targets performance uncertainty a dimension commonly neglected in energy savings calculations [69] despite its potential usefulness in the investment decision-making process [38, 87]. The stochastic profile of energy efficiency projects is illustrated both with and without the use of performance variation control technologies in an attempt to quantify the contribution of such advanced, real-time, high-accuracy control technology. In a sense, the use of this technology is expected to enable a more deterministic accounting of project performance through real-time and high-quality measurement that limits the stochastic range of performance. The conceptual and modeling approach benefits from automatic and interval performance measurement of a variety of devices and equipment (either at the device-level, sub-meter level, or whole-building level) which provide previously unavailable insights into the overall project [27].

The approach devised and tested in this chapter could help accelerate ongoing efforts to improve investor confidence and strengthen the energy efficiency market. For example, ongoing efforts to enhance investor confidence include the Investor Confidence Project from U.S.-based Environmental Defense Fund (EDF) or the European Energy Efficiency Financial Institutions (EEFIG) plan to compile an open source database for energy efficiency finance performance. In particular, the use of advanced, real-time, high-accuracy control technology could have consequences for the placement of the ESCO guarantee in an energy performance contract project. Raising the guarantee by reducing performance variation is one hypothesized benefit of putting controls in place. We have made an attempt at quantifying this benefit for a common building type in the United States and show that controls can potentially deliver a substantial benefit. The combined application of probabilistic performance and deterministic accounting and management transforms uncertainty into metrics legible for conventional risk management strategies such as the implementation of robust energy savings guarantees. These risk management strategies can be attractive to all involved parties, including the third-party investor.

The adoption of building and technology controls for this purpose could be encouraged by city, state, and national governments through standards and building codes, control-specific public funding thresholds and guidelines, project performance database compiling, organizing sustainable energy investment forums, actively supporting the use of energy performance contracting that includes the use of controls, or developing project development assistance centers or facilities that help guide project promoters. In addition, as is being done under the aforementioned EEFIG umbrella, underwriting toolkits can be developed to assist financial institutions in scaling up the injection of capital in the energy efficiency market [7]. Such underwriting toolkits could emphasize the critical function of controls in relation to value and risk appraisal.

Placing controls as a central component of a comprehensive and innovative approach to energy efficiency could help unlock the $1.2 trillion value in the U.S. economy that is Net Present Value (NPV) positive [88]. This value is self-financing, making it an attractive option for financial institutions if the risk profile can be clearly understood and managed. According to McKinsey researchers [88], capture of the opportunity would reduce the U.S. energy bill by 23%, positioning the U.S. well on its way to meeting previously agreed-upon climate protection targets.

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Conflict of interest

The authors declare no conflict of interest.

Notes

Supplementary information, data, and models are available at http://freefutures.org/publications/.

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