RESEARCH

# RISK FRAMEWORK FOR ENERGY PERFORMANCE CONTRACTING BUILDING RETROFITS

George H. Berghorn[1] and M.G. Matt Syal[2]

## ABSTRACT

Energy performance contracting (EPC) has emerged as a useful project financing and delivery tool for building retrofits, particularly among building ownerships which have experienced reduced funding for capital projects. Through EPC, a contractor (called the EPC contractor or the energy service company) guarantees minimum energy savings performance and enables the building owner to finance the project using utility savings over the length of the project (which is typically 12-15 years, or longer). Despite its growing use, there is a dearth of literature regarding a contractor's risks related to the delivery and execution of EPC building retrofits. This is particularly important as the performance guarantee effectively transfers project performance risk from the owner to the EPC contractor. This research proposes a project factors-based risk framework for EPC building retrofits, initially developed through a comprehensive review of relevant literature and project documents and refined through the elicited expertise of 19 highly experienced EPC contracting professionals. A Delphi technique-based expertise elicitation strategy was used to confirm the findings of the a priori (literature-based) framework and provide additional analysis related to risk causes and control measures as well as relative risk importance. This information was used to construct a refined risk framework which provides insight into the lengthy project performance period during the earliest phases of the project's life cycle. This has the advantage of providing rapid screening of the project factors that can potentially lead to the greatest project performance risks.

## KEYWORDS

energy performance contracting (EPC), energy efficient building practices, building retrofits, project performance risks, projected utility savings, controlling operating costs

1. PhD, LEED AP BD+C, Michigan State University, School of Planning, Design, and Construction, 552 W, Circle Drive, East Lansing, MI 48824, berghorn@msu.edu

2. PhD, LEED AP, Michigan State University, School of Planning, Design, and Construction, 552 W, Circle Drive, East Lansing, MI 48824, syalm@msu.edu



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

## 1. INTRODUCTION

Buildings account for approximately 40% of the total energy use in the United States with commercial buildings accounting for nearly half of that consumption (U.S. Department of Energy 2011a; Morganstern et al. 2008). Non-residential buildings with the greatest energy intensities include hospitals, nursing homes, educational, and public safety facilities (U.S. Department of Energy 2011a; U.S. Department of Energy 2011b). The continued operation of inefficient mechanical, electrical, and plumbing equipment can lead to increased utility costs, furthering inefficiencies and increased operating costs. Energy efficient building practices have been identified as one of the most cost effective measures for controlling operating costs in buildings. Such retrofits are a growing and important part of both the construction and energy economies (Drumheller and Wiehagen 2004; Dong et al. 2005; Harvey 2009; Bhattacharjee et al. 2010; Barbose et al. 2013; Forster et al. 2013; Laitner 2013).

Energy performance contracting (EPC) has emerged as a popular project delivery and financing method for executing retrofits in the MUSH (municipalities, universities, schools, and hospitals) market (Hopper et al. 2005). This method is often favored among building owners who have experienced reduced capital budgets to fund energy efficiency retrofit programs (Bharvirkar et al. 2008). EPC finances retrofits using projected utility savings gained through improved energy efficiency. As a result, capital is not required at project startup; rather, the work can be financed over a period of years, termed the contract performance period. EPC retrofits are typically performed by an EPC contracting firm, also known as an energy service company (ESCO), which guarantees a minimum level of energy savings resulting from the completion of the retrofit; this guarantee creates inherent risks to the contractor throughout the life cycle of an EPC project. As a result, the concepts of risk analysis, risk management, decision-making under uncertainty, and EPCs are interrelated and must be treated as such. (Goldman et al. 2005; Hopper et al. 2007).

### *Energy Performance Contracting (EPC) Retrofits*

Energy performance contracting gained significant traction globally in the mid-1980s following the OPEC oil crisis (Hansen 2006; Larsen et al. 2012a; Deng et al. 2014). Despite falling into disuse in the early 1990s, industry revenues have grown significantly over the past 20 years, from less than $500 million in 1990 to an estimate of over $15 billion in 2020 (Stuart et al. 2013).

The complexity of EPC retrofits have increased over the past 25 years. The value of annual savings per square foot increased approximately 25% between 1990 and 2008 and the simple payback period length increased approximately 50% during this same time (Larsen et al. 2012a). However, during this same time period, the number of institutional projects with excess savings decreased significantly. In an earlier study, Hopper et al. (2005) reported that 19% of 517 EPC projects examined experienced savings shortfalls; Larsen et al. (2012a) observed that approximately 16% of the 436 EPC projects they examined experienced a savings shortfall. Further work is required to monetize and include non-energy benefits (NEBs) in these projects to create additional savings opportunities for owners and EPC contractors alike (Jennings and Skumatz 2006; Birr and Singer 2008; Larsen et al. 2012b).

### *EPC Structure and Elements*

Energy performance contracting is a project delivery and financing method that provides turnkey service to deliver a set of energy efficiency-related upgrades to an owner, typically via



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

a performance guarantee issued by the EPC contractor, which is financed through the annual energy savings that result from the retrofit work (Appleman et al. 2010; Seeley 2012) and completed using essentially a design-build approach. During the project performance period, which can be 12-15 years (or longer) in the MUSH market, annual savings from efficiency upgrades are first used to offset debt service (e.g., loan payments for financing the project); any remaining savings are then available to the owner. Debt service payments are completed by the end of the performance period; at that point, the owner retains all savings obtained through the EPC retrofit, and experiences an overall reduction in operational costs (Shonder et al. 2010). Larsen et al. (2012a) found that 73% of public and institutional projects utilized a performance guarantee, whereas only 40-45% of private sector projects included such a guarantee.

During the earliest project life cycle phases, EPC contractors are engaged with completion of the investment grade audit (IGA), which is an analysis of potential energy savings and cash flows, and the final development of the retrofit design (AEPCA 2000; Petersen 2009; Tetreault and Regenthal 2011). Completion of the IGA is a pivotal element of EPC retrofit projects as the audit includes several pre-requisites that define the remainder of the scope of work, including development of the baseline, against which performance guarantees are developed and expected levels of performance from the specified energy conservation measures (ECMs) (Sankey 2007; Ganji and Gilleland 2002; ASHRAE 2011; Baechler et al. 2011). As information is gathered relative to the development of the IGA, the EPC contractor must also analyze the potential impacts of humans on the retrofit, to include behavioral impacts such as the "rebound effect" (Hertwich 2005; Herring and Roy 2007; Strand 2011), the ability for maintenance personnel to operate newly-installed systems based on the contractor's assumptions (Hansen and Brown 2004), and potential changes in the operational profile of the building (e.g., hours of operation, temperature and humidity set points, building use) (Baechler et al. 2011).

### *EPC Savings Models*

The use of shared savings has waned in favor of guaranteed savings (Goldman et al. 2005; Larsen et al. 2012a). The shared savings model of EPC requires that the contractor carry the credit risk of the customer in addition to the technical performance risk of the project; the EPC contractor also bears the risk of energy rate increases that exceed the agreed-upon escalation factor in the contract (Hansen 2006; ICF and NAESCO 2007; IFC 2011; Larsen et al. 2012a). If there are no energy savings, the facility owner pays the utility bill as usual. While the EPC contractor does not receive any payments, they also do not owe anything to the owner.

The guaranteed savings contractual form has a decidedly different risk profile compared to shared savings, and releases the EPC contractor from financial risk; however, the performance guarantee must ensure that a wider range of costs are recoverable, to include debt service, M&V fees to the contractor, and any maintenance obligations or other incremental costs stipulated by the contract (IFC 2011). Owners benefit from the contractually-guaranteed level of energy savings, - in the event of a savings shortfall, the contractor will pay the shortfall amount to the owner using previously-agreed upon utility rates and escalation factors (CCI 2009). The EPC contractor benefits by reducing their risk profile through elimination of carrying owner credit risk and by being able to assemble larger, more complex projects which potentially carry more value (European Commission 2014). Additionally, the EPC

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

contractor is generally paid up-front for the construction costs of the project via the owner's financing, and ongoing payments are directed toward ongoing costs (e.g., O&M and M&V costs, if included in the contract) (Hopper et al. 2005).

### *Research Need*

Despite the growing use of EPCs in the MUSH market, a relatively limited body of related literature restricts the ability for research to inform practice in this important sector of the built environment. Since performance contracting is essentially a mechanism to transfer energy efficiency performance risks from the owner to the EPC contractor, project-level risks specific to these firms must be better-understood. This need has been noted by Hansen (2006) and confirmed by Berghorn (2014) in providing a list of broad risks that contractors should be particularly attune to; however, this work does not provide an evaluative framework for the assessment and evaluation of risk in EPCs. A small body of literature identifies other risks in performing EPCs; however, a comprehensive risk assessment framework for EPC contractors is required to fully understand and implement EPC retrofits in MUSH market buildings. The confluence of the increased use of EPCs in the MUSH market with the need to better study the management of contractor's risk leads to three premises which guide the need for this research.

*Premise #1 – Energy Efficient Retrofits Carry Risks for Contractors*

Construction is an inherently risky enterprise due to the unique nature of projects as well as their size and complexity, and numerous contractual and management interactions among diverse stakeholders, which all occur in an environment with distinct political, economic, and social factors (Zavadskas et al. 2010; Banaitiene and Banaitis 2012). As a result, project risks have been well-studied in the literature, at the level of overall project risks (Tah and Carr 2000; Tah and Carr 2001; Zavadskas et al. 2010; Banaitiene and Banaitis 2012; Goh and Abdul-Rahman 2013) and at the level of individual project phases, elements, and critical success factors such as the project planning phase (Diab 2012), time and cost (Doloi 2012), safety (Hallowell and Gambatese 2010), and delay (Assaf and Al-Hejji 2006). The technical aspects of construction risk management have been explored related to design and retrofit of structures to withstand seismic events (Pampanin 2009) and selection of energy conservation measures (Willis 2008). A second and significant body of the literature addresses business and decision-related aspects of risk (Ward and Chapman 1995; Assaf and Al-Hejji 2006; Subramanyan et al. 2012; Xiang et al. 2012).

*Premise #2 – There is a Need for Energy Efficient Retrofits in the MUSH Market*

Sixty three percent of the EPC contractor industry revenue is derived from MUSH market projects (Stuart et al. 2013). Several factors make this market particularly attractive to EPC-driven work, including high rates of owner occupancy, the relatively low financial risk of MUSH market customers, legislation-driven energy efficiency mandates, and constrained capital budgets that demand alternative retrofit financing strategies (McCabe 2011). Based on estimates from the U.S. Department of Energy (Irwin et al. 2011) and the CBECS 2003 survey (USDOE 2011b), the MUSH market can be assumed to comprise over one million buildings with nearly 20.8 billion square feet of floor area (32.2% of the national commercial building stock floor area).



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

While EPC contractors have been active in the MUSH market for over two decades, there is significant remaining market potential for energy efficiency retrofit. An analysis conducted by the Lawrence Berkeley National Laboratory in 2010 estimated that unmet energy efficiency retrofit opportunities in larger MUSH market facilities could yield annual energy savings of 160 million MMBTU and lifetime savings of 2.4 billion MMBTU, which would require approximately $35 billion in additional EPC contractor investment (Satchwell et al. 2010).

*Premise #3 – Uncertainty and Risk Must be Understood and Managed*

The interrelationships among project risks and decisions in EPC retrofits are still relatively unknown due to the limited literature focused on contractor's risks in such projects. Automated systems such as energy models cannot by themselves replace the need for expertise in making decisions under uncertainty, such as the designer's role in optimizing energy performance, owner's requirements, constructability, and facility operating parameters (Abaza 2008). This information must be provided by technical experts and decision-makers in order to make quality decisions about sustainability-related challenges (Cash et al. 2003). These factors make knowledge-based approaches appropriate to building energy design problems, because numerical methods do not provide designers with a quick means to assess options, whereas analytical methods do not deal well with the multitude of variables inherent in these problems (Kalogirou 2009). Therefore a method that combines both types of information must be considered in developing an EPC contractor risk model.

### *A Priori EPC Retrofit Risk Framework Development*

Hansen (2006) provided an outline of key risks that EPC contractors should be aware of when undertaking EPC retrofits, which was built from over three decades of experience. Using this outline as a base, an extensive literature review was conducted to further examine risks faced by EPC contractors when undertaking building retrofits. The net result of that review was the construction of an a priori risk framework that includes ten risk categories for EPC contractors to consider when undertaking building retrofits. Since the primary technical risk retained by EPC contractors is failure to achieve guaranteed performance, this framework can be considered a first step toward identifying critical risk factors for contractors undertaking EPC retrofits. These categories and the preliminary risk framework are depicted in Table 1. In order to refine this framework, elicitation of expertise from EPC contractor practitioners who have had significant roles in developing, designing, and executing EPC retrofits in the MUSH market was critical.

## RESEARCH SCOPE AND OBJECTIVES

The scope of this research is the identification and prioritization of project-level risks associated with building retrofits delivered via EPC throughout the entire project life cycle. The work is premised on the notion that risks can best be controlled during the earliest project phases, when the costs of change are lowest and the potential impact of those changes is the greatest (Kmenta and Ishii 2000; Horsley et al. 2003; Kishk et al. 2003). As a result, an a priori assumption was made that risks related to project execution will have a relatively low priority, except in the context of their upstream effects on risks that occur in earlier project phases. Research objectives have been defined to support the achievement of the research goal, as described below.



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

### *Objective 1: A Priori EPC Retrofit Risk Framework Development*

Work performed as part of the first objective was directed at performing an exploratory analysis of the EPC retrofit process and identifying key project-level risks requiring further analysis. This consisted of a comprehensive literature review and content analysis of key EPC project documents.

### *Objective 2: Expertise Elicitation Strategy*

Tasks performed under this objective included development of an expertise recruitment and evaluation framework, creating of a multi-faceted protocol by which expertise would be elicited from EPC contracting professionals with significant US project experience, and administration of the principal elicitation instrument, a Delphi questionnaire.

### *Objective 3: Refined Risk Framework for EPC Building Retrofits*

Work conducted as part of this objective consisted of analyzing data obtained through the Delphi questionnaire in Objective 2 in order to refine the literature-based a priori framework

**TABLE 1.** A Priori Risk Framework for EPC Contractors Undertaking MUSH Market EPC Retrofit Projects.

| Risk Category | Risks | References |
|---|---|---|
| Customer Pre-Qualification | Financial factors<br>• Customer may go out of business before full contract payment. | Bertoldi and Rezessy 2005; Hansen 2006 |
| | Facility/technical factors<br>• Customer-preferred short payback periods limit technical approach.<br>• Changes in future occupancy and use.<br>• Unknown latent conditions. | AEPCA 2000; Walker and Dominick 2000; Shonder and Hughes 2005; Hansen 2006; Bertoldi and Rezessy 2005 |
| | People factors<br>• Human activity inconsistent with M&V plans.<br>• Improper O&M undertaken by customer.<br>• Interference with customer operations. | AEPCA 2000; Hansen 2006; Mills et al. 2006 |
| Project Development | Costs incurred from project start-up; long development phases can lead to difficult to recover costs. | Hansen 2006 |
| Energy Audit Quality | The investment grade audit must include a risk assessment for each proposed ECM. | Hansen 2006 |
| | Improperly-established or disputed baseline can impact calculations of energy savings and also give rise to disputes. | Mozzo 2001; Mills et al. 2006; Sankey 2007 |
| Equipment Selection and Installation | Selected ECMs not aligned with findings of the IGA. | Hansen 2006 |
| | ECM package feasibility, failure to perform as designed, uncertainty in factors used to predict performance. | Shonder and Hughes 2005; Mills et al. 2006; Shang et al. 2008; Wang and Chen 2008; Jinrong and Enyi 2011 |
| | Reduced involvement of EPC contractor in ECM selection/installation, procurement through bidding, risk of improper installation if construction activities are contracted to a third-party that was not involved in the audit and during project design. | Hansen 2006 |



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

**TABLE 1.** Continued

| Risk Category | Risks | References |
|---|---|---|
| Commissioning | Failure to commission may lead to missed opportunities to verify ECM performance and better overall project performance; Failure to commission may miss opportunities to verify installed equipment performance, to ensure that calibration, operation, and maintenance procedures are well-understood, and that all system documentation is turned over. | Stum 2000; Sankey 2007 |
| Operations and Maintenance Practices | Poorly understood responsibilities by each party if the O&M plan is unclear. | AEPCA 2000 |
| | The customer may not perform O&M work to specification. | Mills et al. 2006 |
| | Customer self-performance or outsourced O&M may reduce revenue for the EPC contractor. | Hansen 2006 |
| Measurement and Verification of Savings | Poorly-developed M&V plans can create additional risk for the EPC contractor. | Hansen 2006 |
| | Poorly-designed M&V sampling protocols may not accurately reflect the overall performance of the ECM package. | Mills et al. 2006; Mozzo 2001; Shang et al. 2008 |
| | M&V protocols that do not capture non-energy benefits of EPCs may understate overall system performance. | Larsen et al. 2012a |
| | Failure to include O&M in the M&V plan may lead to missed savings. | Schweitzer et al. 2000 |
| Project Management Over the Project Life-Cycle | Failure to adopt life-cycle based management approaches may result in failure to meet project objectives. | Hansen 2006 |
| Construction-Specific Concerns | Schedule growth may cause unrecoverable costs for the contractor. | Silberman 2010 |
| | Cost growth may impact the financial analysis that the savings guarantee is premised on - cost overruns may result from schedule delays, latent site conditions, and field changes. | Smith and Ferber 1996; AEPCA 2000; Sankey 2007; Silberman 2010 |
| Volatility of Energy Prices | Changing prices can reduce project value. | Bertoldi and Rezessy 2005; Shonder and Hughes 2005; Mills et al. 2006; Shang et al. 2008; Wang and Chen 2008 |

developed in Objective 1. Analysis and refinement consisted of confirmation of identified risksioritization, and identification of risk causes and control measures.

### *Expertise Elicitation Strategy*

EPC retrofit projects rely significantly on expert judgment and implicit knowledge to make decisions under conditions of uncertainty and risk, as a result this research is premised largely on qualitative information. A research method is needed that can capture the judgment of experts and resolve any apparent differences among expert opinions. The Delphi technique has been proposed as a useful research method for construction engineering and management research that addresses limitations inherent in existing experimental techniques due to the complexity of the domain and the presence of biases among research subjects (Hallowell and Gambatese 2010). This method has been found to be particularly applicable when source agreement is desired through a refereed process to collect, aggregate, and organize expertise from potentially unique or divergent information sources (Pill 1971; Powell 2003; Yousuf

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

2007). Furthermore, Yousuf (2007) stated that an advantage of the method is its ability to collect such data when time, distance, and other logistical factors make it difficult for such an expert panel to be convened in a single in-person event. The use of Delphi contributes to a robust qualitative approach that provides accuracy and precision, minimizes participant bias, and accounts for expert judgement ((Rauch 1979; Hallowell and Gambatese 2010).

Participant selection is critical, as the success of a Delphi study depends largely on the expertise of the participants comprising the panel (Powell 2003). While there is generally disagreement about the optimal panel size (Keeney et al. 2006), Hallowell and Gambatese (2010) recommended Delphi panels consisting of 8-12 participants for construction engineering and management research, so long as the panel is diverse and members are highly-qualified within their domain. The identification and selection of panelists for this research utilized three purposive sampling methods identified by Teddlie and Yu (2007): (1) expert sampling, (2) snowball sampling, and (3) critical case sampling. Identification and selection of panelists was based on the guidelines presented by Hallowell and Gambatese (2010) for construction engineering and management and Duah (2014) for energy efficient retrofit. The guidelines used in this study included recruitment from industry associations, EPC contractor firms, and from among participants in previous expert-based studies. Nine determinants of expertise were employed in this research; potential panelists had to meet at least five of these qualifications to be included in the Delphi panel (Table 2).

**TABLE 2.** Scoring Rubric for Expert Determination.

| Experience | Points |
|---|---|
| At least 8 years professional EPC experience | 1 |
| At least 8 previous EPC projects | 1 |
| At least 75% of EPC project experience is in the MUSH market | 1.5 |
| At least three building systems impacted per project, on average | 0.5 |
| Role in financing and financial incentives per project | 0.5 |
| Professional registration | 2 |
| Advanced degree in a related field (BS or higher) | 2 |
| Faculty member | 1 |
| Peer-reviewed publications | 1 |
| Invited conference presenter | 0.5 |

A scoring rubric based upon these same researchers' efforts was developed in order to provide a relative measure of expertise among the panelists, provided in Table 2. While a threshold value of points was not used, as was the case with expert qualification categories, a goal was established that panelists would have a score of at least 4.5 points out of the 8.5 points available for professional experience, registration, and education.

Development of the refined risk framework utilized a two-round Delphi questionnaire to investigate consensus- and non-consensus- (e.g., knowledge construction) driven aspects of contractor risks in the EPC retrofit process. A variety of statistical parameters are commonly used in Delphi studies to indicate when consensus has been reached, and include percent

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

agreement, mean, median, standard deviation, and/or mode (Hasson et al. 2000; Hsu and Sanford 2007; Hallowell and Gambatese 2010). This study used percentage of agreement among panelists which is a commonly reported parameter. A predetermined percentage agreement of 70% or more was used as an indicator of consensus (Duah 2014).

The questionnaire also included the ability to detect the difference between participants achieving consensus and achieving agreement. Evans (1997) questioned the working definition of consensus, as possibly meaning (1) views that are "acceptable" to all panelists, (2) the same view that is held by all panelists, and (3) the majority view. Keeney et al. (2006) explained that most studies opt to measure the extent to which participants reach agreement with one another, fundamentally ignoring whether the "correct" answer has been found or whether true consensus has been reached. To address this concern, several items in the questionnaire elicited expertise with regard to elements of the a priori risk framework. This enabled the researcher to capture panelists' reactions to information obtained through the literature review and the preliminary expert interview and provided them the ability to add other risk-related information, as necessary. This approach deemphasized the need for panelists to merely agree with one another, and instead sought triangulation among multiple data sources represented in the preliminary risk framework and provided participants with the opportunity to contribute their expertise to the construction of reality represented by the decision Delphi questions.

### *Expertise Elicitation Strategy*

Since the selection of knowledge elicitation techniques depends on characteristics of the domain and the experts under study, this research followed the framework for selection of elicitation techniques provided by Duah (2014) given the similarity between domains – energy efficiency retrofits – while making appropriate changes to reflect the differences between residential retrofits and MUSH market EPC retrofits. Based on Duah's (2014) framework for selection of elicitation techniques, semi-structured interviews, job shadowing, and the Delphi technique were selected for constructing this framework. Semi-structured interviews were used to collect data from the Delphi panel. An open-ended interview was first conducted with a test panelist in order to clarify information gaps remaining after the literature review and to test the structure of the questionnaire which would be administered to the complete Delphi panel. Job shadowing of experienced EPC contractor and MUSH market energy management professionals was undertaken through observation of their early interactions when the IGA was being conceptualized, developed, and finalized, in order to gain insights about how the retrofit decision process occurs and the types of information used, as well as to gain experience with the risk-based decisions made by contractors during the earliest phases of EPC projects.

### *Administration of Delphi Survey*

Expertise was elicited from 19 EPC contractor professionals following the strategy described above. The panel was comprised of ten members from independent EPC contractors, seven members from manufacturer-based contractors, and two from utilities. Job duties and levels of panelists included business development managers, energy engineers, project managers, engineering managers, business practice group managers, and a vice president. A summary of their expertise attributes are provided in Table 3. Panelists responded to a two round Delphi questionnaire consisting questions about their organizations' risk management processes. Even though constructing a representative industry sample was not the goal of participant recruitment and selection activities, the panel was generally representative of the overall ownership

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

**TABLE 3.** Summary Expertise Attributes of Delphi Members.

| Attribute | Minimum Value | Mean/Mode | Maximum Value |
|---|---|---|---|
| Total Points[a] | 4.5 (31%) | Mean = 8 (55%) | 12 (83%) |
| Total Categories[a] | 5 (50%) | Mean = 7.2 (72%) | 10 (100%) |
| Years involved with EPC projects | 5 | Mean = 16 | 33 |
| Total number of projects | 10 | Mean = 81 | 300 |
| Proportion MUSH market projects | 33% | Mean = 90% | 100% |
| Number of building systems impacted/project | 3-4 | Mode = 5-7 | 10+ |

**Notes:**
a\ Points and categories refer to Table 2

share of the national EPC contractor market. Some minor observed variation between the study sample and EPC contractor population is present (equipment manufacturer-based firms were slightly underrepresented; utility company based- and independent contractors were slightly overrepresented), and likely attributable to the use of snowball sampling and expert sampling in constructing the panel (Sadler et al. 2010).

The risk management process questions sought to elicit expertise about seven knowledge categories relative to the risk management process: (1) MUSH market-specific risks, (2) risk identification methods, (3) risk identification timing, (4) risk identification responsibility, (5) risk evaluation methods, (6) risk identification, and (7) identification of the most important risk categories. Consensus was a goal of four out of ten questions; the other six questions were intended to assist with knowledge construction, as reflected by the goals of the decision Delphi technique (Rauch 1979).

After the first Delphi round, consensus was achieved for three of the four consensus-based questions (75%), as shown in Table 4. Consensus was not achieved for question 2b (new risks identified by panelists during the first round interviews). Additionally, while consensus was achieved on questions 2c (MUSH market-specific risk categories) and 3e (risk importance ranking), further detail was sought from panelists; further detail was also sought with regard to questions 3a (risk identification methods) and 3d (risk evaluation methods). A second Delphi round was conducted using an online survey platform to facilitate participant responses. As part of the second round, panelists were provided with their first round responses, as well as the consensus measures attained for each question through the first Delphi round. The second round resulted in achieving consensus for question 2b and attaining the additional information needed for questions 2c, 2d, 3a, and 3e; at that point, the Delphi process was terminated.

## REFINED EPC RISK FRAMEWORK FOR BUILDING RETROFITS

The a priori risk framework was refined as a result of expertise elicitation and data analysis, as described above. Based on data collected from the Delphi panel, the a priori risk framework was refined in four ways: (1) identification of risk categories was confirmed, (2) risk categories and risks were modified, (3) risk causes and mitigation strategies were added, and (4) risk category identification frequencies and relative risk importance scores were assessed and added. Additionally, panelists provided an assessment of the unique risks posed by MUSH market



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

**TABLE 4.** Summary of Part III Questions and Consensus Results.

| Question Number | Question Focus | Knowledge Goal | Delphi Consensus Status | |
|---|---|---|---|---|
| | | | 1st Round | 2nd Round |
| 2a. | Risk Identification | Elicitation | Achieved | |
| 2b. | | Elicitation | Not Achieved | Achieved |
| 2c. | MUSH Market-Specific Risks | Elicitation | Achieved[a] | Achieved[a] |
| 3a. | Risk Identification Methods | Construction | Not Needed[a] | |
| 3b. | Risk Identification Timing | Construction | Not Needed | |
| 3c. | Risk Identification Responsibility | Construction | Not Needed | |
| 3d. | Risk Evaluation Methods | Construction | Not Needed[a] | |
| 3e. | Identification of Most Important Risk Categories | Elicitation | Achieved[a] | Achieved[a] |
| 4a. | | Construction | Not Needed | |
| 4b. | | Construction | Not Needed | |

**Notes:**
a\ Additional information was sought in the second Delphi round.

EPC retrofits, which is the dominant sector in performance contracting. The elicited expertise is provided in the following results and discussion section. The refined framework can also be viewed in its entirety in Table 5.

**TABLE 5.** Refined Risk Framework for EPC Contractors Undertaking MUSH Market EPC Retrofit Projects

| Risk Category | Delphi Freq[a] | Quart[b,c] | Risks and Causes | Controls/Mitigation[d] |
|---|---|---|---|---|
| Customer Selection Factors | 16/19 (16/19) | 1(3) | Financial Factors<br>1. Customer may not be able to get financing.<br>2. Unacceptable customer debt ratio. | • Utilize standardized qualification method. (1,2) |
| | 16/19 (16/16) | 1(3) | Facility/Technical Factors<br>1. Building staff overrides equipment schedules or set points.<br>2. Changes in future occupancy and use.<br>3. Customers either prefer or have mandated shorter contract lengths which limit technical scope of work.<br>4. Facility age – code update requirements.<br>5. Interference with building operations due to unique schedules or facility needs (e.g., schools, hospitals, and prisons).<br>6. Unknown latent site and facility conditions. | • Address concerns contractually. (1-6)<br>• Conduct code review. (4,6)<br>• Conduct a feasibility study. (6) |
| | 18/19 (18/19) | 1(3) | People Factors<br>1. Improperly-performed O&M by customer's forces.<br>2. Occupants that require special management during project execution.<br>3. "Rebound effect" - human activity inconsistent with M&V. | • Address concerns with potential behavior of occupants contractually. (2,3)<br>• Offer training to operators and building occupants. (1,3) |
| Project Development | 18/19 (16/16) | 3 | 1. Customer self-implementation of specific work packages.<br>2. Cost to do nothing and operate inefficiently.<br>3. Costs incurred from project start-up; long development phases can lead to difficult to recover costs.<br>4. Lack of experience in a given market and/or with utility rebate programs can add significant workload.<br>5. Long procurement times for MUSH products can outdate pricing by a year or longer.<br>6. Political issues – owner's project decision makers in MUSH market may be elected, term-limited, etc. and cause a project to lose continuity.<br>7. Potential utility rebates may expire before the project is awarded.<br>8. Public entities frequently change contract documents, terms, and conditions.<br>9. Some procurement methods require completion of an audit before a contract for the entire retrofit is awarded.<br>10. Timing of public projects can cause delays resulting in price increases. | • Document conversations among parties. (1,2,5,6,7,8,10)<br>• Track approvals given to the project. (1,3,5,6,8,9)<br>• Use escalation factor for price growth if procurement takes too long. (2,3,4,5,7,9,10) |



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

**TABLE 5.** Continued

| Risk Category | Delphi Freq[a] | Quart[b,c] | Risks and Causes | Controls/Mitigation[d] |
|---|---|---|---|---|
| Energy Audit Quality | 18/19 (16/16) | 3 | Existing Conditions<br>1. Facility age – code update.<br>2. Misunderstanding existing conditions, such as possible presence of asbestos.<br>Facility Stakeholder Concerns<br>3. Differing stakeholder needs.<br>Inexperience<br>4. Failure to understand facility operations and EPC goal – lack of EPC experience.<br>Information and Analysis<br>5. Calculation errors.<br>6. Conducting the IGA too quickly.<br>7. Energy model calibration error.<br>8. Inaccurate/incorrect or disputed baseline.<br>9. Information availability and accuracy.<br>10. Missing information.<br>11. Missing risk assessment for each ECM.<br>Project Complexity and Guaranteed Savings<br>12. Establishment of the guarantee amount - difficult balance between providing a large-enough project to generate customer excitement and contractor value and hedging on savings.<br>13. Overstatement of issues leading to mismatch with technical needs; understatement of issues leading to reduced project value. | Existing Conditions<br>• Complete set of facility drawings. (1,2)<br>• Conduct a code review. (1)<br>Facility Stakeholder Concerns<br>• Comprehensive stakeholder interviews/review during IGA. (3)<br>Inexperience<br>• Joint venture with experienced firm or consultant. (4)<br>Information and Analysis<br>• Complete set of facility drawings. (9.10)<br>• Contingency factors. (5,8,9,10,11)<br>• Identify risks for each ECM being evaluated and the entire ECM portfolio. (11)<br>• Include potential but unverified concerns in the IGA. (6,7,8)<br>• Interview all facility staff and back-brief them on the findings to "ground truth" the audit results and uncover any missing information. (5,7,8,9,10)<br>• Third-party internal review based on historical projects. (5,7,8,9)<br>Project Complexity and Guaranteed Savings<br>• Contingency factors. (12,13)<br>• Third-party external reviews. (12,13)<br>• Use stipulation and IPMVP Option A wherever appropriate. (12) |
| ECM Selection and Installation | 19/19 (16/16) | 3 | Contractual Concerns<br>1. Owners and/or project designers and engineers are used to design-bid-build in the public sector and are not used to designing based on fixed budgets and do not understand EPC cost structures.<br>2. Disconnect between the design and audit intent – improper efficiency target; different operating schedule implemented than what was planned; different control system installed.<br>3. Subcontractor quality and reliability.<br>4. Unqualified and unsafe contractors create additional risks.<br>ECM-Specific Issues<br>5. Cheapest equipment sometimes selected – leads to sub-optimal O&M savings.<br>6. ECM package constructability and feasibility.<br>7. ECMs are not aligned with the IGA findings.<br>8. Failure to perform as designed.<br>9. Uncertainty in factors used to predict performance.<br>Facility Factors<br>10. Installation location.<br>Occupant Concerns<br>11. Comfort complaints can add extra work after construction is complete.<br>12. Lighting is difficult to demonstrate before installation; owner and occupants can be unhappy with light quality after a retrofit.<br>Project Complexity and Guaranteed Savings<br>13. "Low-hanging fruit has been picked" – increasing complexity of ECMs.<br>14. Lowest-cost solutions may create value concerns during O&M.<br>Security Concerns (Correctional Facilities)<br>15. Accessibility to inmates/physical security. | Contractual Concerns<br>• Align outsourced design team with internal energy auditing team. (1,2)<br>• Coordinate phase handoffs between project developer and energy engineer. (2)<br>• Coordinate EPC contractor and construction team members. (1,3,4)<br>• Pre-qualify subcontractors. (3,4)<br>• Robust CM practices. (1,2,3,4)<br>• Use EMR ratings to assess subcontractor safety. (4)<br>ECM-Specific Issues<br>• Identify risks for each ECM being evaluated and the entire ECM portfolio. (5,6,7,8,9)<br>• EPC contractor's in-house design teams for specialty ECMs (e.g., lighting) that can have complex design and performance issues. (6,8,9)<br>Facility Factors<br>• Conduct feasibility review of post-installation performance. (10)<br>• Use cost-contingency factors. (10)<br>Occupant Concerns<br>• In-house design teams for specialty ECMs that can have complex design and performance issues. (11,12)<br>Project Complexity and Guaranteed Savings<br>• Use cost-contingency factors (13).<br>• In-house design teams for specialty ECMs that can have complex design and performance issues. (13,14)<br>Security Concerns<br>• Specify tamper-resistant fixtures. (15)<br>• Use cost-contingency factors (15). |
| Commissioning | 19/19 (19/19) | 2 | 1. Commissioning is often taken out of the project if cost overruns are projected.<br>2. Failure to commission can affect system performance.<br>3. Missed opportunities to verify ECM performance if fail to commission.<br>4. Implementing and managing a controls program can add extra cost and delay to commissioning and closeout. | • Balance amount of commissioning with project specifics to save costs. (1,2,3)<br>• Commission every point of a building automation system. (2,3,4)<br>• Commission with the customer. (1)<br>• EPC contractor self-performs commissioning. (1,2,3,4)<br>• Improve communications and collaboration with controls vendors. (1,4) |
| Operations and Maintenance Practices | 18/19 (18/19) | 1 | 1. Cheapest equipment sometimes selected – leads to sub-optimal O&M savings.<br>2. Missed opportunities to ensure that calibration, operation, and maintenance procedures are well-understood and documented. | • Stipulate factors that the EPC contractor does not have control of (e.g., human behavior – lighting and HVAC use; changes in occupant density and building use). (1)<br>• Delineate EPC contractor and owner responsibilities for O&M in the contract. (2) |



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

**TABLE 5.** Continued

| | | | | |
|---|---|---|---|---|
| Measurement and Verification of Savings | 19/19 (16/16) | 2 | 1. Failure to include O&M in the M&V plan may lead to missed savings.<br>2. Improper measurement.<br>3. Lack of sub meters.<br>4. M&V protocols that do not capture non-energy benefits of EPCs may understate overall system performance.<br>5. Poorly-designed M&V sampling protocols may not accurately reflect the overall performance of the ECM package.<br>6. Use of an inaccurate baseline. | • Internal M&V review process. (1,2,3,4,5,6)<br>• Review M&V plan at the same time as energy savings are being calculated. (2,3,5,6)<br>• Stipulate factors that the EPC contractor does not have control of (e.g., human behavior – lighting and HVAC use; changes in occupant density and building use). (1,2,4) |
| Project Management Over the Project Life-Cycle | 14/19 (14/19) | 1 | 1. EPC contracting firm personnel turnover.<br>2. Handoffs to different managers at each phase; can often be a long time between handoffs. | • Document everything properly. (1,2) |
| Construction-Specific Concerns | 18/19 (18/18) | 3 | 1. Change orders are generally not allowed.<br>2. Cost growth.<br>3. Facility operating profile may limit times of the year when work can be done – long waits until then and short construction seasons may be common.<br>4. Long lead times for equipment.<br>5. Poor project handoffs among engineers and CMs.<br>6. Schedule growth.<br>7. Unknown site and facility conditions.<br>8. Unqualified or unprofessional sub-contractors.<br>9. Work productivity losses due to correctional facility security procedures. | • Build safety factors into proposals. (1,2,4,6,7,9)<br>• Early involvement of CM in project team. (1,2,3,4,5,6,9)<br>• Pre-qualify subcontractors. (8,9)<br>• Strong construction management. (1,2,3,4,5,6,7,8,9)<br>• Utilize a mandatory handoff process. (5,9) |
| Volatility of Energy Prices | 17/19 (17/19) | 1 | 1. Changing prices can reduce project value.<br>2. Difficult to predict energy rate increases more than 2-3 years from the present time. | • Guarantee a quantity of energy saved, not energy costs. (1,2)<br>• Frequently monitor energy rates. (1,2)<br>• Use an acceptable energy rate escalation factor in the contract. (1,2)<br>• Use a floor rate to protect against large rate decreases. (1) |
| Perception of the Performance Contracting Industry | 15/15 (15/15) | N/A[e] | 1. Lack of knowledge regarding EPC enabling statutes by the EPC contractor limits some customers' understanding of how they can use EPC.<br>2. Unethical behavior negatively impacts the industry as a whole. | |

Notes: a\ X/y values indicate the frequency of risk category identification out of the total sample of Delphi panelists. The value in parentheses is the frequency with outliers removed.
b\ Quartile rankings come from Delphi panelists voting for the top three risk categories they believe can most negatively impact performance.
c\ Customer selection factors were presented to Delphi panelists as three separate risks; however, many indicated that these should be treated as a single risk. The value in parentheses indicates the quartile ranking when each individual customer selection factor was considered collectively as a single consolidated risk category.
d\ Values in parentheses connect risks and causes with their corresponding mitigation and control strategies.
e\ None of the panelists identified this risk category as being among those they believe most negatively impact project performance, therefore no quartile score could be calculated.

Important qualitative findings during data collection for the refined framework included EPC contracting firms' near total reliance on experience in the risk management process, their general use of informal risk management methods, and their interest in including NEBs, despite their reluctance to monetize them due to perceived financial and performance risks. Much of the emphasis on risk identification and management was placed in the pre-construction phases, as change orders are typically unavailable once installation activities commence. Additionally, construction-related risks and longer-term risks, such as measurement and verification and operations and maintenance, are typically underemphasized and appeared to be addressed primarily through contractual means or via a "hedge" on the final project cost.

The importance of this refined framework to the EPC contracting industry is in its ability to quickly prioritize risk categories based upon their relative impact across all project phases. This is critical for such projects where contractor-initiated change orders are typically limited as the execution phase is entered. The framework also provides the ability to quickly identify potential risk causes and possible control measures that can be used for mitigation, in early, mid-project, or later phases of the life cycle.



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

## RESULTS AND DISCUSSION

Results obtained from the Delphi panel are provided in this section. The results are organized along the lines of the information categories used in developing the refined risk framework.

### *MUSH Market-Specific Risks*

Consensus was sought and obtained for this question in order to reject or confirm the assertion that MUSH market projects carry additional risks and as such require the construction of a specific risk framework. Fourteen out of 17 Delphi panelists indicated that there are differences in the risk profiles between MUSH and non-MUSH segments; non-MUSH segments were defined as commercial and industrial (C&I) retrofits. Of those 14 panelists, 11 indicated that at least one or more MUSH sub-markets is riskier than C&I, (9 - all MUSH sub-markets; 1 - correctional facilities only, 1 - hospitals only). Two other respondents indicated their belief that C&I projects are riskier in all cases. In the second Delphi round panelists were asked to identify which MUSH market facility types (correctional facilities, hospitals, K-12 schools, mission-critical facilities, and continuously operated facilities) had the greatest project risk profiles; response frequencies for each facility type were 10/15, 7/15, 2/15, 8/15, and 7/15, respectively. Additionally, just one out of 15 respondents believed that MUSH market facility EPC retrofits are no riskier than private sector EPC projects.

Panelists provided an analysis of the sources of risk in the two MUSH market facility types with the greatest project risk profiles. Six unique sources of risk in correctional projects were identified. These included: (1) costs related to productivity loss due to security protocols, (2) health and safety protocols that override the ability to cycle HVAC equipment off during low utilization times, (3) project conflicts arising from the "militaristic structure" of correctional agencies, (4) difficulties of scheduling and conducting work in a continuously-operated facility, (5) security concerns with installed ECMs and vandalism of equipment after installation, and (6) security level-dependent risks.

### *Differences Between A Priori and Refined Risk Frameworks*

The significant changes made between the a priori and refined risk frameworks are detailed in the following sections. The insights gained in the refined framework reflect improvements to the risk management process by more clearly identifying risks, focusing management activities on the most critical risk factors, including mitigation strategies for identified risks. For example, the inclusion of risk causes and mitigation strategies in the refined framework enables a clearer focus on the sources and management of each risk.

#### *Risk Identification*

Consensus was sought, and obtained in the first Delphi round with regard to the risk categories included in the a priori risk framework (Table 1). The first category, Customer Prequalification, was subdivided into three related risk categories: (1) Financial Factors, (2) Facility/Technical Factors, and (3) People Factors. Panelists were asked the frequency with which they consider each risk category in their MUSH market EPC retrofit projects, using a seven-point Likert-type scale (Vagias 2006), which utilized the following response categories: (1) 100% - Every Time, (2) ~90% - Usually, (3) ~70% - Frequently, (4) ~50% - Sometimes, (5) ~30% - Occasionally, (6) <10% - Rarely, and (7) 0% - Never. Positive risk identification was denoted when a panelist indicated that they considered the risk in categories one through six. Consideration was defined as addressing a risk category through contractual means (e.g.,



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

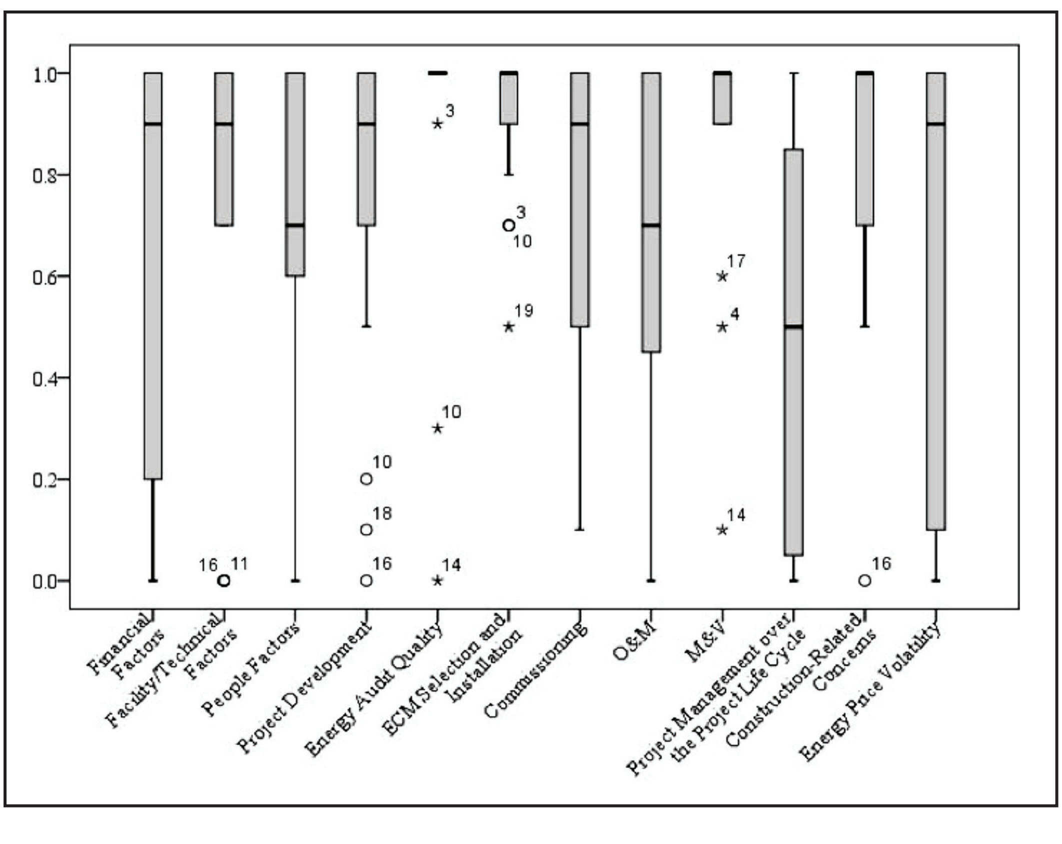
inclusion of an energy rate escalation term), via technical means (e.g., conduct a peer review of energy model results), through project management (e.g., specific team member assigned to coordinate activities among planning, engineering, and execution groups), or by financial means (e.g., include a "hedge" factor to account for potential uncertainty). Sixty-six individual risks were identified as belonging to these risk categories. Achieving consensus also confirmed the selection and identification of the risk categories from the a priori framework. The distribution of risk identification responses is shown in Figure 1.

*Modification of Risk Categories and Risks*

Panelists were afforded the opportunity to add additional risk categories that did not appear in the a priori framework; 11 additional risk categories were identified. Analysis of transcripts and a summative review of each of the newly-identified risk categories resulted in 10 being classified as individual risks belonging to existing risk categories; one was retained as a new risk category – "Perception of the Performance Contracting Industry."

Since consensus could not be achieved in the first Delphi round for the newly identified risk category or the newly identified risks, during the second Delphi round, panelists were asked to rate their consideration frequency of the new risk category and for their concurrence with the other ten risks. Consensus was achieved for the inclusion of the new risk category, with 100% agreement (15/15 respondents) during the second round. Consensus was also achieved for eight of the ten risks identified by panelists. Design development (67%) and safety (60%) did not meet the threshold value for participant agreement (70%), and were thus excluded from further analysis

**FIGURE 1.** Range and Distribution of Risk Consideration Frequency.




Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

*Identification of Risk Causes and Mitigation Strategies*

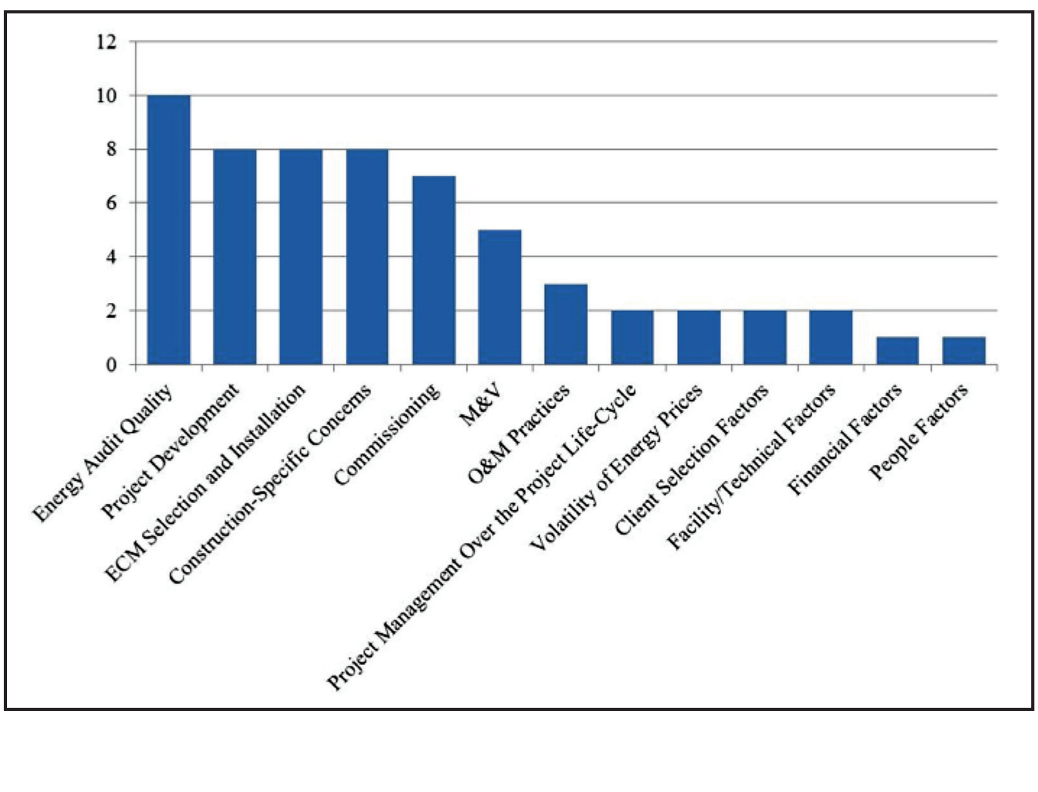
Expertise was elicited from panelists with regard to causes of and control measures used for energy audit quality-related risks and equipment selection and installation- related risks. Achieving consensus among panelists was not a goal for the two knowledge categories addressing individual risks (e.g., risk causes) and their associated control measures (e.g., mitigation strategies) because the intent was to fully-describe the risk-based decision making process with regard to the top two identified risk categories. Since risk causes and mitigation strategies would be subject to review by SFMEA panelists as part of the risk scenario construction process, assessing the validity of the knowledge constructed by Delphi panelists was possible.

It is worth noting that examples exist of potential mitigation measures that were not addressed by panelists. For example, risks related to inaccurate baselines could be addressed contractually via a pre-determined agreement on baseline adjustments during the project's life cycle. Similarly, improperly-performed O&M by the owner could be addressed contractually, through required minimum standards, or via a follow-on O&M performance contract from the EPC contractor. If adequate controls have been installed, continuous commissioning may be employed to minimize the impact of human activity that is inconsistent with energy retrofit program goals. While these are routinely-recognized control and mitigation strategies, because panelists did not identify them, they have not been presented as part of the data analysis in Table 5.

*Identification of Most Important Risk Categories*

Delphi panelists were asked to identify the most important risk categories among those presented to them during the interview. The purpose of this review was to identify the risk categories that would be subject to further analysis and evaluation in later phases of this research. Consensus was sought on this question, and panelists were asked to assign a de-facto risk

**FIGURE 2.** Pareto Histogram of Relative Importance Scores for Risk Categories .






Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

importance score rank by identifying the three risk categories that they believed to have the greatest contribution to failing to meet guaranteed performance. A Pareto histogram of the relative importance scores for each risk category is provided in Figure 2.

From the Pareto histogram, six risk categories were identified and ranked in the upper two quartiles for risk importance scores: (1) energy audit quality, (2) project development, (3) ECM selection and installation, (4) construction-specific concerns, (5) commissioning, and (6) measurement and verification (M&V). Risk consideration frequencies were reviewed for these six risk categories, and they were ranked again. The results of ranking using quartile analysis/Pareto histogram of risk importance scoring and ranking due to risk consideration frequencies are shown in Table 6. During the second Delphi round, panelists were asked to rank each of the six risk categories from 1 (most important) to 6 (least important). Results are shown in the rightmost column of Table 6. Consensus was achieved if two of the three ranking measures had rank order agreement for a given risk category. By that measure, four risk categories achieved consensus (energy audit quality, ECM selection and installation, commissioning, and M&V), while two did not (construction specific concerns and project development).

**TABLE 6.** Risk Importance Ranking from Delphi Panel Data.

| Risk Category | Pareto/Quartile[a] | Consideration Frequency[a,b] | Delphi Round 2[a] |
|---|---|---|---|
| Energy audit quality | 1 (10) | 4/1 (18/19 / 19/19) | 1 (2.4) |
| ECM selection and installation | 2 (8) | 1/1 (19/19 / 19/19) | 2 (3.0) |
| Construction-specific concerns | 2 (8) | 4/1 (18/19 / 19/19) | 6 (3.9) |
| Commissioning | 4 (7) | 1/1 (19/19 / 19/19) | 4 (3.6) |
| Project development | 5 (5) | 4/1 (18/19 / 19/19) | 3 (3.1) |
| M&V | 5 (5) | 1/1 (19/19 / 19/19) | 5 (3.7) |

**Notes:**
a\ Numbers in parentheses are the raw values (e.g., non-ranked) for each variable.
b\ Values are consideration frequency/total sample with outliers retained (left of slash) and with outliers removed (right of slash).

*Risk Categories by Project Phase*

Over the course of a typical EPC retrofit project with a 12-15 year performance period, decisions regarding the project design are made during the earliest parts of the project life cycle. Since EPC retrofits generally contain little to no opportunity for contractor-driven change orders once construction begins, there is limited opportunity for cost recovery once the performance contract is signed. As a result, it is posited that performance risks are generally greater during the latter phases of the project, after the energy savings guarantee is signed. The most important risk management actions would likely take place during the earliest project phases, when decisions are made that have long-term impacts on project performance and can effectively mitigate risk by including them in the project's pro forma before the energy savings guarantee is signed.

Based on elicited expertise related to the knowledge categories pertaining to risk identification and risk importance scoring, each risk category was assigned to the project phases where their attendant risks are realized, and a mean risk importance score was recorded. Project life cycle phase assignments and risk importance scores are provided in Table 7. As expected, the risk importance score is highest in the earlier phases, since decisions made here have lasting



Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

impact over the length of the performance contract; this corresponds to the time when the cost of changes is the lowest and the ability to influence project performance is the greatest.

**TABLE 7.** Risk Category Importance by Project Phase.

| Risk Category | Project Phase | Mean Risk Importance Score[a] |
|---|---|---|
| Financial Factors [b] | Project Development | 7 |
| Facility/Technical Factors [b] | | |
| People Factors [b] | | |
| Project Development | | |
| Energy Audit Quality | Energy Audit | 10 |
| ECM Selection and Installation | Retrofit Design | 5 |
| Volatility of Energy Prices | | |
| Commissioning | Project Execution | 7.5 |
| Construction-Specific Concerns | | |
| O&M Practices | Energy Performance | 4 |
| M&V | | |
| Project Management Over the Project Life Cycle[c] | Not Assigned | 2 |

**Notes:**
a\ The mean score is the average frequency of all risk categories in a given project phase.
b\ While listed separately, these risk categories were treated as one for the purposes of calculating the mean score, since they were sub-factors of "customer selection risks."
c\ A single phase score was not assigned because this risk category occurs in each project phase.

## CONCLUSIONS AND FUTURE RESEARCH

This paper introduced the need for a risk framework for contractors undertaking EPC retrofit projects, particularly in MUSH market buildings. The framework expanded the earlier work of Hansen (2006) through the elicitation of expertise from EPC contracting experts utilizing a two-round Delphi questionnaire, following guidance from Duah (2014) and Hallowell and Gambatese (2010). The questionnaire focused on risk identification as well as a prioritization of risk categories, risk causes, and potential mitigation strategies. Panelists reached consensus on identifying the most important risk categories, which were given as energy audit quality, ECM selection and installation, commissioning, and M&V. Additionally, risks occurring during earlier project phases received higher importance scores, as did those taking place during project execution (retrofit construction). These findings underlie the need to adequately plan for and manage EPC project risks early in the project, when changes to the scope of work and energy savings guarantee-related measures are generally still allowed.

This framework serves as a preliminary step to a complete risk management scheme for better understanding project-level risks faced by EPC contractors when undertaking EPC retrofits. After identification and classification, risks must be analyzed and evaluated with planning included for risk mitigation and/or allocation (Edwards and Bowen 1998). In a broad sense, this paper contributes to improved project performance throughout the green buildings sector. Energy efficiency is a significant aspect of green building performance measures and ratings, making additional project management tools to support the effective mitigation of energy efficiency-related project risks an important part of this building sector.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

The work in this paper points to the need for additional research that should focus on development of the risk evaluation and analysis framework into a model-based system that enables the incorporation of expert knowledge and quantitative data in the assessment and analysis of specific project-level risk factors for EPC contractors undertaking building retrofit projects. Such a system will ultimately improve the understanding of long-term project risks in early phases, when planning and control activities can be better planned, thereby leading to enhanced outcomes for such projects.

## REFERENCES


Abaza, H. (2008). An interactive design advisor for energy efficient buildings. Journal of Green Building 3(1): 112-125.

AEPCA (2000). A Best Practice Guide to Energy Performance Contracts: Reducing operating costs through guaranteed outcomes. Castle Hill, New South Wales, Australia.

Appleman, T., Owsenek, B., Clough, D., and Hanna, M. (2010). Energy savings through performance contracting at wastewater treatment plants. In Proceedings of WEFTEC 2010. October 2-6, 2010. New Orleans, Louisiana, USA.

ASHRAE (2011). Procedures for Commercial Building Energy Audits (2nd Ed). ASHRAE: Atlanta, Georgia, USA.

Assaf, S.A. and Al-Hejji, S. (2006). Causes of delay in large construction projects. International Journal of Project Management 24: 349–357.

Baechler, M., Strecker, C., and Shafer, J. (2011). A Guide to Energy Audits. PNNL-20956, Pacific Northwest National Laboratory. Richland, Washington, USA.

Banaitiene, N. and Banaitis, A. (2012). Risk Management in Construction Projects. In N. Banaitiene (Ed.) Risk Management - Current Issues and Challenges. InTech: New York, New York, USA.

Barbose, G.L., Goldman, C.A., Hoffman, I.M., and Billingsley, M. (2013). The Future of Utility Customer Funded Energy Efficiency Programs in the United States: Projected Spending and Savings to 2025. LBNL-5803E, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.

Berghorn, G.H. (2014). Life Cycle Cost-Based Risk Model for Energy Performance Contracting Retrofits . PhD Thesis, Michigan State University, East Lansing, Michigan, USA.

Bertoldi, P. and Rezessy, S. (2005). Energy service companies in Europe; Status report 2005. EUR 21646 EN, European Commission, Institute for Environment and Sustainability, Renewable Energies Unit. Ispra, Varese, Italy.

Bharvirkar, R., Goldman, C., Gilligan, D., Singer, T.E., Birr, D., Donahue, P., and Serota, S. (2008). Performance Contracting and Energy Efficiency in the State Government Market. LBNL-1202E, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.

Bhattacharjee, S., Ghosh, S., and Young-Corbett, D. (2010). Energy service performance contracting in construction. In Proceedings of the 46th Annual International Conference of Associated Schools of Construction. April 7-10, 2010. Boston, Massachusetts, USA.

Birr, D. and Singer, T.E. (2008). NAESCO Analysis of Non-Energy Benefits of Efficiency Retrofits for ESCOs and ESCO Customers. National Association of Energy Service Companies (NAESCO). Washington, DC, USA.

Cash, D.W., Clark, W.C., Alcock, F., Dickson, N.M., Eckley, N., Guston, D.H., Jäger, J. and Mitchell, R.B. (2003). Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences of the United States of America 100 (14): 8086-8091.

CCI (2009). An Introduction to EPC: EPC Toolkit for Higher Education. Clinton Foundation, Clinton Climate Initiative, and American College & University Presidents Climate Commitment. New York, New York, USA.

Deng, Q., Zhang, L., Cui, Q., and Jiang, X. (2014). A simulation-based decision model for designing contract period in building energy performance contracting. Building and Environment 71: 71-80.

Diab, M.F. (2012). Integrating risk assessment in planning for sustainable infrastructure projects. In Proceedings of the 2012 International Conference on Sustainable Design, Engineering, and Construction. November 7-9, 2012. Fort Worth, Texas, USA.


Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

Doloi, H. (2012). Understanding impacts of time and cost related construction risks on operational performance of PPP projects. International Journal of Strategic Property Management 16(3): 316-337.
Dong, B., Kennedy, C., and Pressnail, K. (2005). Comparing life cycle implications of building retrofit and replacement options. Canadian Journal of Civil Engineering 32: 1051-1063.
Drumheller, S. C. and Wiehagen, J. (2004). Strategies for Energy-Efficient Remodeling: SEER 2003 Case Study Report. Building America Technical Report NREL/SR-550-36474.
Duah, D.Y.A. (2014). Intelligent Decision Support System Framework for Energy Retrofits in Existing Homes. PhD Thesis, Michigan State University, East Lansing, Michigan, USA. Edwards, P.J. and Bowen, P.A. (1998). Risk and risk management in construction: a review and future directions for research. Engineering, Construction and Architectural Management 5(4): 339-349.
European Commission (2014). Energy Performance Contracting. European Commission Joint Research Centre – Institute for Energy and Transport. Downloaded from http://iet. jrc.ec.europa.eu/energyefficiency/european-energy-service-companies/energy-performance-contracting on March 14, 2014.
Evans, C. (1997). The use of consensus methods and expert panels in pharmacoeconomic studies: practical applications and methodological shortcomings. Pharmacoeconomics 12(2): 121 -12.
Forbes, D.R., Smith, S.D., and Horner, R.M.W. (2008). A comparison of techniques for identifying risks in sustainability assessment of housing. In Proceedings of the 24th Annual ARCOM Conference. September 1-3, 2008. Cardiff, Wales, United Kingdom.
Forster, H.J., Wallace, P., and Dahlberg, N. (2013). 2012 State of the Efficiency Program Industry: Budgets, Expenditures, and Impacts - Annual Industry Report. Consortium for Energy Efficiency. Boston, Massachusetts, USA.
Ganji, A.R. and Gilleland, B. (2002). Investment grade energy audit. In Proceedings of the 25th World Energy Engineering Congress. October 9-11, 2002. Atlanta, Georgia, USA.
Goh, C.S. and Abdul-Rahman, H. (2013). Applying risk management workshop for a public construction project: a case study. Journal of Construction Engineering and Management 139: 572–580.
Goldman, C., Hopper, N., and Osborn, J. (2005). Review of U.S. ESCO Industry Market Trends: An Empirical Analysis of Project Data. LBNL-52320, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.
Grimaldi, S., Rafele, C., and Cagliano, A.C. (2012). A Framework to Select Techniques Supporting Project Risk Management. In N. Banaitiene (Ed.) Risk Management - Current Issues and Challenges. InTech: New York, New York, USA.
Hallowell, M.R. and Gambatese, J.A. (2010). Qualitative research: application of the Delphi method to CEM research. Journal of Construction Engineering and Management 136: 99-107.
Hansen, S.J. (2006). Performance Contracting: Expanding Horizons. The Fairmont Press, Inc.: Lilburn, Georgia, USA.
Hansen, S. and Brown, J.W. (2004). Investment Grade Energy Audit: Making Smart Energy Choices. The Fairmont Press, Inc.: Lilburn, Georgia, USA
Harvey, L.D.D. (2009). Reducing energy use in the buildings sector: measures, costs, and examples. Energy Efficiency 2:139-163.
Hasson, F., Keeney, S., and McKenna, H. (2000). Research guidelines for the Delphi survey Technique. Journal of Advanced Nursing 32(4): 1008-1015.
Herring, H. and Roy, R. (2007). Technological innovation, energy efficient design and the rebound effect. Technovation 27: 194-203.
Hertwich, E.G. (2005). Consumption and the rebound effect: an industrial ecology perspective. Journal of Industrial Ecology 9(1-2):85-98.
Hopper, N., Goldman, C., Gilligan, D., Singer, T.E., and Birr, D. (2007). A Survey of the U.S. ESCO Industry: Market Growth and Development from 2000 to 2006. LBNL-62679, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.
Hopper, N., Goldman, C., McWilliams, J., Birr, D., and Stoughton, K.M. (2005). Public and Institutional Markets for ESCO Services: Comparing Programs, Practices and Performance. LBNL-55002, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.
Horsley, A., France, C., and Quatermass, B. (2003). Delivering energy efficient buildings: A design procedure to demonstrate environmental and economic benefits. Construction Management and Economics 21: 345-356.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

Hsu, C-C. and Sandford, B.A. (2007). The Delphi technique: making sense of consensus. Practical Assessment, Research & Evaluation 12(10): 1-8.
ICF and NAESCO (2007). Introduction to Energy Performance Contracting. U.S. Environmental Protection Agency, Energy Star Buildings Program. Washington, DC.
IFC (2011). IFC Energy Service Company Market Analysis. Ref. 5712. International Finance Corporation – World Bank Group. Washington, DC, USA.
Irwin, J., Rhodes-Conway, S., White, S.L., and Rogers, J. (2011). Making MUSH Energy Efficient: Energy Efficiency in the Governmental and Institutional Sector. Center on Wisconsin Strategy. Madison, Wisconsin, USA.
Jennings, J. and Skumatz, L.A. (2006). Non-energy benefits (NEBs) from commissioning in schools, prisons, and other public buildings. In Proceedings of the 2006 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Buildings. August 13-18, 2006. Pacific Grove, California, USA.
Jinrong, H. and Enyi, Z. (2011). Engineering risk management planning in energy performance contracting in China. Systems Engineering Procedia 1: 195–205.
Kalogirou, S.A. (2009). Artificial neural networks and genetic algorithms in energy applications in buildings. Advances in Building Energy Research 3(1): 83–120.
Keeney, S., Hasson, F., and McKenna, H. (2006). Consulting the oracle: ten lessons from using the Delphi technique in nursing research. Journal of Advanced Nursing 53(2): 205-212.
Kishk, M., Al-Hajj, A., Pollock, R., Aouad, G., Bakis, N., and Sun, M. (2003). Whole Life Costing in Construction: A State of the Art Review. RICS Foundation Paper Series, Volume 4, Number 18. RICS Foundation. London, England, United Kingdom.
Kmenta, S. and Ishii, K. (2000). Scenario-based FMEA: a life cycle cost perspective. In Proceedings of the 2000 ASME Design Engineering Technical Conferences. September 10-14, 2000. Baltimore, Maryland, USA.
Laitner, J.A. (2013). Calculating the Nation's Annual Energy Efficiency Investments. Research Report E133, American Council for an Energy Efficient Economy. Washington DC, USA.
Larsen, P.H., Goldman, C.A., and Satchwell, A. (2012a). Evolution of the U.S. energy service company industry: Market size and project performance from 1990–2008. Energy Policy 50: 802-820.
Larsen, P., Goldman, C., Gilligan, D., and Singer, T.E. (2012b). Incorporating non-energy benefits into energy savings performance contracts. In Proceedings of the 2012 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Buildings. August 12-17, 2012. Pacific Grove, California, USA.
McCabe, M.J. (2011). High-Performance Buildings – Value, Messaging, Financial and Policy Mechanisms. PNNL-20176, Pacific Northwest National Laboratory. Richland, Washington, USA.
Mills, E., Kromer, S., Weiss, G., and Mathew, P.A. (2006). From volatility to value: analysing and managing financial and performance risk in energy savings projects. Energy Policy 34: 188–199.
Mozzo, M.A. (2001). Setting the energy baseline for performance contracts. Strategic Planning for Energy and the Environment 21(1): 12-19.
Pampanin, S. (2009). Alternative Performance-Based Retrofit Strategies and Solutions for Existing RC Buildings. In A. Ilki et al. (Eds.) Seismic Risk Assessment and Retrofitting, Geotechnical, Geological, and Earthquake Engineering. Springer: New York, New York, USA.
Petersen, S. (2009). Evaluating how energy performance contracting impacts the business case for investing in building energy efficiency improvement. Presented at Towards NET-ZERO London. November 20, 2009. London, England, United Kingdom.
Pill, J. (1971). The Delphi method: substance, context, a critique and an annotated bibliography. Socio-Economic Planning Sciences 5: 57-71.
Powell, C. (2003). The Delphi technique: myths and realities. Methodological Issues in Nursing Research. 41(4): 376-382.
Rauch, W. (1979). The decision Delphi. Technological Forecasting and Social Change 15(3): 159–169.
Sadler, G.R., Lee, H-C., Lim, R.S-H., and Fullerton, J. (2010). Recruiting hard-to-reach United States population sub-groups via adaptations of snowball sampling strategy. Nursing & Health Sciences 12(3): 369-374.
Sankey, M.S. (2007). Performance contract failures – causes, cases, and remediation. In Proceedings of the World Energy Engineering Congress 2007. August 15-17, 2007. Atlanta, Georgia, USA.
Satchwell, A., Goldman, C., Larsen, P., Gilligan, D., and Singer, T. (2010). A Survey of the U.S. ESCO Industry: Market Growth and Development from 2008 to 2011. LBNL-3479E, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

Schweitzer, M., Shonder, J.A., Hughes, P.J., and Schmoyer, R.L. (2000). Methodology for Recalculating and Verifying Savings Achieved by the Super ESPC program. ORNL/CON-496, Oak Ridge National Laboratory. Oak Ridge, Tennessee, USA.

Seeley, C.C. (2012). Innovative Financing Mechanisms for Energy Efficiency Retrofits in Buildings – A Shift in the Traditional Paradigm. In Proceedings of EcoDesign 2011: The 7th International Symposium on Environmentally Conscious Design and Inverse Manufacturing. November 30 -December 2, 2011. Kyoto, Japan.

Shang, T-C., and Zhang, L-R. (2008). Energy Performance Contracting Project Evaluation and B-S Model. In Proceedings of the 4th International Conference on Wireless Communications, Networking and Mobile Computing. October 12-14, 2008. Dalian, China.

Shonder, J.A. and Hughes, P.J. (2005). Seeing Savings from an ESPC Project in Fort Polk's Utility Bills. ORNL/TM 2004/294, Oak Ridge National Laboratory. Oak Ridge, Tennessee, USA.

Shonder, J., Morofsky, E., Schmidt, F., Morck, O., and Himanen, M. (2010). Best Practice Guidelines for Using Energy Performance Contracts to Improve Government Buildings. IEA ECBCS Annex 46, International Energy Agency, Energy Conservation in Buildings and Community Systems Programme. Paris, France.

Silberman, A.P. (2010). Disputes and litigation of energy savings performance contracts. Construct! 19(1): 1, 10-13.

Smith, D.O. and Ferber, J.J. (1996). Performance contracting with state and local governments. Public Contract Law Journal 25(2): 393-422.

Strand, J. (2011). Rebound Effects with Emphasis on Long-Term Infrastructure Investments, and Their Interaction with Absolute (Ordinary) Rebound Effects. The World Bank. Washington, DC, USA.

Stuart, E., Larsen, P.H., Goldman, C.A., and Gilligan, D. (2013). Current size and remaining market potential of the U.S. energy service company industry. LBNL-6300E, Ernest Orlando Lawrence Berkeley National Laboratory. Berkeley, California, USA.

Stum, K. (2000). Commissioning in energy savings performance contracts. In Proceedings of the 2000 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Buildings. August 20-25, 2000. Pacific Grove, California, USA.

Subramanyan, H., Sawant, P.H., and Bhatt, V. (2012). Construction project risk assessment: development of model based on investigation of opinion of construction project experts from India. Journal of Construction Engineering and Management 138: 409-421.

Tah, J.H.M. and Carr, V. (2001). Knowledge-based approach to construction project risk management. Journal of Computing in Civil Engineering 15: 170-177.

Tah, J.H.M. and Carr, V. (2000). Information modelling for a construction project risk management system. Engineering, Construction and Architectural Management 7(2): 107-119.

Teddlie, C. and Yu, F. (2007). Mixed methods sampling: A typology with examples. Journal of Mixed Methods Research 2007 1: 77

Tetreault, T. and Regenthal, S. (2011). ESPC Overview: Cash Flows, Scenarios, and Associated Diagrams for Energy Savings Performance Contracts. Technical Report NREL/ TP-7A30-51398.

U.S. Department of Energy (2011a). Buildings Energy Data Book, Chapter 1: Buildings Sector. U.S. Department of Energy - Energy Efficiency & Renewable Energy. Washington, DC, USA.

U.S. Department of Energy (2011b). Buildings Energy Data Book, Chapter 3: Commercial Sector. U.S. Department of Energy - Energy Efficiency & Renewable Energy. Washington, DC, USA.

Vagias, W. M. (2006). Likert-type scale response anchors. Clemson University - Clemson International Institute for Tourism & Research Development, Department of Parks, Recreation and Tourism Management. Clemson, South Carolina, USA.

Walker, A. and Dominick, J. (2000). Performance contracting of a parabolic trough system at the Federal Correction Institution-Phoenix. In Proceedings of the 35th Intersociety Energy Conversion Engineering Conference and Exhibit. July 24-28, 2000. Las Vegas, Nevada, USA.

Wang, J. and Chen, X. (2008). Estimation of the risks of energy performance contract projects based on the unascertained measure model. In Proceedings of the IEEE International Conference on Automation and Logistics. September 1-3, 2008. Qingdao, China.

Ward, S.C. and Chapman, C.B. (1995). Risk-management perspective on the project lifecycle. International Journal of Project Management 13(3): 145-149.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access

Willis, K. (2008). How the "dirty dozen" ECMs created a need for a risk assessment tool. In Proceedings of the 2008 American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Buildings. August 17-22, 2008. Pacific Grove, California, USA.

Xiang, P., Zhou, J., Zhou, X., and Ye, K. (2012). Construction project risk management based on the view of asymmetric information. Journal of Construction Engineering and Management 138: 1303-1311.

Yousuf, M.I. (2007). Using experts' opinions through Delphi technique. Practical Assessment, Research & Evaluation 12(4): 1-8.

Zavadskas, E. K., Turskis, Z., and Tamosaitiene, J. (2010). Construction risk assessment of small scale objects by applying TOPSIS method with attributes values determined at intervals. Computer Modelling and New Technologies 12(4): 38–43.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-08-29 via free access