Financial Valuation for Commercial Energy Retrofits under Private Risks

Hyun Woo LEE, M.ASCE1, Kunhee Choi, A.M.ASCE2, John A. Gambatese, M.ASCE3, and Doyoon Kim4

1 Assistant Professor, School of Civil and Construction Engineering, Oregon State University, 220 Owen Hall, Corvallis, OR 97331; Phone (510) 715-0175; email: hw.chris.lee@oregonstate.edu
2 Assistant Professor, Department of Construction Science, Texas A&M University, 3137 TAMU, 429 Langford Bldg A, College Station, TX 77843-3137; (PH) (979) 458-4458; email: kchoi@tamu.edu
3 Professor, School of Civil and Construction Engineering, Oregon State University, 201B Kearney Hall, Corvallis, OR 97331; (PH) (541) 737-8913; email: john.gambatese@oregonstate.edu
4 Senior Sustainability Engineer, ASTAD Project Management, Al Dana Tower, Al Dafna, Doha, Qatar, PO Box 23242; (PH) +974 4425-8194; email: do.kim@astad.qa

ABSTRACT
Investments in commercial energy retrofits are exposed to unique types of risks that can be placed into two categories of risk: market risks (risks due to volatile market conditions) and private risks (risks due to volatile energy consumptions). By identifying such risks as a major contributor to the financial barrier, most studies to date have focused on market risks, yet these studies lacked consideration of the impact of private risks. In response, this paper aims to present a real options valuation (ROV) which aids in determining the financial impact of private risks on commercial energy retrofit investments. In particular, the study focuses on the valuation of phased investments in a large building portfolio under private risks that contribute to the option to defer (wait-and-see). The ROV adapts the binomial lattice method based on the level of volatility that is estimated using Monte Carlo simulation. The ROV results of the one-phase strategy are compared to those of the two-phase strategy in order to quantify the benefit of the increased managerial flexibility of the phased investments. The valuation presented in this paper is expected to help building owners and investors make better-informed decisions in commercial energy retrofits and, as a result, effectively overcome the financial barrier.

INTRODUCTION
In 2010, commercial buildings accounted for 45.3% of the primary energy consumed in the U.S. building sector, and 18.6% of the nation’s total consumption (DOE 2011). This makes the commercial building stocks a primary target in efforts to reduce greenhouse gas (Yudelson 2010). With the recognized importance of commercial energy retrofits, the U.S. government has launched a long-term initiative to reduce the energy consumption level of commercial buildings by 20%, by 2020 (The White House 2011).
However, investment decision making for commercial energy retrofits is adversely impacted by inherent risks related to expected energy saving benefits (IBEF 2011). The returns from the investments in commercial energy retrofits are realized by direct benefits from energy savings and indirect benefits (such as increased rents, increased building values, reduced vacancy rates, etc.; not the scope of this study). The direct benefits from energy savings are calculated by Equation 1, and are represented by $V$ in Equation 2.

\[
\text{Energy Saving} = \text{Energy Consumption Reduction} \times \text{Energy Unit Price}
\]  

(1)

Therefore, the returns of energy retrofit investments are affected by two types of volatility as follows, which are represented by $\sigma$ in Equation 3: Volatility around energy consumption reductions (private risks due to volatile energy consumptions), and volatility around energy unit prices (market risks due to volatile market conditions).

The limitations of traditional valuation methods such as discount cash flow or net present value (NPV) in evaluating such risks have motivated a number of studies to apply real options valuation (ROV) methods to energy efficiency (EE) investments in buildings (e.g., Kim et al. 2012; Menassa 2011; Van der Maaten 2010). However, previous studies have focused primarily on market risks and lacked consideration of the impact of private risks.

In response, the objective of this paper is to suggest an ROV for commercial energy retrofits by taking into account the private risks that stem from building operations. The ROV is then tested with an illustrative example of a subsidized investment in ten commercial buildings. The valuation combines a binomial lattice model for option pricing, with Monte Carlo simulation for volatility estimation of the private risks. The valuation specifically aims at determining the financial value of private risks, and assessing the impact of government subsidies that can offset the value of the option to defer (wait-and-see). The valuation can contribute to assessing the value of having managerial flexibilities (i.e., ability to adapt investment decisions to varying uncertain project environments as a project progresses) prior to the commencement of retrofit projects, and will therefore help building owners and decision-makers make better-informed decisions in EE investments.

REAL OPTIONS VALUATION

Traditional valuation methods such as discounted cash flow and NPV assume a constant risk profile over the project life (Triantis 2003), which can lead to the under- or over-valuation of the investment. Therefore, traditional methods have limitations in valuating EE investments under significant uncertainty (Menassa 2011). Alternatively, ROV has been suggested for determining the value of real investment options under uncertainty by applying the option pricing theory from finance. The options considered in ROV include expanding, phasing, abandoning, deferring, reducing, and so forth (Fichman et al. 2005), and ROV allows for determining the value of managerial flexibility by having such options.

NPV typically implies that the investment is viable when the present value of benefits ($V$) is greater than the initial investment ($I$). In contrast, the option value ($C$)
is considered in ROV when comparing $V$ to $I$. For example, in the case of considering an option to defer under significant uncertainty, ROV suggests investing when $V - I > C$, where $C$ represents the value of the option. Otherwise, project stakeholders are advised to defer their investment until $C$ becomes smaller than $V - I$. This condition means that when it comes to an EE investment under uncertainty, $C$ counteracts the owner’s commitment to make such an investment (Van der Maaten 2010), and accordingly contributes to the financial barrier. Therefore, Equation 2 represents the decision of the ROV for the option to defer, where inherent risks of EE investments are factored in to determine the investment payoff.

\[
\text{Investment Payoff} = V - I - C + S \quad (2)
\]

where $S$ is an investment incentive such as government subsidy, if any.

This study adapts the binomial lattice model developed in the study by Cox et al. (1979) to solve American options that are more applicable to ROV for energy retrofits than European options because American options can be exercised anytime. Investing in energy retrofits can also be regarded as a call option because an owner has the right to buy an asset [e.g., a package of energy efficiency measures (EEMs) in an energy retrofit] in contrast to a put option that represents the right to sell an asset (Menassa 2011; Van der Maaten 2010).

The adapted American call model consists of two steps: (1) creating a binomial lattice that represents the forward movement of the present value of energy savings, and (2) performing a backward calculation to determine the value of the option. First, the forward binomial lattice calculates the savings value movement by upward ($u$) and downward ($d$) factors, and the values are calculated to the option maturity. The value of energy savings can decrease or increase over each time period with respect to a probability of $p$ or $1 - p$, respectively. Adapted from Cox et al. (1979), Equations 3 and 4 present the formulas to compute $u$, $d$, and $p$:

\[
u = e^{\sigma \sqrt{\Delta T}} = 1 / d \quad (3)\]

\[
p = (e^{\Delta T} - d) / (u - d) \quad (4)
\]

where $\sigma$ is the volatility; $\Delta T = T/n$ is the time period of the lattice; $T$ is the time to maturity (e.g., the expiration of available subsidies); $n$ is the number of time periods; $p$ is the risk-neutral probability; and $r$ is the risk-free rate.

Second, a backward calculation starts with moving backward from the maturity. The option value ($C$) in each time period is determined by $C_u$ and $C_d$ in the following period using Equation 5 [Adapted from Cox et al. (1979)]. The calculations are repeated until the option value in the present is obtained.

\[
C = \max \left[ e^{-r \Delta T} (pC_u + (1 - p)C_d), V - I \right] \quad (5)
\]

where $V$ is the savings value at the specific node and $I$ is the initial retrofit investment.
MARKET RISKS VERSUS PRIVATE RISKS

Market risks stem from volatile market conditions (Chen et al. 2009) and are typically represented by the volatility estimated from historical market data (e.g., electricity price, oil price, carbon credit price, etc.). Particularly in commercial energy retrofit investments, the decision making directly relies on future market forecasts where an increase or decrease of the energy price will make EE investments more attractive or less attractive. That led most previous studies to focus on market risks as the main volatility factor in their ROV frameworks (to name a few, Kim et al. 2012; Reedman et al. 2006; Van der Maaten 2010).

In contrast to market risks, private risks represent project-specific risks (Mattar and Cheah 2006), a typical characteristic of technology-based investment (Chen et al. 2009) that includes commercial energy retrofits. Private risks in commercial energy retrofits pertain to the volatility around energy consumption reductions. They result from building operational factors such as weather, occupancy, technology, vacancy, and so forth. Only a few studies have investigated private risks in EE investments, but they have nevertheless indicated a significant magnitude of private risks. For example, a study done by Mathew et al. (2012) found that through the energy simulations of benchmarking buildings, varying operational practices are the biggest volatility source that can increase energy consumptions upwards of 80%. Another study by Torcellini et al. (2004) field-measured the actual energy savings of high performance buildings and found that the consumption rates of each building far exceeded their original estimates. The results of those studies suggest that private risks in EE investments are a significant volatility factor that contributes to the option to defer, and accordingly the financial barrier. This volatility factor has provided a motivation for the ROV study presented herein.

Volatility estimation of private risks

Despite their significance, private risks are very difficult to estimate due to the lack of historical data available to estimate the volatility parameter; hence they are often disregarded (Godinho 2006). In order to overcome the limitation, Herath and Park (2002) and Copeland and Antikarov (2001) suggested a Monte Carlo simulation-based method that the present study adapts to estimate annualized volatilities for the proposed ROV.

The simulation method suggests that the return on the underlying asset can be simulated at two different and independent points in time (Cobb and Charnes 2004), such as $PW_n$ and $MV_{n-1}$ in Equation 6. Then, the ratio of the two estimates becomes an estimate for the rate of return ($k$) in each simulation run, and the distribution of $k$ is created by combining the ratios from all simulation runs (Copeland and Antikarov 2001). Finally, the volatility is estimated by examining the standard deviation of the simulated distribution. Therefore, performing the simulation for a distribution of one-period returns can lead to estimating the volatility around the rate of return (Equation 7).

$$PW_n = \sum_{i=n}^{r} A_i e^{-k(t-n)} = (MV_{n-1})e^k$$ (6)
Risk-adjusted discount rates

In financial valuations of projects, it is important to consider a risk-adjusted discount rate (RADR) as a project-specific discount rate, because it represents the rate of return as well as the risk-adjusted cost of capital in project valuations (Farid et al. 1989; Ashuri et al. 2012). The two commonly used methods for determining a RADR are the Weighted Average Cost of Capital (WACC) method and the Capital Asset Pricing Model (CAPM) (Ashuri et al. 2012). These methods can be applied to calculate the present value of future benefits for both NPV and ROV valuations. This study adapts the WACC to determine a RADR, which is based on Equation 8 (Crundwell 2008):

\[ \text{RADR} = \text{Risk-free Rate} + \text{Company Risk Premium} + \text{Project Risk Premium} \] (8)

The following sections introduce an illustrative example and the results of sensitivity analyses to demonstrate the application of the proposed ROV.

ILLUSTRATIVE EXAMPLE

Suppose a business park has ten identical office buildings totaling 600,000 ft². The owner considers benefiting from an energy subsidy program established by the state government, which expires in one year. An EEM package of $200,000 construction cost is developed and is estimated to reduce the energy use intensity (EUI) by 3 kWh per ft² per annum. Electricity unit price is $0.15/kWh with a 2.5% increase each year. The estimated EUI reduction makes each building entitled to a one-time subsidy of $5,000. The investment period is set at 15 years with a continuous discount rate of 12% determined by Equation 8 with the risk-free rate of 2% plus a company risk premium of 5% and a project risk premium of 5%. As a result, the NPV is calculated at $53,588 (simple payback of 7.2 years) for the energy retrofit project of the ten buildings, which appears to be a financially sound investment proposition.

Suppose that three different operational practices are identified through energy simulations of the selected EEMs (Table 1). Depending on operational practices, the actual energy consumption can swing from lower bounds to upper bounds. For example, Practice 1 will result in consumption variations from 5% less than the original estimate (0%) to 25% more than the estimate. Energy simulations (such as EnergyPlus and eQuest) can be used to estimate the risk boundaries due to the varying operational practices after the retrofits. Using Equations 6 and 7, and assuming a PERT-Beta distribution for the private risks, Table 1 summarizes the magnitude of the private risks, and annualized volatility estimates for each practice.

| Table 1. Private Risk Boundaries due to Varying Operational Practices |
|------------------------|----------------|----------------|----------------|
| Variation              | Practice 1     | Practice 2     | Practice 3     |
| Upper bound            | 20% more       | 30% more       | 40% more       |
Using the annualized volatility estimates, the ROV can then be performed to compare the one-phase strategy versus the two-phase strategy. Unlike the one-phase strategy where a full-scale investment is made for the ten buildings at once, the two-phase strategy allows for testing the intended EEM package, as the first phase with a representative sample of the portfolio. Then, determining whether or not to make a full-scale investment for the second phase is based on whether the risk is deemed acceptable or reduced after the first phase (Ashuri et al. 2011). Therefore, the ROV suggests performing a two-step process in order to determine the financial impact of changed (preferably, reduced) private risks for the two-phase strategy.

For the illustrative example, suppose the owner decides to implement and test the selected EEMs only in three of her ten buildings for the first six months. Also, suppose the testing reveals that the upper bounds were overestimated and are accordingly reduced by half. Based on the results of the first phase, Table 2 summarizes the payoffs of the ROVs in the one-phase strategy versus the two-phase strategy using Equation 1. The results show that the two-phase strategy consistently indicates larger payoffs than the one-phase strategy due to the increased managerial flexibilities.

<table>
<thead>
<tr>
<th>Practice 1</th>
<th>Practice 2</th>
<th>Practice 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payoff of one-phase strategy</td>
<td>$8,966</td>
<td>$4,303</td>
</tr>
<tr>
<td>Payoff of two-phase strategy</td>
<td>$22,408</td>
<td>$20,091</td>
</tr>
</tbody>
</table>

Figure 1 summarizes the investment payoffs of different valuation approaches. As seen in Figure 1, the option to defer ($C$ in Equation 2; the differences between NPV and ROV values in Figure 1) due to the significant private risks significantly offsets the NPV, contributes to the financial barrier, and adversely impacts the owner’s commitment to make the investment. In contrast to the one-phase strategy, the two-phase strategy allows for mid-course corrections (Mun 2005), and contributes to offsetting the option value of deferring. Therefore, the two-phase ROV can lead to a commitment to earlier development, and hence contribute to overcoming the financial barrier.
SENSITIVITY ANALYSIS

The sensitivity analysis allows for the determination of how varying inputs and assumptions affect the results of ROV (Van der Maaten 2010). Examining the results from such sensitivity analysis helps reduce the chance of biased analysis and accordingly can support decision makers in making better-informed decisions. This paper presents two types of sensitivity analysis. First, the level of subsidies that compensate for the option value is investigated. Second, in order to determine the best combination for the two-phase strategy, different numbers of buildings in the first phase are examined.

Figure 2 illustrates the increasing trend of the payoffs from the one-phase strategy with respect to varying subsidies. Practice 3 requires a higher subsidy than Practice 1 for the same payoff due to its larger volatility. For example, when a subsidy of $5,000 is provided, the one-phase ROVs for both Practices 1 and 2 indicate positive payoffs, while Practice 3 still indicates a negative payoff.

Figure 3 summarizes the investment payoffs of five different scenarios for the number of buildings to be tested in the first phase. For example, if one building is to be tested, then the other nine buildings will be retrofitted in the second phase. The
results of the analysis show that selecting fewer buildings for testing leads to a higher payoff. Accordingly, the impact of a subsidy on offsetting the option to defer is diminished. In addition, the decreasing trend of Practice 3 is steeper than Practice 1 due to its larger volatility.

![Figure 3. Numbers of buildings versus investment payoffs of two-phase strategy](image)

CONCLUSION AND FUTURE RESEARCH

The commercial building sector accounts for a significant share of the primary energy consumption in the U.S., which makes the sector a primary target for reducing greenhouse gases. However, investing in commercial energy retrofits is a risky venture, which makes using traditional valuation methods undesirable. Alternatively, ROV methods have been suggested by a number of studies, yet they lacked consideration to determine the impact of private risks, which is a major source of volatility. In response, this paper presents an ROV specifically aimed at determining the financial value of private risks and assessing the impact of government subsidies that can offset the value of the option to defer. The ROV combined the binomial lattice model with Monte Carlo simulation, with the purpose of supporting the decision making for a portfolio of similar buildings. In order to support the comprehension of readers, an illustrative example of a subsidized investment in a ten-building retrofit project was introduced and the results were compared for the one-phase strategy versus the two-phase strategy.

The key findings include: (1) the two-phase ROV can support more realistic valuation than the traditional NPV or one-phase ROV, (2) the payoff of the two-phase strategy is higher than that of the one-phase strategy, and (3) more volatile operational practice (i.e., higher private risk) requires a larger government subsidy to compensate for the option value.

This paper presented the background and structure of the proposed ROV, which can help increase owners’ confidence to invest in energy retrofits by valuating the managerial flexibility associated with the strategy of phased investment. By examining different scenarios (such as the number of buildings, the level of subsidy, etc.) the proposed valuation can be used to support decision making in a subsidized EE investment. As a result, the ROV is expected to contribute to overcoming the financial barrier to commercial energy retrofits, by helping to valuate (1) the impact...
of private risks that contribute to the option to defer the investment, and (2) the benefit of the two-phase strategy that offsets the option value.

Further research should be conducted to expand the application of the proposed ROV, especially using a real case. Another study could be conducted to expand the application of the ROV and phased investment strategy to residential buildings, especially multifamily housing that shares similar system characteristics.

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REFERENCES


