The Investment Risk in Whole Building Energy-Efficiency Upgrade Projects

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ABSTRACT

The investment in whole building energy-efficiency upgrades is a business decision. Capital is invested to reduce building operating costs, and the investment is expected to produce positive cash flows. Managers compare the expected return on energy-efficiency upgrades investments to the returns to be earned from other investment opportunities competing for the organization's capital.

In addition to examining the relative returns on invested capital, managers also want to examine the investment risk. This risk-return relationship forms the basis of any investment decision, and while the process is well known for many investment opportunities, there is little information on the relative risk of investing in energy-efficiency projects.

This paper discusses the application of financial risk concepts to energy-efficiency upgrade projects. We believe that, by clarifying how financial risk measurements can be used in the energy-efficiency upgrade decision process, it will encourage managers to consider these investments with the other possible uses of their firm's capital.

Following an explanation of investment risk concepts and how they apply to the investment in whole building energy-efficiency upgrade projects, we present a simulation demonstrating the usefulness of evaluating investment risk in this context. Our example is in evaluating the commercial building energy-efficiency upgrade investment risk due to variability in underlying cash flow factors such as weather conditions. We calculate statistical measures of investment risk and compare the simulated risk-return estimate for these investments to the historical investment risk associated with selected stock and bond portfolios.

Introduction

This paper is based on Aspen Systems Corporation's work in support of the Environmental Protection Agency's (EPA) ENERGY STAR® Buildings and Green Lights Partnership[1]. The overall goal of ENERGY STAR Buildings and Green Lights is to increase the energy efficiency of commercial and industrial buildings in order to reduce the energy use and associated emissions of greenhouse gases and other pollutants. Organizations participating in these voluntary programs commit to invest in those energy-efficiency building design, technology, operations, and maintenance project that taken together meet a minimum investment criteria of a 20% internal rate of return, while maintaining or improving building occupant comfort levels.

[1] The research described here was funded wholly or in part by the United States Environmental Protection Agency under contract 68-W6-0032 to Aspen Systems Corporation. It has not been subject to the Agency's review and therefore does not necessarily reflect the views of the Agency, and no official endorsement should be inferred.

The economic and environmental justifications for investing in building energy efficiency are compelling. The energy to run commercial and industrial buildings costs about $100 billion every year, and produces 19% of US carbon dioxide emissions (DOE/EIA 1995). The US EPA estimates that if implemented nationally by 2010, ENERGY STAR Buildings and Green Lights could cut cumulative energy bills by $130 billion and reduce carbon dioxide emissions by the equivalent of eliminating 20 million automobiles from the highways (DOE/LBNL 1997). In order to compete for scarce capital against a wide variety of other potential investment opportunities, organizations need to understand, quantify, and be able to compare the investment return and investment risk of energy-efficiency projects. The purpose of this paper is to examine and begin to quantify the metrics necessary to make those investment decisions.

The financial risk of a building energy-efficiency upgrade project can be quantified as with other types of investments (e.g., stocks or bonds). This financial risk measurement, based upon the performance of actual projects, may be useful in convincing firms of the significant high-return and low-risk investment opportunities available in energy-efficiency upgrades. This paper begins with an introduction of terms used to characterize financial returns and financial risk and how these terms may be applied to building energy-efficiency upgrade projects[2]. We then present a model that examines the potential financial risk in a sample of whole building energy-efficiency upgrade projects, where the variability of simulated annual energy cost savings (a source of financial risk) is due to the variability of several potentially important underlying cash flow factors such as weather and energy prices. We end the paper with a summary of findings and suggestions for future research.

Definitions of Financial Return and Risk

The investment return for a stock, bond, or any investment of capital is the percentage gained or lost in the value of this investment over some period of time. Return can be measured in several ways. The total return on a stock, for example, is defined as the net change in the capital value of the stock, plus any dividends paid during the period, minus any sales charges, commissions, or other loads. Similarly, the return on investment for a piece of machinery is based on the value of the cash flows generated by this equipment over a time period, and can also be evaluated as a percentage of the initial investment. An investment in new equipment that reduces energy use in a facility will theoretically decrease facility operating costs, thus producing a positive cash flow, and the value of this cash flow over time can be used to calculate the investment return of an energy-efficiency upgrade project.

The decision to make an investment is based upon the expected or predicted cash flows coming from this capital investment and the risk of not actually generating the predicted cash flows. The standard deviation of the distribution of historical investment returns is a common measurement of a security's investment risk, and that is how we use it here, since it is frequently impossible to precisely predict how well an energy efficiency upgrade investment will perform. Similarly, we define risk as the variability in the expected investment returns[3]. The expected value of the returns is then presented as the weighted mean of this given range of possible values, and the variability of investment return refers to how much the actual annual returns may deviate from this expected value at any time. The risk of an investment in such financial instruments as stocks and bonds is commonly analyzed by

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[2] The authors wish to acknowledge the work of Thomas Yoder Ph.D. for initiating the research for this project, and Sud Associates and Energy Capital Partners for their data support.

[3] Many common indices of stock investment risk, such as the Sharpe or Treynor Index, use standard deviation in their calculations.

examining historical mean and standard deviation of actual returns.

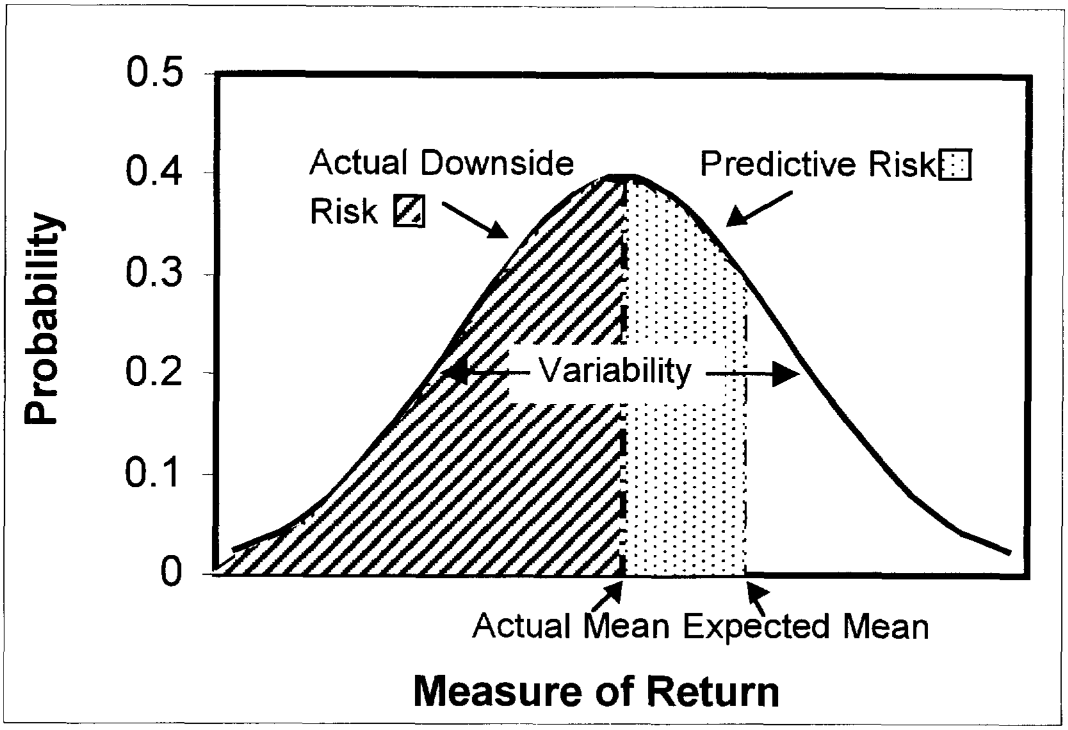

Figure 1: Actual vs. Expected Returns

For the purposes of energy-efficiency upgrade projects, investment risk is defined as the risk that the energy-efficiency upgrade will produce more or less than the expected return on investment. Downside risk refers to the probability that the actual investment return over a given period is less than the expected return. Downside risk may be especially important to firm-level investment decisions since in the decision processes of corporations contemplating ENERGY STAR Building (ESB) type upgrades, an individual suggesting to management a project estimated to produce a 20% return on investment is less concerned over the probability of a realized 35% return than he or she is of a 5% return on the use of this company's capital[4].

In this paper, we refer to risk as the total variability about the mean, both upside and downside. Figure 1 presents a hypothetical distribution of investment returns. This distribution has an actual mean and variability about the mean. If an individual overestimates the expected mean for this distribution, expected returns will likely not be realized, since the majority of the area beneath this distribution is to the left of the expected mean. This larger probability of seeing less-than-expected returns will be due to both what we will call the *actual downside risk* and the *predictive risk* caused by

[4] In this paper we focused on corporate risk.The related concepts of beta risk and the use of the Capital Assets Pricing Model (CAPM) to integrate energy-efficiency upgrade project investments into a firm's portfolio are important aspects of the firm-level investment decision and could be useful additions to this line of research. For a discussion of corporate versus beta risk see for example E.F. Brigham's *Fundamentals of Financial Management*, 3rd Edition, CBS College Publishing, 1983.

an erroneous estimation process.

The standard deviation of the distribution of actual (historical) returns over time is the parameter that forms the basis of most risk indices. A related measurement is the coefficient of variation (CV), which is the mean-normalized standard deviation of a distribution (the standard deviation divided by the distribution's mean $\left(\sigma/\mu\right)$). The CV offers a method of comparing the risk between distributions with different means, since it is a measurement of dispersion per unit. For example, consider two distributions with the same standard deviation, where one of the distributions (distribution A) has a mean over twice as large as the other (distribution B). The CVs for these distributions will be different, reflecting the proportionally higher risk of distribution B given its lower mean return. This is illustrated in Figure 2.

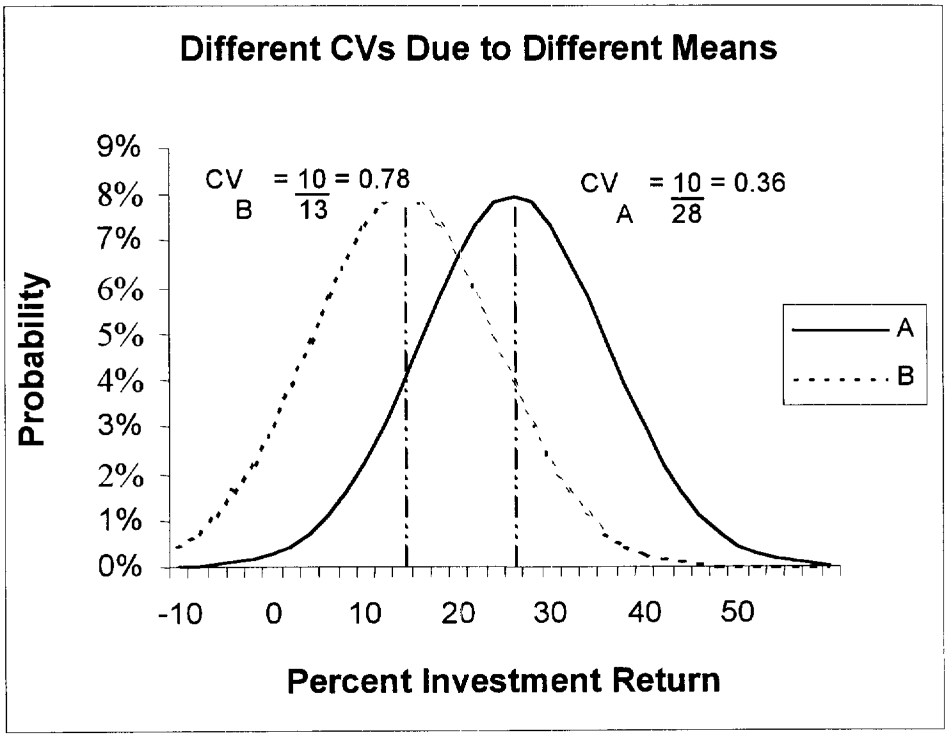

Figure 2: Different Coefficients of Variation (Risk) Due to Different Means (Returns)

Sources of Error in Predicting Building Energy-efficiency Retrofit Savings and Returns on Investment

There are two separate and distinct reasons why any energy-efficient building upgrade project may produce lower-than-expected returns. The first reason is that values of the underlying factors that affect cash flow are not known with certainty. Underlying factors are defined here as variables that affect the cash flow and consequently the return on investment. For energy-efficient building upgrades, these variables may include weather, energy prices, energy-efficient product failures, hours of operation, and maintenance expenses, among others. Since these factors are not known with certainty, an investment made based upon expected levels for these underlying factors may produce lower- or higher- than-expected returns if these factors take on unexpectedly low or high values.

The second reason for variability in expected returns is biases in the equation used to predict returns. Even if the expected values for the underlying factors actually occur, the investment return may vary from expected return due to a biased predictor. Biased predictions are of special concern for energy-efficiency upgrades because, unlike securities markets which base predicted returns on past performance, predicted returns on energy-efficiency upgrades are usually calculated based on engineering principles (such as energy audits) and expected values for the underlying factors. If, for example, the relationship between weather and energy savings is incorrectly specified, then even if the expected weather pattern occurs, the predicted return on the investment will not be realized.

Measurements of Investment Return

Internal Rate of Return (IRR) is the interest rate percentage that produces a net present value of zero when calculated for the expected stream of future costs and revenues. For the firm, an expected project IRR that is greater than this firm's hurdle rate (the minimum investment return necessary to entice the firm to invest) suggests that the project should be undertaken. The ENERGY STAR Buildings program participants agree to a project 10-year IRR hurdle rate of 20%, which is consistent with equipment operational lifetimes. The IRR is calculated for a given time span, and for a project with up-front costs and a fixed stream of positive cash flows (or savings) continuing for a number of years. While the longer the time span used in the calculation, the larger the value of IRR, this marginal increase rapidly diminishes.

Unlike simple payback, which is the ratio of first costs to annual returns and measures of how quickly initial project costs are recouped, IRR takes into account the long-term nature of energy-efficiency upgrade project benefits. For this reason, the ENERGY STAR Buildings Partnership uses this measure of financial effectiveness.

The Trade-Off Between Risk and Return

To the potential investor, investment risk and return are tied closely together. In order to be attractive to an investor, riskier projects must offer higher expected returns than less-risky alternatives. For the risk-adverse investor considering two possible investments offering the same predicted investment returns, the investment offering less risk will likely be preferable[5]. Other investors may be willing to tolerate more risk in order to achieve higher returns.

Measuring Investment Risk for Energy Efficient Building Upgrades

In financial markets, a frequency distribution of actual returns can be developed from a historical database, and the mean, standard deviation, and coefficient of variation (CV) parameters of this distribution provide information on the expected return and the riskiness of the investment. Assuming that the past is an accurate predictor of the future, the historical mean provides an unbiased predictor of the expected return. The tighter the distribution, the lower the CV and the less risky the investment since there is less chance the investment will show wide variations from the expected value (both upside and downside).

[5] Again, the type of risk and the CAPM may also factor into this decision.

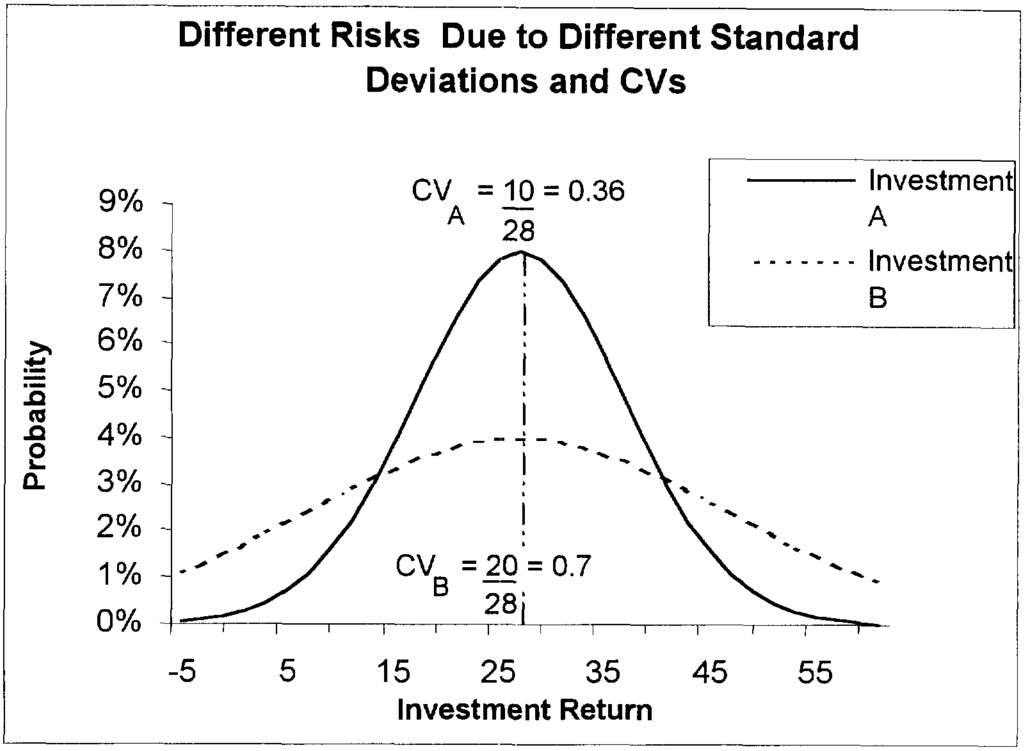

Figure 3: Increased Risk Due to Different Standard Deviations and CVs

For example, consider two investments, A and B, each offering an expected 28% return on investment. If investment A has a mean expected return of 28% with a standard deviation of 10% while investment B has the same mean expected return but with a standard deviation of 20%, investment B will be over 14 times more likely to produce negative returns (a loss) than will investment A, making it a more risky use of the firm's capital (see Figure 3).

To date, there is no systematically developed database of historical returns with which to estimate risk parameters for the energy-efficiency upgrade investment. This market is relatively immature and does not have a long history of projects to draw upon. To be comparable to financial and securities markets, similar measurements of investment risk and return should be available for energy-efficiency upgrade projects. For the firm making investment decisions on how to spend the organization's capital, the ability to compare investment return measurements based upon a large pool of historical project data may improve the credibility and stability of the energy-efficiency upgrade investment.

Assuming that a capital project was properly scoped and executed, the level of risk accompanying this project due to uncertainty about cash flow factors has two determinants: (1) the variability of the underlying factors that affect cash flow, and (2) the sensitivity of the return on investment to the variability of these factors. With the establishment of an industry database of actual energy-efficiency upgrade project returns, the effects of these two sources of variability could be examined. Actual returns could be compared to their predicted returns to produce information on systematic prediction bias. *If the predicted returns overstate the actual returns even when the expected values of the underlying cash flow factors are realized, then lower than expected returns are* *caused by biases in the prediction model.* Investigations into "realization rates," defined as the ratio of actual to predicted savings and returns, are the starting point for this type of measurement.

Identifying these prediction biases benefits both the potential investor and suppliers of energy-efficiency upgrade projects. Reducing prediction biases could reduce investment risk, which may entice a larger number of firms to invest in these upgrade projects. In addition, for the firm already willing to undertake these projects, greater confidence in their expected investment returns may lead these companies to invest in energy-efficiency upgrade projects with lower expected returns. To the firm selling energy-efficiency upgrades, the ability to more accurately estimate predicted investment returns benefits both parties. And to the investment market as a whole, lowering the level of investment risk to a value on par with other safe investments while showing investment returns superior to those of riskier alternatives would attract outside financing sources, which may lower borrowing costs.

In order to create this database, project-level information information will be needed, including building information, upgrades installed, all project costs, expected savings, and the actual annual energy cost savings for the duration of the project performance period. Since much of this information could be considered proprietary or confidential, the investment risk measurements and investment return distributions reported could be aggregated and reported as mean values similar to the reporting methodology used in the US DOE/EIA's Commercial Buildings Characteristics reports, which uses data collected in the Commercial Buildings Energy Consumption Survey (CBECS).

Besides confidentiality issues, there are a number of possible reasons why this database does not already exist. The marketing of whole-building energy-efficiency upgrades is relatively new, thus so is the concept of examining a historical database. It is possible that many energy service companies already collect and analyze a similar distribution of investment returns for their own projects, and it will only require a concensus that sharing this information will benefit all parties more than their share of the database development costs. Bringing such a database into existence could be facilitated by the involvement of interested parties, such as trade associations acting as a data clearinghouse, along the lines of the Association of Home Appliance Manufacturers (AHAM).

Simulating Investment Risk Due To Underlying Factor Variability in Energy-Efficiency Upgrade Projects

In order to evaluate the potential use of the proposed historical database in evaluating investment risk, we developed a simple model to simulate the variability of a number of underlying factors. Our goal was to examine the size of the combined influences of these factors upon annual energy cost savings in any year and over the performance period, and compare the simulated average investment risk CV measurement with those of other commonly held stock and bond indices. This exercise shows one type of analysis that will be possible using a historical database of actual projects.

We used data from 14 whole-building energy-efficiency upgrade projects from firms that chose to become Showcase projects of the US EPA ENERGY STAR Buildings program. As Showcase projects, the firms provided detailed project implementation information, including building characteristics, pre-upgrade energy use, investment costs, and first-year energy performance information.

Our simulation examined the combined variability introduced by several indentified underlying factors such as energy prices and weather. Other sources of variability and hence investment risk such as project scoping and execution were not addressed in this analysis. The reported first-year energy cost savings were used as the expected mean energy cost savings value (i.e., similar savings were assumed for all subsequent years of the projects' assumed 10 year life).

We modeled the buildings' actual energy cost savings as the expected savings level and the sum of a number of savings shifters which are based upon the particular values of the underlying factors:

$$\text{actual savings} = \text{expected savings} + \sum \text{underlying factor influences} .$$

Each underlying factor's influences may increase or decrease expected savings, and the sum of their effects becomes the difference between expected and actual energy cost savings for that simulated year. Ten years' simulated values were calculated to examine energy cost savings variability over the project life.

We modeled two types of functional relationships: additive (A) and proportional (P). Additive relationships are those where saving changes by some specific quantity, such as one cent per kilowatt hour. Proportional relationships are those where the percentage of total savings of that type varies in proportion with the percentage change in the underlying factor value. For example, if facility operating hours increased by 10% above the mean value, total energy cost savings is simulated to increase proportionally by 10% above its mean value.

The particular value of an underlying factor may have a positive or negative effect upon energy cost savings. A positive effect represents an increase in energy cost savings. Since this increase is in comparison to the energy costs that the building owners would have faced if the owner hadn't installed the energy-efficiency upgrades, increased energy cost savings are associated with higher levels of energy use and larger energy bills. This concept of larger energy bills in periods of higher levels of energy cost savings is an acknowledged difference between these investments and investments in more traditional financial instruments.

The type of functional relationship modeled for each underlying factor, and which types of energy cost savings are influenced by this factor, are shown in Table 1. For example, energy cost savings attributable to upgraded heating equipment was modeled as increasing proportionally (+P) with increased heating load requirements.

Table 1: Estimation Relationships for Upgrade Type and Underlying Factor

	Energy and Operating Cost Savings Attributed to:			
Underlying Factor	**Lighting Upgrades**	**Fans Upgrades**	**Cooling Upgrades**	**Heating Upgrades**
Heating Load				+P
Cooling Load			+P	
Maintenance Costs	-A	-A	-A	-A
Electricity Prices	+A	+A	+A	+A
Nat. Gas. Prices				+A
Operating Hours	+P	+P	+P	+P
Capacity Utilization	+P	+P	+P	+P

Key: A Additive
P Proportional
\+ Positive relationship
\- Negative relationship

As shown in Table 1, the magnitude of influence an underlying factor has upon overall annual energy cost savings has two components: the proportion of the overall project that this factor can influence, and the magnitude of the effect upon each upgrade type. Thus one factor which has a large influence upon only heating energy cost savings may have less of an overall impact upon project investment returns than another factor which has a smaller influence, but impacts all four types of upgrades.[6]

The 14 sample sites used in this simulation represent a variety of building types and sizes. The mean facility size was 224,242 square feet (std. dev. 233,090), and the mean reported upgrade costs were \$2.19 (std. dev. \$1.31). From the area-weighted averages for these sample projects, fans and heating represented approximately 13% of the pre-upgrade energy use, while cooling represented 30%. Using these proportions, an underlying factor which influences only cooling requirements can only affect up to 30% of total annual energy cost savings, while a factor influencing fans or heating can change total annual energy cost savings by up to 13%.

For proportional factors (heating degree days (HDD), cooling degree days (CDD), capacity utilization, and operating hours), the underlying factor's influence upon the expected annual savings level ($\Delta\text{Savings}$) was modeled as:

$$\Delta\text{Savings} = \left(100 * \left(\frac{\text{factor value}}{\text{mean factor value}}\right) - 100\right) * \left(\text{expected energy cost savings} * \textit{potential}\right)$$

where *potential* (coming from the sample proportions) is 0.30 for CDD, 0.13 for HDD, and 1 for capacity utilization or operating hours. For additive factors (maintenance expense, electricity prices, and natural gas prices), which influence all upgraded equipment, the influence of the underlying factor upon expected annual savings was modeled as:

$$\Delta\text{Savings} = (\text{factor value} - \text{mean factor value}) * \text{quantity used}$$ [7]

In order to simulate various combinations of the possible values for the underlying factors, the mean and standard deviations were calculated for the recent historical performance of the underlying factor. We assumed that these factors were independent of the others[8], with the exception of heating degree days (HDD) and cooling degree days (CDD), which were assumed to be correlated by their recent historical correlation coefficient. While a higher value for HDD could represent a colder winter of average duration, it could also signify a winter of average temperatures but of longer duration, and as a result a shorter cooling season.

Using the random number generator in SAS® version 6.12, we generated sets of simulated values for each of the underlying factors to create a simulation year. The positive or negative impact that each factor had upon annual savings was calculated, and the sum of these effects were used to increase or decrease the baseline savings estimation.

The simulation program generated 500 "simulation years" for each site, where for each year values for all underlying factors were generated. The values of these underlying factors influenced the site's predicted annual energy cost savings. Groups of ten of these simulation years were used to calculate the ten-year IRR for each site.

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[6] While not modeled, the existance of the upgrades may influence the magnitude and variability of the influence these underlying factors upon energy savings if occupant behavior changes. For example, lights may be left on for longer periods if the occupants of buildings with energy-efficient lighting feel less need to minimize their lighting energy use.

[7] We did not include a factor for the price elasticity of demand for energy for electricity or natural gas prices.

[8] Factor independence is, of course, a strong assumption, especially when one of these factors is energy prices.

Simulation Results

Across all of the sample sites, simulated annual savings per square foot had a mean of $0.47 and a standard deviation of $0.24, producing a mean CV of 0.52. Simulated values ranged from negative $0.45 to positive $1.32, with 99% of the observations showing positive savings values.

This relatively tight distribution is due in part to the tight distribution of the underlying factors. For any particular underlying factor, the year-to-year variation in its value tends to counteract itself over the time frame of the simulation, and in any particular simulation year, the positive and negative impacts of the various underlying factors tend to cancel each other out, reducing the overall impact upon baseline savings. This simulation shows that a site can still experience significant year-to-year fluctuations in its energy cost savings *due solely to the values that these underlying factors take on in any particular year*, with annual energy cost savings varying from one year to the next by $0.25 to $0.50 per square foot.

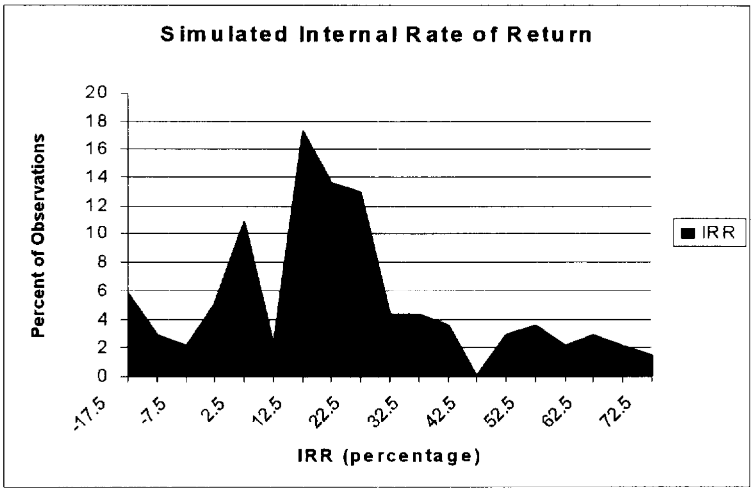

Figure 4: Simulated Internal Rate of Return

Across all sample sites, the mean of the simulated ten-year IRR observations was 20% with a standard deviation of 19%, producing a mean CV of 0.95. Values ranged from negative 50% to positive 77%, with 93 percent of the observations showing positive values. [9] The simulation also shows there is a downside risk in energy-efficiency investments (just like any other investment), with a 7% probability of actually losing money (a negative IRR).

A CV of 0.95 represents a relatively low level of variability for a distribution of investment earnings, as can be seen in Figure 5. In this chart the CV of investments in other types of common securities are compared to that of the simulated IRR of ENERGY STAR Buildings projects.

A larger sample of projects might change the position of whole-building energy efficiency upgrades on the risk-return graphic. However, it is instructive to see one type of analysis that an accurate tracking of whole building energy-efficiency upgrade project investment risk makes possible. As presented here, the investment risk for these projects offers investors seeking the investment

[9] One reason why this simulation produced a larger CV than that of savings per square foot is because IRR calculations include project upgrade costs, which appeared to be calculated differently in some of the projects. This is another issue which must be addressed in the development of a historical project database.

security of municipal and long-term bonds similar risk at higher returns. For the less risk-adverse investor, these projects offer superior returns to more risky finanical investments.

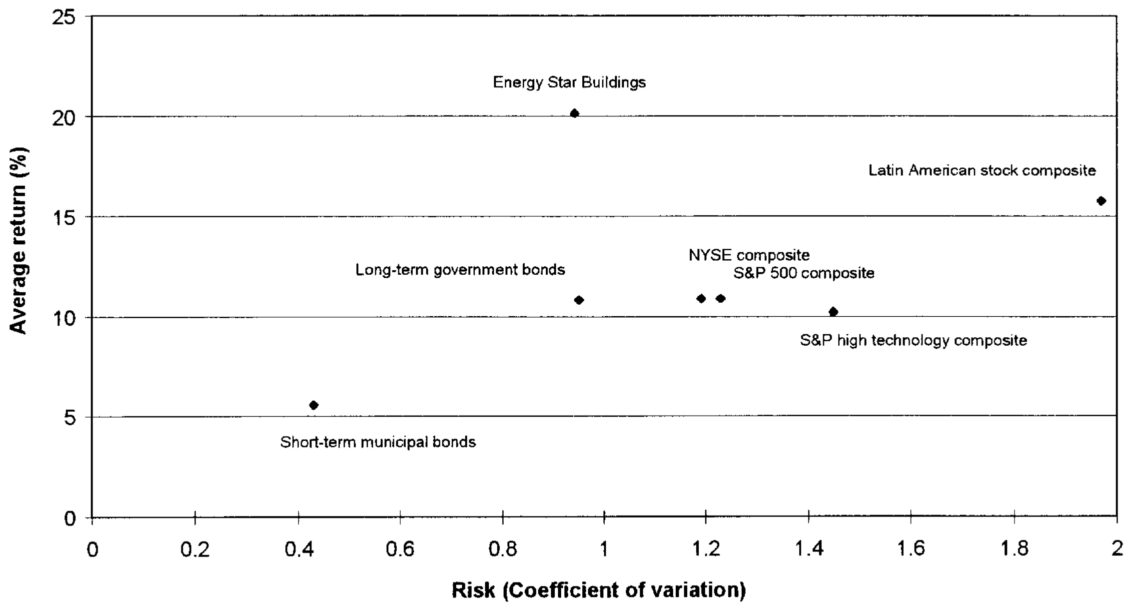

Figure 5: Comparison of Investment Risk Indices

Another example of how this information can be used is to compare the investment return for these buildings to average return on equity (ROE) metrics for the relevant industry. For example, a supermarket would compare the energy-efficiency upgrade investment producing a mean 20% IRR with the long-term (10 year) industry average return on equity (ROE) of 15.2% (Food Marketing Institute 1997). The performance of the mean upgrade (exceeding the industry ROE) coupled with the upgrade investment's relative low risk would generally indicate an attractive investment of the supermarket firm's capital.

Summary and Conclusion

This analysis suggests the following:

- While the creation of a database of historical energy-efficiency upgrade projects will require the collection of both engineering and financial data, the calculation of reliable estimates of investment risk will be beneficial to the further development of the building energy-efficiency upgrade market.
- The net effect of the underlying factors examined (weather, energy prices, operating hours, and capacity utilization) does not appear to significantly influence project annual savings. Over the course of the ten years their individual influences cancel out themselves and each other. *This implies that other areas, such as the pre-upgrade engineering analysis may be a key risk element in an energy-efficiency upgrade, as well as possibly occupant behavior and decisions relative to the building operation.*

- With a historical database of actual energy-efficiency upgrade projects, investment risk estimates may be refined.

This work on examining the investment risk of energy-efficiency upgrade projects could be extended in several useful ways. As previously stated, the development of a database of actual project histories, including investment costs, with follow-up data collection of actual energy cost savings for a number of years following project completion, will facilitate calculations of the actual investment risk. In addition, these risk calculations may include explicit estimations of investment risks for subcategories of energy-efficiency upgrades (such as lighting vs. chillers). Finally, the ability to factor out the biases caused by underlying factor variability may help to hone engineering approaches used to predict energy savings.

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