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Promoting energy efficiency investments with risk management decision tools

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ABSTRACT

This paper reviews current capital budgeting practices and their impact on energy efficiency investments. The prevalent use of short payback "rule-of-thumb" requirements to screen efficiency projects for risk is shown to bias investment choices towards "sure bet" investments bypassing many profitable efficiency investment options. A risk management investment strategy is presented as an alternative to risk avoidance practices applied with payback thresholds. The financial industry risk management tool Value-at-Risk is described and extended to provide an Energy-Budgets-at-Risk or EBaR risk management analysis to convey more accurate energy efficiency investment risk information. The paper concludes with recommendations to expand the use of Value-at-Risk-type energy efficiency analysis.

1. Introduction

Increasing economic stability, low interest rates, tax incentives, utility incentives, high energy prices and the certainty of future energy price increases would seem to set the stage for a considerable increase in energy efficiency investments over the next several years. However, if past experience is a guide, most cost-effective energy efficiency investment opportunities will be rejected in favor of other capital spending. The reluctance of firms to invest in energy efficient technologies has been recognized since the late 1970s and has been dubbed the "efficiency gap" or the "energy paradox" because firms appear to bypass profitable energy efficiency investments. In other words, firm reject investments that provide more in energy savings than they cost.

A variety of studies provide estimates of this unrealized energy efficiency potential, typically ranging from 15 to 25 percent for the US (Brown et al., 2001; Bresssand et al., 2007; Ehrhardt-Martinez and Laitner, 2008). Potential estimates are similar for other countries, for example the IEA's Cool Appliances study estimated a 24 percent potential in OECD residential electricity for 2010 (Guéret, 2005).

Why does the efficiency gap exist? A substantial body of literature has developed around the efficiency gap or energy paradox in the past quarter century. A variety of factors have been advanced to explain this phenomenon, well documented in DeCanio (1993), Sanstad and Howarth (1994), Brown et al. (2001), Schleich (2009) and Ansar and Sparks (2009). These factors include principal-agent issues that result in short-term managerial decisions, capital rationing, capital market imperfections, the irreversible nature of energy efficiency investments, bounded rationality, lack of information on equipment performance, energy price uncertainty, transactions costs and other factors.

The objective of this study is to consider current capital budgeting practices as a factor in explaining the efficiency gap and to identify an alternative capital budgeting decision process that can reduce the rejection of profitable projects. The next section reviews traditional capital budgeting approaches and evidence on investment decision-making behavior. A risk management strategy is presented in Section 4 as an alternative to risk avoidance practices currently achieved with payback thresholds. The financial industry risk management tool Value-at-Risk is presented and its application to energy efficiency investments is described. An example application is provided to illustrate the value of applying this risk management process to convey more accurate investment risk information to financial decision makers. The paper concludes with recommendations for expanding the use of Value-at-Risk based energy efficiency investment analysis.

2. Capital budgeting decisions

Energy efficiency investments are part of traditional firm level capital budgeting processes. Efficiency investments in commercial, institutional and government building typically include lighting, heating, ventilation, and air conditioning (HVAC) end uses as well as motors, reflective roofs and a variety of other

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applications. Efficiency selections are made during initial design of the building, when equipment wears out and is replaced, or during efficiency upgrades that can occur at any time.

Energy efficiency investments in industrial firms take two distinct forms. Significant changes in production technology and production processes occur as infrequently as a decade or more and are primarily driven by decisions related to technology changes, market demand and other longer-term strategic issues (Elliott et al., 2008). However, between major capital investments, manufacturing plants are often shut down for short periods for routine or emergency maintenance providing an opportunity to increase energy-efficiency of existing production lines and manufacturing processes. Examples of these operating and maintenance (O&M) investments include optimization of steam, compressed air and motor systems along with investments in more efficient end-use technologies such as lighting, HVAC, high efficiency boilers and so on.

Capital budgeting issues addressed in this paper are relevant to commercial, institutional and government building efficiency investments along with industrial O&M efficiency investments.

2.1. Investment analysis basics

Traditional capital budgeting investment decisions identify a profitable energy efficiency investment when the discounted sum of savings, S, is greater than the investment cost, I. This net present value (NPV) provides an estimate of the net financial benefit provided to the organization if this investment is undertaken. The NPV calculation is represented as

$$NPV = \sum_{t=1}^{T} S/(1+i)^t - I \qquad (1)$$

with an interest rate, i, and a technology life of T.

One can alternatively set NPV equal to zero, and solve for I to determine the internal rate of return (IRR) provided by an investment, I, that provides savings of S. If the IRR is greater than the cost of capital, the investment will be profitable. NPV is generally considered superior to IRR as an investment criterion primarily because IRR does not distinguish among projects where some of the cash flows are negative (Keat and Young, 2006; Ryan and Ryan, 2002). Since cost-effective energy efficiency investments typically provide only positive annual savings, NPV and IRR analysis are considered equivalent in this discussion.

Uncertainty associated with investment costs and benefits is incorporated by specifying expected values of investment cost, benefits and equipment lifetimes along with a risk factor, r, to reflect a risk premium associated with the investment:

$$E(NPV) = \sum_{t=1}^{E(T)} E(S)/(1+i+r)^t - E(I) \qquad (2)$$

Eq. (2) reveals a significant problem encountered in applying traditional investment theory to risky investments: the value of the variable r is difficult if not impossible for most financial decision makers to determine when considering energy efficiency investments. The standard recommendation concerning the specification of $i+r$ is to apply the rate of return for investments of similar risk; however, for non-financial investments such as energy efficiency, few comparable investments are available for comparison. The capital asset pricing model theoretically provides a process to determine the size of the risk factor; however, the required historical data is not likely to be available to estimate the nondiversifiable risk and the CAPM model does not account for the fact that efficiency investments cannot be sold once the investment is made (Golove and Eto, 1996). The reality is that no single satisfactory methodology exists to determine the appropriate risk-adjusted discount rate (Keat and Young, 2006).

In addition, the formulation in Eq. (2) does not provide the decision-maker with the probability of a "bad" investment outcome, a frequently used decision-maker characterization of investment risk (Petty et al., 1975; Lefly, 1997)

2.2. Investment analysis in practice

The literature on actual capital budgeting decision-making is extensive and based largely on surveys of corporate financial officers (CFOs). These survey data indicate that payback analysis is more frequently used than the standard net present value (NPV) or internal rate of return (IRR) analysis recommended by the financial academic community (Schall et al., 1978; Chen and Clark,1994; Lefley, 1994; Pike, 1996; Graham and Harvey, 2001; Ryan and Ryan, 2002; Sandahl and Sjogren, 2003; Berkovitch and Israel, 2004; Marino and Matusaka, 2005; Hynek and Janecek, 2005). Multiple investment criteria are used in most firms with IRR, NPV, and PB by far the three most-used analysis tools. Pike (1996) found only 4 percent of firms used one investment criteria with all four using PB. Twenty-eight percent used two investment criteria, 32 percent used three, and 36 percent used four criteria. Only 5 percent of the multicriteria firms did not use PB in their investment analysis. Ryan and Ryan (2002) found 75 percent of firms used NPV, IRR and PB while the Graham and Harvey (2001) survey data revealed that 90 percent of firms using either NPV or IRR also used PB for investment analysis.

While the recommended financial investment approaches of NPV and IRR analysis appear to be increasing over time (Pike, 1996; Ryan and Ryan, 2002), the role of PB does not appear to be diminishing in the capital budgeting process.

Payback (PB) analysis provides an easy-to-apply and intuitive decision process where investment cost is divided by annual savings to show the number of years required for the investment to pay for itself. Payback analysis, however, suffers from many well-known deficiencies as an investment analysis tool with the most obvious being the inability to distinguish between short- and long-lived investments. Firm level payback rules-of-thumb, by definition, use conservative assumptions to protect against "bad" decisions; otherwise, bad investments would be accepted. The result is that some investments that would have been identified as profitable with more detailed investment information are rejected with payback analysis.

Given the complexity of the energy efficiency investment environment described in the energy paradox literature, it is not surprising that most firms apply simple payback rule-of-thumb decision-rules to evaluate energy efficiency investments. This use of simplified decision rules is consistent with the concept of bounded rationality or satisficing behavior (Simon, 1955) and with Nelson and Winter's (1982) procedural rationality which explains firm level procedural rules as a mechanism to incorporate firm-level learning and decision-making continuity. Other behavior factors such as loss aversion where the prospect of a loss is weighted more heavily that the prospect of an equal gain (Kahneman and Tversky, 1979; Kahneman et al., 1991) likely impact the decision process at the individual agent level.

The relationship between payback and internal rate of return can be determined for any measure lifetime by setting NPV equal to zero in Eq. (1) and solving for I/S as

$$PB = I/S = \sum_{t=1}^{T} 1.0/(1+r)^t \qquad (3)$$

Given this relationship, it is possible for a firm to base its payback rule on a required IRR. For example, if a firm requires a 30 percent internal rate of return on its capital projects, the target payback is 3.1 years for an investment with a 10-year lifetime. Considering uncertainty associated with energy prices, equipment performance and other factors based on past experience, the firm might apply a subjective confidence interval, say ± 50 percent, around the expected annual savings to provide a payback threshold of about 2.0 years to insure against a bad outcome. A payback of 2.0 years is equivalent to a 50 percent IRR. If potential investments pass this 2.0 year payback threshold based on expected values associated with the investment, a more detailed NPV and/or IRR analysis can be undertaken.

This application of a low payback threshold to assess project risk is consistent with the accepted view that decision-makers use PB as a risk-assessment tool (Petty et al., 1975; Weingartner, 1969; Brigham, 1975; Fama, 1996; Kee and Bublitz, 1988; Pike and Ooi, 1988; and Yard, 2000). Survey results support the notion that payback is used as a risk screening tool. Lefley's (1994) survey found 71.5 percent of firms report the use PB to address investment risk while only 17.4 percent adjusted the discount rate for risk in NPV. The fact that most firms use multiple investment criteria and decision-makers identify PB as a risk screening tool suggests that PB is used in the manner suggested in the paragraph above, where a short PB estimate is a necessary condition for a project to be considered further in a multiple criteria process.

If the PB risk-screening threshold is short enough, further IRR analysis may be unnecessary, as expected values will provide a sufficiently large IRR to insure passing the IRR step. The present value (NPV) of the investment may still be important to assess to insure that the project provides sufficient financial benefits to cover management or overhead costs not considered in the efficiency investment analysis.

These investment analysis practices are consistent with the limited literature on energy efficiency investment decision-making. Ross (1986) reviewed energy efficiency investment decision-making for more than 400 energy efficiency projects at 12 large manufacturing firms and found PB applied to screen potential projects with more detailed financial analysis applied to projects that meet PB hurdle rates. Harris et al. (2000) found PB analysis used by 80 percent of Australian manufacturers with 50 percent using IRR and 30 percent using NPV. Anecdotal and case study evidence by Koomey (1990), Kulakowski (1999), Muller et al., (1995) and the US Department of Energy (1996) unanimously found short paybacks as a primary energy-efficiency investment evaluation criterion.

3. Moving from payback to risk management

Energy engineers traditionally develop estimates of initial costs, energy savings, operating costs and maintenance costs as "best estimates" or expected values for potential energy efficiency projects. High and low energy price cases and savings are sometimes provided to assess investment risk (Short et al., 1995; Environmental Protection Agency, 2004).

These data are sufficient to perform both payback and net present value analysis; however, as indicted in the previous section, the first step in most actual evaluation processes is to require the investment to meet a conservative payback threshold to avoid risky investments. Ross's (1986) study found only a limited number of profitable energy-efficiency investments passed the payback screening process. A study by Anderson and Newell (2002) of 9000 small to medium manufacturing firms found an average payback requirement of 1.29 years.

However, a potentially significant opportunity cost is associated with using rules-of-thumb designed to screen out risky projects. If payback analysis is applied to avoid investment risk using only the annual savings and investment cost, it cannot distinguish between shorter or longer lived investments nor can it distinguish between investments that are intrinsically more risky because of weather impacts or other factors that vary across investment options. To be effective at screening out bad investments, rule-of-thumb analysis must be based on conservative assumptions concerning lifetimes, and other characteristics that create uncertainty across individual investments. In other words, rules-of-thumb are developed using "worst-case" assumptions, which means that many investments the firm would have considered profitable are likely to be screened out as well.

This result is more pronounced when investment options are characterized by diverse lifetimes, operating characteristics diversity and other variables that create a larger variation in potential investment outcomes. For example, consider the example above where a firm requires a 30 percent internal rate of return on its capital projects, equivalent to a maximum target payback of 3.1 years. Uncertainty and a subjective confidence interval of ± 50 percent around the expected savings translated into a requirement to achieve a payback of about 2.0 years or less in order to insure against a bad outcome. However, a lighting retrofit project that involves very little savings uncertainty may have an estimated payback of 2.4 years (40 percent IRR) but virtually no chance of providing an actual payback worse than the maximum target of 3.1 years. In this case the lighting project would be rejected because its estimated payback is 2.4 years, greater than the 2.0 year threshold, even though there is no chance the actual payback will be greater than the required 3.1 years.

While decision-maker use of low payback hurdle rates is consistent with other factors associated with the efficiency gap, the fact that efficiency investment risk is not addressed in an explicit systematic way in most efficiency decision suggests that biased payback-based risk analysis plays at least some part in explaining the efficiency gap.

Compared to a payback risk-screening process, a more systematic management decision-oriented investment risk management analysis approach can better inform energy efficiency investment decisions.

4. Energy efficiency and risk management

The value of risk management in energy industry applications has long been recognized. Development of US wholesale electricity markets in the 1990s and the introduction of competitive electricity markets in various states beginning in the late 1990s significantly expanded the application of financial risk management tools to hedge against fuel and electricity price risk (Fusaro, 1998; Sadeghi and Shavvalpour, 2006; Deng, 2006).

Energy efficiency has been widely promoted as a risk management tool (Russell, 2005; Naumoff and Shipley, 2007); reducing energy costs reduces exposure to energy price volatility. Energy service contracts or performance contracts provide a vehicle for transferring risk from building owners to energy service companies; however, energy service companies have had relatively modest success as indicted by the sizeable efficiency gap that still exists (Goldman et al., 2005). Other means of risk transfer such as energy-savings insurance have been suggested as a traditional risk management tool that could potentially remove barriers to energy efficiency investments (Mills, 2003). An approach to actuarial pricing of energy efficiency projects, based in part on a system developed and applied at Enron has been suggested (Mathew et al., 2005). Mills et al. (2006) provide a wide ranging discussion concerning the analysis and management of risk associated with energy efficiency investments.

To date, however, no energy-efficiency risk management framework has been advanced to provide the intuitive appeal of the simple payback decision-variable along with a substantive investment risk evaluation. Such a framework could presumably provide the basis for building owners and their financial managers, energy engineers, energy service companies and financial institutions to view energy-efficiency projects and investments from a more common and accurate viewpoint.

Financial industry risk management has evolved over the past two decades to rely in large part on a statistic called Value-at-Risk (VaR) (Crouhy et al., 2006; Bernstein, 1996; Holton, 2002). VaR analysis provides an estimate of the greatest likely loss of a portfolio over some time period. VaR analysis applies historical stock prices, or other financial values, to calculate the probability of adverse impacts on the market value of a stock portfolio. VaR allows an analyst to focus on maximizing returns of the portfolio while protecting against the risk of losses. For example, a one-day VaR of one million dollars at a 95 percent confidence level means there is only a 5 percent probability that value of the stock portfolio will fall by more than one million dollars in one day. If the firm's risk management policy is to limit the portfolio VaR to no more than one million dollars, replace an existing under-performing stock in the portfolio with another stock is desirable if the expected return on the portfolio increases and the new portfolio VaR remains less than one million dollars.

The financial VaR application has been expanded by Jackson (2008) and applied for the first time to analyze risk and returns of energy efficiency investments with several "energy budgets at risk" or EBaR statistics. EbaR applies historical energy use data, weather data, engineering-based efficiency savings analysis and other factors to quantitatively determine the risk associated with any efficiency investment or menu of efficiency investments. For example, an energy efficiency investment with an IRR EbaR of *X* at the 97.5 confidence level means the probability that the investment actually achieves an IRR less than *X* is only 2.5 percent.

EBaR allows the analyst to maximize the net monthly savings, or increased cash flow, associated with efficiency investments while protecting against making investments that realize returns below an acceptable threshold. EBaR can incorporate all important sources of uncertainty surrounding energy efficiency investments and provide information on the distribution of expected savings with an explicit consideration of risk.

VaR has gained widespread acceptance in the financial industry because it provides a single, easily interpreted decision variable that directly measures risk.[1] EBaR or a similar VaR-based approach can provide a single, easily interpreted decision variable that directly measures risk in a much more efficient way than the single, easily interpreted simple decision variable payback now used by most organizations to account for risk.

[1] Value-at-Risk has its share of critics (Einhorn and Brown, 2008); however, the most serious criticism is not a serious issue for energy-efficiency investment applications. VaR analysis assumes normal market conditions; during the financial crisis 2007–2008, stock, interest rate and other financial variable volatility moved outside the bounds of "normal market conditions" resulting in underestimates of risk associated with most financial portfolios. Efforts to rebalance many of these portfolios were constrained by liquidity constraints that were exacerbated by shareholder withdrawals. With respect to energy efficiency investments, uncertainty surrounding weather, technology performance, and building operating characteristics is bounded by physical characteristics while fossil fuel energy price lower bounds can reasonably be estimated from historical periods where an excess supply of oil and natural gas limited prices to something close to the marginal cost of extraction, processing and delivery. Since fossil fuel costs account for only about one-third of electricity prices, fossil fuel price volatility has a smaller impact on electricity prices.

Short payback periods address risk by accepting only "sure bets," and, at the same time, reject some desirable investments while risk analysis allows the decision-maker to consider both investment returns and the associated risk of investments simultaneously.

5. If it's better, why Isn't it already used?

The implied hypothesis of the discussion in the previous section is that decision-makers have not yet learned of, recognized, nor accepted the value of energy efficiency investment risk analysis based on financial risk management principles. A counter argument is that the simplified decision process reflects a reasonable decision approach given the complexity involved in dealing with uncertainty, transaction costs, real options, and other factors and if risk analysis were a better approach firms would already be using it and that.

However, as illustrated in the next section, energy efficiency risk analysis is relatively easy to apply. In addition, unlike financial risk management analysis used by virtually every financial institution, many of the sources of uncertainty such as weather and operating characteristics are reasonably easy to quantify with acceptable accuracy.

The "if risk analysis were a better approach, most firms would already be using it" implies that changes can never occur. However, the evolution of financial industry quantitative risk management analysis practices provides a good example of the considerable lag in improvement in decision-making procedures relative to events that prompt that improvement.

The collapse of the Bretton Woods agreement in 1971 signaled the end of fixed international exchange rates significantly increasing foreign exchange rate volatility. The OPEC oil embargo in 1973 generated unprecedented energy price volatility while interest rates and prices exhibited greatly increased volatility beginning in the early 1970s. These events should have prompted almost immediate changes in traditional financial analysis to more adequately evaluate significantly increased financial investment risks. However, it was not until two decades later when JP Morgan began promoting Value-at-Risk (VaR) analysis through its RiskMetrics service in 1994, that quantitative risk management came to be viewed as an essential addition to traditional financial analysis (Bernstein, 1996).

VaR measures are now institutionalized through the US and internationally as part of the regulation of banks and other financial institutions. VaR is the most widely recognized class of risk management tools and is the subject of intense research efforts by private firms and the academic community (Holton, 2002). The two-decade lag between a need for quantitative financial risk analysis and its widespread application was not for lack of a conceptual framework because a seminal paper in 1952 by Nobel prize winner Harry Markowitz described a quantitative solution for developing an "efficient" portfolio that maximized returns subject to some level of risk (Markowitz, 1952).

While the hypothesis that decision-makers have not yet learned of, recognized nor accepted the value of energy efficiency investment risk is difficult to test, the historical development of financial industry risk management analysis suggests that this hypothesis is worthy of consideration in utility, state and federal government efforts to encourage greater investments in energy efficiency

The example in the next section illustrates an energy efficiency application of the Value-at-Risk analytical approach.

6. An energy efficiency investment risk analysis example

An engineering analysis of an efficiency investment specifies an investment cost, expected future energy use reductions associated with the investment, and future energy prices. Assuming average weather patterns, these variables are sufficient to calculate the internal rate of return (IRR) of the investment and, given an interest rate, to calculate the net present value (NPV). High and low assumptions on these variables are sometimes applied to provide some measure of risk associated with alternative outcomes.

Energy Budgets at Risk, or EbaR, analysis develops information on potential variations in each of these variables and applies them in a Monte Carlo analysis that incorporates all of the influences simultaneously to provide investment outcomes as a probability distribution of outcomes.

The example energy efficiency investment problem in this section is similar to the lighting and heating, ventilation and air conditioning (HVAC) options described in Jackson (2008); however, energy prices, weather data, energy uses have been modified to reflect a 120,000 square foot average US office building.

The building is a five story, office building built in the 1980s and has never been recommissioned or upgraded. Annual electricity use is 14.45 kWh/square foot and natural gas use is 90.38 kBtu/square foot with annual energy bills of $227,724 and $111,176 per year for electricity and natural gas respectively. Natural gas is used for space heating and water heating; electricity is used for other end uses.

The lighting upgrade includes replacing T12 lamp/ballast systems with super T8 lamp/electronic ballasts, and selected delampling, occupancy and day lighting controls and replacement of selected incandescent lamps with compact fluorescent lamps. The HVAC system is oversized and poorly designed for the current occupants and is to be remodeled to the extent possible and recommissioned. A building energy management control system is to be installed.

Estimated annual energy cost savings are $153,400 with installation costs of $325,000 providing a payback of 2.1 years. A summary of the efficiency investment results based on engineering data is shown in Table 1.

The payback of nearly 2.1 years is likely to disqualify this investment option even though it would reduce the building's annual energy costs by 45 percent. From the owner's perspective, the 2.1-year expected payback carries too great a possibility of realizing an unacceptable investment return. This evaluation would likely be the end of the story until investment options are considered in next year's budgeting process when the outcome would likely be the same.

An EBaR risk management analysis provides much more information on this investment opportunity, its risk and returns. Monte Carlo Analysis is applied to translate uncertainty surrounding investment characteristics into a distribution of investment outcomes as illustrated schematically in Fig. 1. Uncertainty surrounding electricity prices, natural gas prices, weather and operating performance is specified and the Monte Carlo analysis pulls a variable value from each distribution. Repeating this process many times provides a distribution of energy cost outcomes that reflect the probability distributions of the individual variables. In some cases the distributions are related, for example, in this case the variable value drawn from the natural gas distribution also helps determine the electricity price because natural gas is used as a generating fuel.

Table 1
Investment analysis summary.

Item	Value
Total investment cost	$325,000
Estimated energy cost savings	$153,400
Payback	2.1 years
Internal rate of return	46.1%
Net cash flow	$95,900

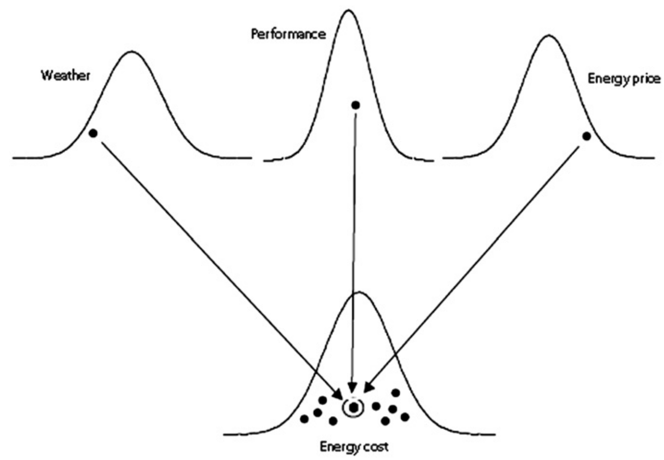

Fig. 1. Monte Carlo analysis.

Table 2
Sources of variation in energy-efficiency investment returns.

Variable	Source of mean and variance values
Natural gas price	Current US average price; no increase in price, range of likely values based on recent historical variation (approximately ±10 percent)
Electricity price	Current US average price; variation determined by statistical relationship as a function of natural gas prices
Efficiency technology operating performance	Expected savings based on manufacturer, ESCO, and energy manager evaluations; ±15 percent variation for lighting savings estimates and ±20 percent variation for HVAC savings estimates
Weather	Historical US average heating and cooling degree days with variance based on historical data
Heating and air conditioning energy use and peak loads	Normalized base year heating, ventilation and air conditioning energy use; weather-related variance based on statistical relationships estimated with regression of monthly energy use on weather data
Random	Statistical characterization based on historical variation in monthly energy use data that could not be explained by statistical weather variations

Monte Carlo analysis is a well-known analytic technique; consequently its application is not discussed in more detail other than to summarize development of the individual distributions in Table 2.

Distribution development in its simplest form reflects the selection of an expected value and an indication of the variance of the distribution which, in its simplest form, can be defined with relationships as simple as plus-or-minus 50 percent of the mean. Applying these relationships in the Monte Carlo Analysis provides a distribution of expected outcomes. However distributions and the explanation of probabilities as the area under the probability density function are not particularly user-friendly, consequently EbaR analysis summarizes the outcomes with selected IRR, net savings and energy cost statistics. Table 3 shows IRR and net savings, or increased cash flows, in a presentation format for the lighting and HVAC investment based on the distributions of price, weather and other variables described above. The 90 percent confidence level indicates that there is less than a 10 percent

Table 3
Efficiency investment program returns.

Confidence level (%)	Minimum IRR (%)	Minimum net savings
Expected	46.1	$95,900
90	39.5	$75,500
95	37.5	$69,600
97.50	36.2	$65,900

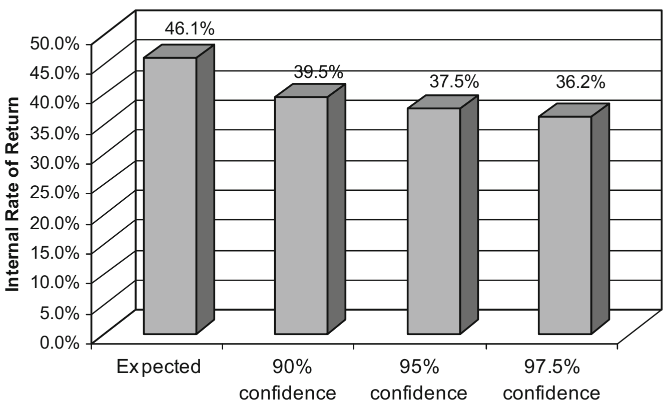

Fig. 2. Internal rate of return at different confidence levels.

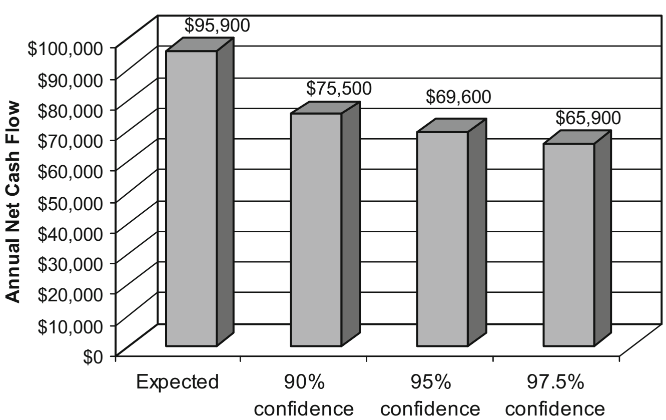

Fig. 3. Net savings at different confidence levels.

probability of achieving an IRR or net savings less than that value. Thus, based on the characterization of uncertainty described above, there is less than a 2.5 percent chance of achieving an IRR less than 36.2 or net savings (savings after subtracting financing costs) less than $65,000.

These results are presented graphically below in Figs. 2 and 3. The net savings column indicates that this investment will provide an expected increase of $95,900 in cash flow after financing costs have been deducted from annual energy bill savings. The expected IRR for this investment is 46.1 percent. Of greater interest is the fact that while the investment would have been rejected because the 2.1 year payback reflected an investment that was too risky, this investment actually has almost no probability of providing an IRR of less than 36.2 percent or net savings of less than $65,900.

If the IRR is greater than the cost of capital or the interest rate required to finance the investment, the efficiency projects reflects a profitable investment. Net savings reflect the profit associated with the investment and the increase in cash flow that results from a profitable investment if the investment is financed over its lifetime.

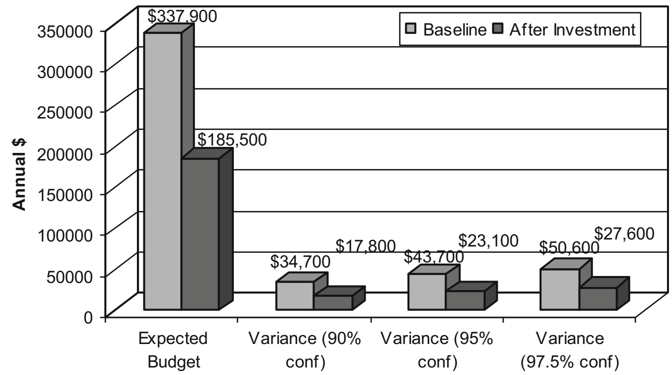

Fig. 4. Budget estimates at different confidence levels.

Fig. 4 shows annual energy cost distributions with a mean or expected annual cost of $337,900 with existing baseline systems and $185,500 after the efficiency investments. The expected values are the same as the engineering-based estimates however the figures show a range of possible outcomes and their associated probabilities. Uncertainty surrounding the weather, equipment performance and other variables results in uncertainty associated with energy costs both before and after the investments that result in budget variances or deviations from the expected budget. The expected budget and budget variances are considerably smaller after the efficiency investments are undertaken. In other words, in addition to reducing expected costs by $153,400, investing in the lighting and HVAC options reduces financial risks associated with annual energy budget variations.

Comparing traditional analysis results shown in Table 1 with the EbaR analysis presented in Table 3 and Figs. 2–4 illustrates the decision-making advantages associated with the Value-at-Risk-based analysis compared to the traditional engineering "best estimates." With the traditional analysis a best estimate of savings, payback, and internal rate of return are provided; however, no indication is provided on the probability of achieving less attractive returns if lower energy price, moderate weather or other factors result in less savings. Scenario analysis can be used where the engineer attempts to calculate savings in a series of worst-case scenarios. While scenario results are relatively easy to provide, determining the probability of a worst-case scenario is more difficult. The probability of multiple independent events is the product of their individual probabilities; consequently, if one selects a worst-case value for five factors that with an estimate likelihood of occurrence of 20 percent for each factor, the probability that all five events will occur at the same time is .032 percent, providing a much worse outcome than one would consider as a possibility. Without a systematic approach to evaluating the probability of alternative variable values, scenario results are difficult to incorporate in the decision-making process.

On the other hand, Value-at-Risk-based analysis provides the traditional expected investment outcome results along with the probability of achieving smaller internal rates of return, net savings and energy cost savings permitting the decision-maker to more intuitively evaluate the possibility of outcomes less attractive than the expected outcomes. That is, this approach allows the decision-maker to more intuitively evaluate the risk associated with the investment.

7. Stress testing

The Value-at-Risk-based analysis simultaneously reflects uncertainty surrounding all investment analysis variables including

Table 4
Worst case outcomes under alternative natural gas price forecasts.

	Baseline	−$1.00	−$2.00	−$3.00
IRR	36.2	32.9	29.4	25.8
Net savings ($)	65,900	55,900	45,900	35,800

energy prices, equipment operating characteristics, weather variations and so on. The characterization of this uncertainty is based on the best efforts of the analyst; however, a number of these inputs reflect assumptions that are themselves subject to uncertainty. While the analyst may feel confident that these specifications cover all likely outcomes with 95 percent confidence, or 97.5 percent confidence, financial decision-makers several management levels above may want to explore outcomes based on alternative assumptions concerning some of the basic investment problem specifications. For example, the chief financial officer (CFO) may feel comfortable with the analyst's characterizations of uncertainty surrounding weather, equipment operating characteristics and similar technical characterizations, but based on other information may want to explore the Value-at-Risk analysis results with the price of natural gas lower than the current estimate of $10.20/1000 Cubic Feet. Without additional analysis results reflecting these fundamentally different views of some of some the forecast variables, the analysis results presented in the previous section are likely to be significantly discounted to account for this unquantified additional source of investment decision-making risk.

Table 4 shows worst-case outcomes, that is values at the 97.5 percent confidence level, for IRR and Net Savings at the baseline natural gas price of $10.20/thousand cubic feet and at prices $1.00, $2.00 and $3.00 lower than the baseline. This assumption on future natural gas prices impacts investment returns both as a result of smaller avoided natural gas costs for space heating and as a result of smaller avoided lower electricity costs because of the relationship between natural gas prices and electricity prices. As indicated in Table 4, the reduction in natural gas price of $3.00, which represents a 29.4 percent decline, reduces worst case IRR by 28.7 percent and worst-case net savings by 45.7 percent; however the worst case IRR is still 25.8 percent.

This evaluation of alternative natural gas prices is an example of Value-at-Risk stress testing (Crouhy et al., 2006; Berry, 2009). Stress testing is the application of alternative scenarios to the Value-at-Risk analysis to identify sensitivity of the results to basic assumptions. Stress testing is an important part of establishing credibility of the Value-at-Risk analysis for decision-makers as suggested by the example above. Stress testing also provides greater insight on the nature of risks associated with the efficiency investment under consideration.

Stress testing includes evaluating the results of both small and large changes in assumptions used to define the basic Value-at-Risk analysis. Stress testing can be accomplished by modifying one or more than one assumptions at a time. One useful application is the reverse stress test where the question is how large a deviation in the investment characteristic is required to convert a good investment into a bad investment. For example, if the company considers an IRR of less than 20 percent to be unacceptable, how low would the price of natural gas have to drop to make this investment unacceptable? In this example analysis the answer is commercial customer natural gas prices would have to decline by 44.9 percent to $5.62/thousand cubic feet to yield an IRR of 19.9 percent, a US natural gas price not seen since 1999.

8. Promoting energy efficiency investment risk analysis

The example analysis presented above illustrates the value of applying a Value-at-Risk (VaR) analysis to energy efficiency investments. The fact that similar risk management tools have become an accepted part of financial industry investment analysis suggests that most businesses can utilize these tools to make better-informed decisions concerning energy efficiency investments.

Since this approach is not currently used, an important question is: what needs to change within traditional business decision-making processes to establish a VaR-based approach like EBaR as the preferred energy-efficiency investment decision-making tool in practice? There is something of a chicken-and-egg problem in changing current practices in that corporate financial decision-makers are unlikely to embrace the VaR approach because they lack technical understanding of energy efficiency investment options while energy engineers and facility managers who understand and appreciate the technical and cost savings aspects of alternative efficiency investments do not typically possess the financial analysis tools to undertake and present risk management analysis results to financial decision-makers.

Given the broad range of CFO financial responsibilities, it is unrealistic to expect financial decision makers to devote much, if any, time becoming educated on chiller upgrades, lighting retrofits and recommissioning, to name a few. It is incumbent on energy engineers, facility managers and related professional organizations to take the lead in promoting the translation of energy-efficiency project analysis into the kind of financial risk management language provided by VaR approaches.

Most energy engineers and facility managers will find this application of engineering-based results in financial analysis to be a relatively straightforward exercise as illustrated in Jackson (2008). Analysis of utility billing data, weather analysis, and Monte Carlo analysis are analysis areas that are often applied in current energy management activities or, in the case of Monte Carlo analysis, that apply a quantitative framework consistent with many engineering analyses.

Professional licensing agencies in states and other jurisdictions can require training in this area as part of their required continuing education course requirements. Professional organizations like the US Association of Energy Engineers (Association of Energy Engineers, 2010) that already provide energy manager certification should be encouraged to extend the traditional "engineering economics" approach to include the EBaR or similar analysis.

State and local licensing agencies can mandate similar educational requirements a prerequisite for license renewals.

Utilities, state, and federal agencies can play an important role in assisting businesses in transitioning from payback analysis to this more useful assessment of investment risk by requiring beneficiaries of financial incentives to qualify their investments using a Value-at-Risk analysis such as the EBaR process applied in this paper.

These same organizations can provide business customers who receive audits and investment assistance with similar risk management analysis providing a more comprehensive view of risk and rewards associated with alternative energy efficiency investments.

Energy costs are often a minor component of a facility owner's operating costs but a major source of budget risk. Labor, waste management, security and other expenses are reasonably easy to forecast and reducing service levels can mitigate unforeseen cost increases. However, energy costs can be volatile and are difficult to reduce to any great extent except through investments in energy efficiency. Consequently, energy costs reflect an important source of risk for individuals and financial organizations who invest in real estate. Both real estate investment firms and their investors can benefit from risk analysis using EBaR-type analysis.

Finally, state and federal governments can codify basic risk measures such as those illustrated in the example above and require their application at their own facilities to demonstrate the value of the additional investment information provided by EbaR-type analysis.

The policy initiatives suggested above are likely to prompt equipment and other energy service providers to offer energy risk management analysis as part of their services similar to their provision of energy-saving analysis for lighting, HVAC and other equipment.

Institutionalizing the practice of Value-at-Risk-based energy efficiency investment analysis through utility, government and energy service providers can help elevate efficiency investment decision-making to a more sound financial basis, reduce energy use, increase cash flows and contribute to environmental goals.

9. Securitizing energy efficiency Investments

Loans provided to firms and government agencies for energy efficiency investments can be bundled together and sold as new securities in financial markets. The returns on the new securities are provided by payments on the loans available from the energy efficiency net savings. This securitization of energy efficiency loans can potentially provide a flow of capital in the market for energy efficiency investments not previously available.

The Value-at-Risk analysis framework presented in this study provides a well accepted financial analysis framework for facilitating securitization of energy efficiency investments because it provides a direct translation from the engineering characterizations of energy efficiency investments to the financial analysis and risk measures required for securitization. Unlike the mortgage-backed securities that created the financial crisis of 2008, risk associated with efficiency investment-backed securities can be quantitatively measured and represented with VaR-based analysis providing the improved risk transparency that will be required of future securitizations.

This investment transparency and the promotion of energy-efficiency investments through securitization is especially important in the current financial situation where investment risk and capital shortages have limited funds available for energy efficiency investments. In the case of profitable energy efficiency investments identified in VaR-based analysis, these loans permit borrowers to reduce energy costs by an amount greater than the amortized loan costs, increasing business cash flows and improving the credit worthiness of borrowers.

This securitzation process is especially important in developing countries where capital availability is a significant constraint in achieving greater energy efficiency, reducing energy costs and reducing carbon emissions. A standardized EbaR-type analysis can significantly assist lenders in assessing risk by providing technical analysis for a predetermined set of investment options, limiting the technical expertise required of lenders.

10. Summary and conclusion

This paper reviews current capital budgeting practices to develop a better understanding of the processes applied in energy efficiency investment decisions. These studies indicate that financial decision makers typically use payback analysis to screen investments for risk with projects that pass the initial screening evaluated with more traditional financial analysis methods such as net present value and internal rate of return analysis.

The prevalent practice of screening energy efficiency investment projects with short payback hurdle rates to screen out risky projects results in potentially significant opportunity costs. To be effective, rules-of-thumb are developed using "worst-case" assumptions, which means that many investments the firm would have considered profitable are likely to be screened out as well.

The financial risk management tool Value-at-Risk is described and a new energy efficiency risk management application called Energy Budgets at Risk (EBaR) is presented as a framework for presenting efficiency project risk and return analysis to financial decision-makers. An example application using the EBaR process demonstrates the value of providing energy efficiency project risk analysis along with traditional engineering project presentations.

The paper recommends incorporating Value-at-Risk-type energy efficiency analysis in utility, state and federal incentive programs and in government energy efficiency projects, through profession organizations, licensing requirements and other channels to elevate efficiency investment decision-making to a more sound financial basis, reduce energy use, increase cash flows and contribute to environmental goals.

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