Selling Energy Efficiency:
The Energy Engineer as Investment Advisor

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ABSTRACT

This article evaluates the energy efficiency investment decision-making used by most organizations. A financial risk management process is shown to provide greater financial returns and less risk in selecting investment projects compared to the traditional practice of payback analysis. An example application of *Energy Budgets at Risk*, a value-at-risk-based energy efficiency investment analysis, is presented to illustrate the advantages of risk management analysis in evaluating energy efficiency projects. Summary risk analysis results are presented as a communication bridge between technical project engineers, chief financial officers, and other financial executives and decision-makers. The article concludes with the suggestion to expand the traditional roles of energy engineers and managers to include providing energy efficiency and budget financial risk management analysis.

INTRODUCTION

Though lower than their peak in 2008, commercial and industrial firms face energy prices that are high by historical standards. For example, US commercial sector electricity prices are 31% higher than their 2000 levels while natural gas and oil prices are 51% and 66% greater, respectively (US Department of Energy, 2010). In spite of the current economic recession, oil prices still hover around $70/barrel, more than three times their two-decade average prior to 2000.

While some excess oil supply capacity exists because of the economic downturn, strong developing-country demand growth and the emergence of developed countries from the recession over the next several years will undoubtedly send oil prices higher, followed closely by

natural gas prices. Electricity prices will increase as the cost of generation fuels increases. Additional upward pressure on electricity prices exists because of regulatory decisions and overdue infrastructure investments. For example, electric utility customers are facing price increases of as much as 30% in Pennsylvania as price freezes associated with competition are removed, while some utility customers like those in the Duke Energy Indiana service area surrounding Indianapolis are facing price increases of 20% to pay for new generating capacity.

Federal and state tax incentives and utility incentives, along with high energy prices, continued economic growth, and low interest rates would seem to set the stage for significant increases in energy efficiency investments.

However, if the past is prelude to the future, most cost effective energy efficiency investment opportunities will be rejected in favor of other capital spending. This reluctance to invest in energy efficient technology has been recognized since the late 1970s and has been dubbed the "efficiency gap," or the "energy paradox," because firms appear to be bypassing profitable energy efficiency investments.

The efficiency gap has been publicized in recent studies, such as the widely referenced McKenzie reports (Bressand, 2007), and by public interest groups like the ACEEE (Ehrhardt-Martinez and Laitner, 2008). The literature in this area indicates that current energy use can be reduced by as much as 25% with cost effective energy efficiency investments.

More detailed end-use studies confirm these results. For example, a US Department of Energy study (2002) of industrial motor energy use estimated potential savings of 11-18% if firms were to accept paybacks of three years, consistent with an observed discount rate of approximately 30%. Koomy, et al. (1996) reported that most firms bypass efficient fluorescent ballast choices that provide paybacks of less than two years, equivalent to a discount rate of about 50%. Anderson and Newell (2002) analyzed information on detailed efficiency investments of more than 9,000 small and medium manufacturing firms and found that projects with paybacks with an average of greater than 1.29 years were rejected.

The required short paybacks imply extremely high internal rates of return (IRR) thresholds for energy efficiency projects, where the IRR is the implicit return on the efficiency investment determined by the annual savings. Table 1 shows the relationship between annual savings, payback, and the internal rate of return for an investment with a ten

year lifetime. The Anderson and Newell finding of a 1.29-year payback is consistent with an 80% IRR.

Table 1. Payback and Discount Rate Correspondence

Annual Savings for $1,000 Investment	Payback (PB, years)	Internal Rate of Return (%)
800	1.25	80
508	1.97	50
415	2.41	40
324	3.09	30
239	4.19	20
163	6.14	10

If an organization can borrow money at a rate of 10% and can achieve an IRR of 80%, it will make a profit of 70% on its investment. Bypassing this level of investment return does indeed appear to be a paradox.

Why does the efficiency gap exist? A variety of factors have been identified over the past two decades, including short-term managerial decisions, capital rationing, lack of information on equipment performance, energy price uncertainty, transactions costs, and other factors. This literature is documented by DeCanio (1993), Sunstad and Howarth (1994), Brown (2001), and Ansar and Sparks (2009).

One issue that has received little attention is the actual practice of capital budgeting that occurs in organizations. This article reviews current capital budgeting practices and identifies the prevalent use of low payback "rules of thumb" to screen projects for risk as a significant problem in promoting energy efficiency investment projects. A risk management strategy is presented as an alternative to risk screening currently achieved with short payback thresholds. The financial industry risk management tool *Value-At-Risk* (VaR) is described, as well as a new application to energy efficiency investments, Energy Budgets at Risk (EbaR) is illustrated with an example. The example demonstrates the value of applying this risk management process to translate engineering information on an energy efficiency investment into financial analysis and decision-variables useful to financial decision makers.

ENERGY EFFICIENCY INVESTMENT DECISION-MAKING

Capital budgeting is the planning process used to determine which long-term investment projects will be undertaken. Traditional investment theory defines a profitable investment as one with a positive net present value (NPV), where:

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

S is annual savings, i is a risk free interest rate, T is the life of the energy efficiency technology, and I is the initial investment cost. Alternatively, one can set NPV equal to zero, solve for *i*, and compare this internal rate of return (IRR) to the cost of capital.

Uncertainty is a problem in applying this traditional investment approach, because actual annual savings, equipment lifetime, and even the initial investment cost are subject to uncertainty. The traditional approach is to use expected values for T, S, and I and to add a risk premium to the interest rate. Increasing the size of i reduces future financial benefits associated with the investment; the greater the risk, the less weight expected future savings has in the investment analysis.

The problem in applying this traditional financial capital budgeting analysis arises in determining the appropriate value for the risk premium. While some methods such as the capital asset pricing model (CAPM) are used in financial portfolio applications, the lack of appropriate historical data required for this computation and the fact that energy efficiency investments have to be "held," unlike stocks in a portfolio, make application of these quantitative efforts to determine the appropriate risk premium questionable in energy efficiency investment analysis (Golove and Eto, 1996).

How do decision makers identify attractive capital budgeting projects? A variety of survey results reveal decision-making processes that differ from the standard net present value analysis recommended by the academic community. These data on actual capital budging decisions identify payback as a primary financial evaluation tool.

Schall, et. al (1978), Chen and Clark (1994), Lefley (1994), Pike (1996), Graham and Harvey (2001), Ryan and Ryan (2002), and Hyneck and Janecek (2005) report payback (PB) used as a primary capital bud-

geting investment tool in 56-94% of firms. Most firms use more than one investment criteria, with internal rate of return PB, IRR ,and NPV being the three most frequently used analysis tools. Pike (1996) found only 96% of firms using more than one investment criteria, with only 5% of those firms omitting PB from their investment analysis.
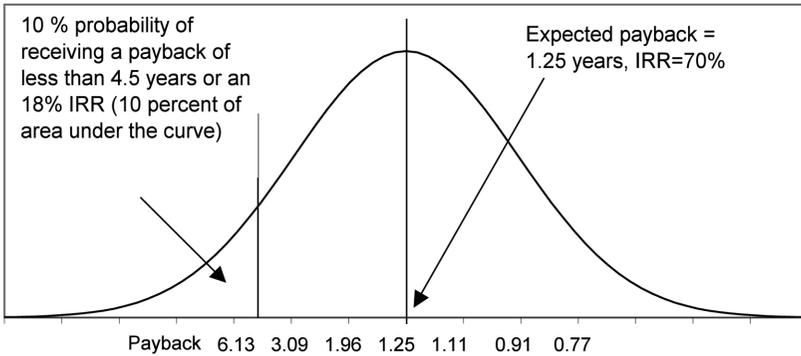
This literature shows that decision-makers use PB as a risk-assessment tool (Petty, et al., 1975; Weingartner, 1969; Brigham, 1975; Fama, 1996; Kee and Bublitz, 1988; Pike and Ooi, 1988; and Yard, 2000). For example, Leftley (1994) reported that 71.5% of firms report the use PB to address investment risk. Short payback periods reduce risk by definition because they limit the time periods to the near future where energy prices and other factors are more certain.

Evidence on decision-maker behavior specific to energy efficiency investments is limited. Ross's (1986) detailed 1982 surveys of twelve large manufacturing firms reviewed decision-making for more than 400 energy efficiency projects. The study found that PB used to screen potential projects with more detailed financial analysis applied to projects that pass the PB screening. Harris, et. al. (2000) reported 80% of Australian manufacturers used PB analysis, 50% used IRR, and 30% used NPV. Case study results and anecdotal reports (Koomey,1990; Kulakowski, 1999; Muller, et al., 1995; US Department of Energy, 1996) identify short paybacks as a primary energy efficiency investment requirement.

From a management perspective there is significant value in using a simple, intuitive, and easy-to-apply decision rule such as payback to screen out risky projects. If a payback requirement can be reasonably related to the organization's IRR while also considering investment uncertainty, then payback can potentially serve as a good proxy for an IRR or NPV analysis. Projects that pass the payback screening can then, as Ross found, be evaluated with more detailed analysis.

The relationship between investment risk and a payback decision rule is illustrated in Figure 1, using a 15-month payback criterion similar to that reported in the quoted Anderson and Newell study. The figure shows a distribution of investment outcomes. A distribution is appropriate because uncertainty surrounding energy prices, operating hours, equipment performance, and other factors creates a distribution of likely investment outcomes. The mean or expected investment payback is 15 months or 1.25 years. If risk is defined as the probability of an unacceptable outcome (Petty, 1975; Lefley, 1997)—in this example the probability of realizing a payback of less than 4.5 years—a rule that requires the

expected energy savings to provide a payback of 1.25 years is equivalent to a rule that requires investments to have less than a 10% probability of achieving an IRR less than 18% and a payback less than 4.5 years.

10 % probability of receiving a payback of less than 4.5 years or an 18% IRR (10 percent of area under the curve)

Expected payback = 1.25 years, IRR=70%

Payback   6.13   3.09   1.96   1.25   1.11   0.91   0.77

Figure 1. Payback Limits Investment Risk

It is easy to see from Figure 1 why using short paybacks are attractive as a simplified management tool to limit investment risks. The expected payback is easy to calculate and, as long as the investment lifetimes and distribution of returns are the same for all potential investments, a payback rule is an easy way to avoid risk, in this case realizing a payback of less than 4.5 years or an internal rate of return (IRR) of 18%. Internal rates of return are a more traditional financial criterion; however, the payback rule, *under these assumptions*, provides a perfect proxy for traditional IRR measures.

The problem in using payback to screen out risky investments is that to be effective the rules must be defined with a worst-case scenario; otherwise, risky investments will slip through the process. Any efficiency investment with less uncertainty over performance, operating hours, or any of the other variables will be summarily rejected even though it may actually meet the risk tolerance objectives of, in this case, providing less than a 10% probability of achieving an IRR of less than 18%.

Payback rules also break down for investments with longer lifetimes than the standard, since there is no way of capturing benefits of longer streams of energy cost savings with payback analysis. Any investment that provides returns over a longer period than what is used to develop the initial payback rule may be inadvertently rejected.

The costs of bypassed efficiency investments caused by conser-

vative payback requirements are considerable. In addition to creating unnecessary carbon emissions and overusing scarce energy resources, individual firms, institutions, and government agencies are foregoing increases in cash flow, because annual energy costs savings are greater than annualized investment costs as long as the IRR is greater than the cost of capital.

The following section translates the energy efficiency investment decision process into a portfolio management problem to illustrate how modern financial risk management principals can be applied to energy efficiency analysis to resolve difficulties presented by payback analysis.

ENERGY EFFICIENCY INVESTMENTS AS A FINANCIAL ANALYSIS PROBLEM

Risk associated with financial investments has increased significantly over the last several decades because of volatility in international exchange rates, commodity prices, interest rates, and geopolitical events. Financial markets have developed an impressive array of instruments that investors use to hedge these risks, including financial futures contracts, options contracts, and other contractual arrangements that limit the impact of adverse price movements. The recent crises created by subprime mortgage-backed securities reveals the kind of chaos that can result when proper risk management tools are not used to evaluate investments.

Investment portfolio management has evolved to accommodate increased investment risks; financial portfolio managers depend heavily on an array of quantitative tools to assess risks and returns associated with portfolios and to evaluate the benefits of including new investments in existing portfolios. The most widely used quantitative tool is "value at risk," or VaR, which measures the probability that portfolio losses over some period will exceed a set amount at a predetermined confidence level. A daily VaR of $10 million at a 95% confidence level means the probability that the portfolio will lose more than $10 million in a day is less than 5%. VaR statistics are calculated using historical data on returns of the individual stocks or other financial investments in the portfolio. Calculating a VaR for alternative portfolio holdings permits financial analysts to select individual stocks that maximize returns on the portfolio while limiting the risk of losses to that specified by a maximum VaR value.

Managing energy budget and investment risk can be viewed as a process similar in many ways to managing financial portfolio and investment risk. Each energy-using component in a building's energy budget portfolio can be considered a separate investment. Energy budget variance, or the amount by which actual costs will exceed the budgeted amount, reflects energy budget risk. Energy Budgets at Risk, or EBaR®, (Jackson, 2008) extends and applies VaR concepts to define energy budgeting and efficiency investment analysis within a quantitative risk management framework. Not only has the framework for these analytical applications been vetted in the international financial community, their application provides a set of simple decision variables comparable to the decision-making simplicity of payback analysis.

The correspondence of VaR and EBaR analysis is illustrated in Figure 2, where risk associated with a stock portfolio and an energy equipment portfolio are quantified. The expected energy budget and the probability that actual energy costs will exceed the budget (the budget variance) are specified in the same way in which portfolio losses are specified in VaR analysis.

AN EXAMPLE OF ENERGY BUDGETS AT RISK (EBaR)
INVESTMENT ANALYSIS

Figure 2 illustrates the application of EBaR budget analysis to evaluate energy budget risk or risk of exceeding a given budget variance. A more important application with respect to efficiency programs is EBaR investment risk analysis. As indicated in Figure 1, energy efficiency investment risk can be measured by the probability that the investment will fail to meet a critical investment return threshold. Risk tolerance is measured by the organization's maximum acceptable probability of a "bad" outcome. Every potential efficiency investment reflects a distribution of outcomes created by uncertainty associated with future energy prices, weather, operating characteristics, etc.

Energy efficiency investment decision variables are derived from distributions of investment returns and net savings (energy costs savings beyond the annualized cost of the equipment). EBaR investment analysis provides two decision variables based on these distributions.

EBaRirr,x is an investment form of the EBaR statistic showing the smallest expected investment internal rate of return (IRR) at a given con-
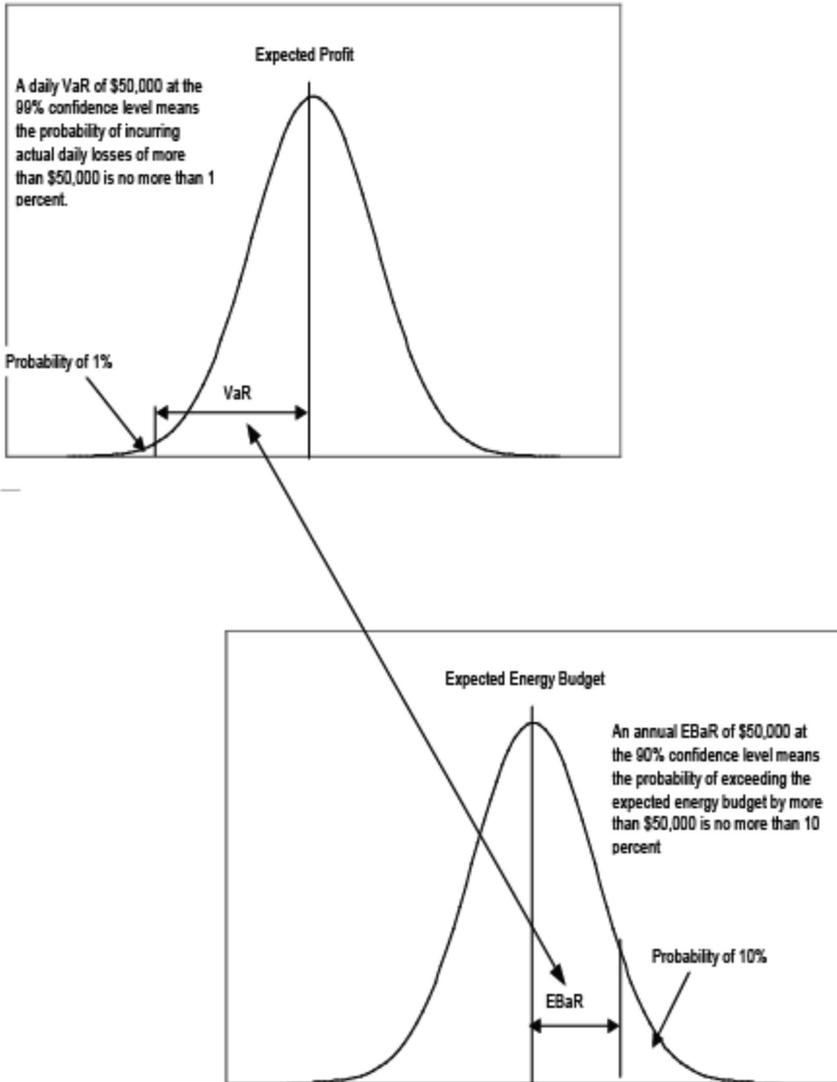
Figure 2. Correspondence of VaR and EBaR Budget Analysis

fidence level, x. An EBaRirr,90 = 35.5% indicates that the likelihood of achieving an internal rate of return of 35.5% or more is 90%.

EBaRnetsav,x is the smallest net savings (energy cost savings minus amortized cost of the equipment, including financing costs) at a given confidence level, x. An BaRnetsav,99 = $44,000 indicates a 90% likeli-

hood of achieving a net savings of $44,000 or more.

The EbaR IRR and net savings examples above are shown in Figure 3. The 90% confidence level reflects the fact that 10% of the area under the probability distribution is greater than 35.5%IRR and less than $44,000.
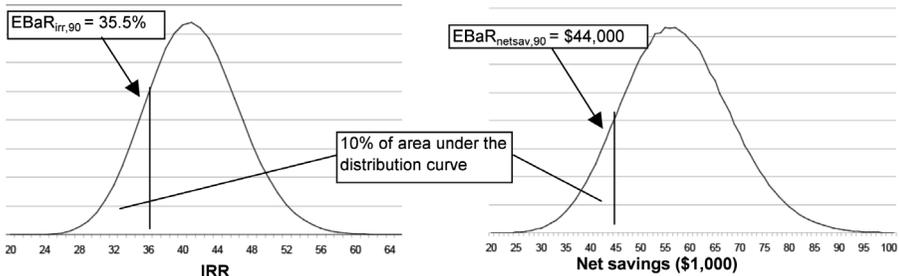

Figure 3. EBaR IRR and Net Savings Definitions

APPLYING EBaR ANALYSIS

EBaR is illustrated in this section with a hypothetical energy efficiency example application. The example case study establishment is a 120,000-square-foot Houston office building. HVAC and lighting system energy efficiency options are considered in this example. The HVAC system is more than twenty years old and has not been recommissioned. The lighting system has an average connected load of 2.0 W/square feet. Standard high efficiency ballasts are used with T12 lamps. Little attention has been paid to energy efficiency since the building was constructed. The annual electricity use is 15.97 kWh/square foot, and natural gas use is 34.05 kBtu/square foot.

Energy bills are about $194,500 US per year for electricity and $48,500 US for natural gas, up by about 25% for electricity and 80% for natural gas since 2002. The building owner is concerned about the continuing impact of high energy bills and wants to consider measures to reduce energy costs and avoid the impacts of the volatile natural gas market.

The lighting efficiency options include replacing T12 lamp/ballast systems with super T8 lamp/electronic ballasts, delamping, installation

of occupancy and day lighting controls in selected areas, and replacement of selected incandescent lamps with compact fluorescent lamps. Lighting analysis indicates savings of 483,000 kWh per year and 145 kW peak electricity use. The total cost of the lighting retrofit program to the owner is $100,000. Electricity savings are approximately 20%.

The HVAC system is an oversized and poorly designed system. Proposed HVAC updates include recommissioning in addition to a building energy management control system. Estimated savings are 30% for AC electricity use and 65% for natural gas heating use. Cost of the HVAC component is $125,000.

A summary of the efficiency investments is shown in Table 2.

Table 2. Investment Analysis Summary

Item	Value
Customer investment cost	$225,000
Estimated energy cost savings	$96,800
Net cash flow	$57,000
Internal rate of return	41.70%
Payback	2.3 years

The payback is 2.3 years, which is longer than the firm's 2-year requirement. Consequently, even though this investment would reduce the building's annual energy costs by 38%, the investment would not be made because it fails the payback criteria. From the owner's perspective, investments with expected paybacks greater than 2 years reflect too much risk of unacceptable investment returns.

How does this investment fare when evaluated with the EBaR risk management framework? Uncertainty surrounding electricity prices, natural gas prices, and weather and operating performance must be specified to answer this question. Operating performance includes performance variations as well as variations in operating hours, equipment utilization, energy savings estimation errors and other factors. This uncertainty is represented with distributions for each variable. Details on the development of these distributions are available in Jackson (2008) and will be summarized here.

Historical natural gas price variation is used to define likely high and low values around the current price for future years. Changes in natural gas prices impact the local utility's electric prices because about

half the electricity generating capacity is fueled with natural gas. The relationship between natural gas prices and electric prices is estimated statistically. An evaluation of energy savings estimates suggests a range of uncertainty of +/- 15% for the lighting systems and +/- 20% for the HVAC program. Variations in HVAC energy use are also caused by weather variations; these relationships are estimated statistically with historical building and weather data. Finally, additional random variations caused by unidentified factors are characterized statistically.

Table 3 summarizes the sources of variation in components that determine energy efficiency investment returns, their impact on the energy cost component, and their development.

Table 3. Sources of Variation in Energy efficiency Investment Returns

Variable	Impact on Cost	Source
Natural gas price	Energy price	Range of likely values based on history
Electricity price	Energy price	Statistical relationship based on natural gas prices
Operating performance	Energy savings	Manufacturer, ESCO and energy manager evaluations
Weather	Energy savings	Statistical relationship: HVAC energy use and weather data
Random	Energy savings	Statistical characterization based on historical data

Savings from efficiency investments are determined by multiplying the lighting and HVAC program savings by electric and natural gas prices. However, since the factors in Table 3 are represented with distributions, determining the distribution of energy cost savings outcomes requires repeatedly sampling information from each distribution and saving the results. This Monte Carlo analysis process is widely used in every branch of social science, engineering, finance, business, and other areas to translate variability in inputs (prices, weather, etc.) in a process (building energy use) to determine a distribution of outcomes (IRR and net savings).

Representing investment returns (IRR) and investment profits (net savings) with the distributions is not a "user friendly" presentation for

most financial and other executives. Selecting several levels of risk that match potential decision-maker risk tolerance provides more transparent decision statistics. Table 4 and Figures 4 and 5 show IRR and net savings (savings after deducting financing costs) in presentation format for the lighting and HVAC investment.

Table 4. Efficiency Program Returns

Confidence Level	Minimum IRR (%)	Minimum Net Cash Flow
Expected	41.7	$57,000
90%	34.9	$42,900
95%	32.9	$38,000
97.50%	31.9	$36,700

As indicated in the table and figures, this investment with an expected value payback of 2.3 years and 41.7% IRR has virtually no chance of providing an IRR less than 31.0% and yielding an annual net savings of less than $36,700. In other words, even in a "worst outcome" situation likely to occur with only a probability of 2.5%, the energy efficiency investment will increase annual cash flows by $36,700.
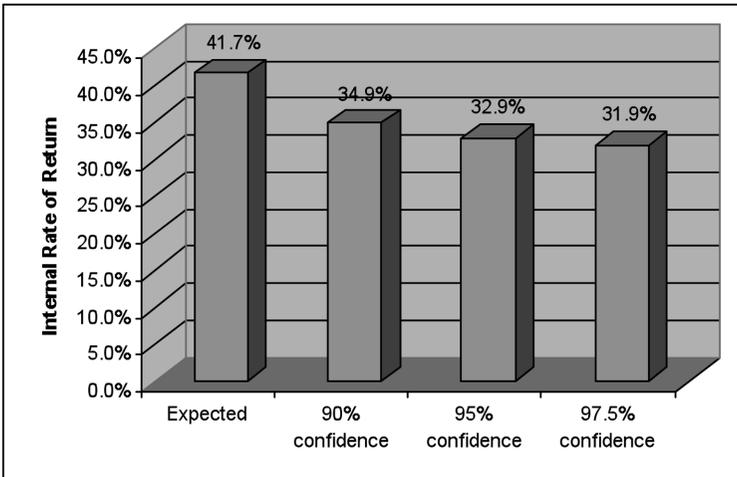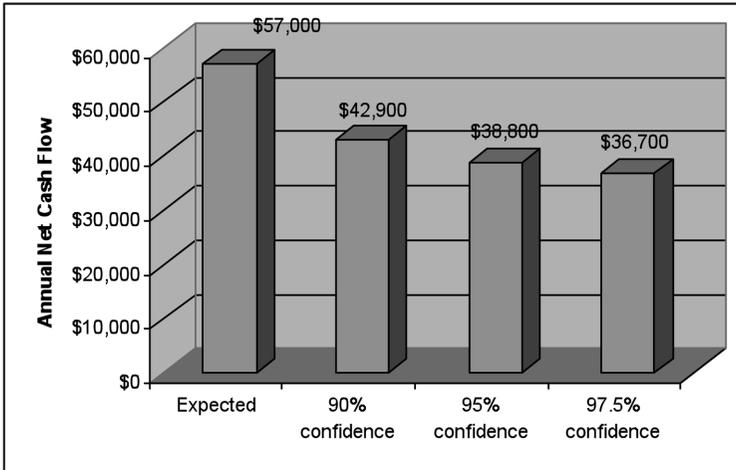

Figure 4. Investment Internal Rates of Return (IRR)

Figure 5. Investment Net Savings

While a payback approach requires a short expected payback to insure against unacceptable investment returns, EBaR provides information on the least attractive returns likely to occur at various confidence levels. EBaR manages to provide this information in a simple decision variable framework like payback analysis; however, EBaR avoids all of the limitations of payback analysis. Investments with varying lifetimes, savings throughout the life of the equipment, and a comprehensive and explicit accounting of the uncertainty associated with every aspect of the analysis is included in EBaR analysis. The EBaR analysis framework also allows the analyst to evaluate impacts of alternative assumptions on input variable uncertainty and to identify the importance of uncertainty surrounding each variable on the distribution of investment returns.

In this example, expected returns are great enough and the risk of unacceptable results small enough to recommend the investment. The impact of efficiency investments on the expected annual energy budgets can now be evaluated. Figure 6 shows the expected budget before and after the investments and expected budget variances at three confidence levels. Not only have the investments reduced the expected annual energy budget from $250,000 to $157,200, but also the size of likely budget variances (the amount by which actual costs exceeds the budgeted amount) is reduced by about 45%. Both the annual budget and budget risk have been significantly reduced.
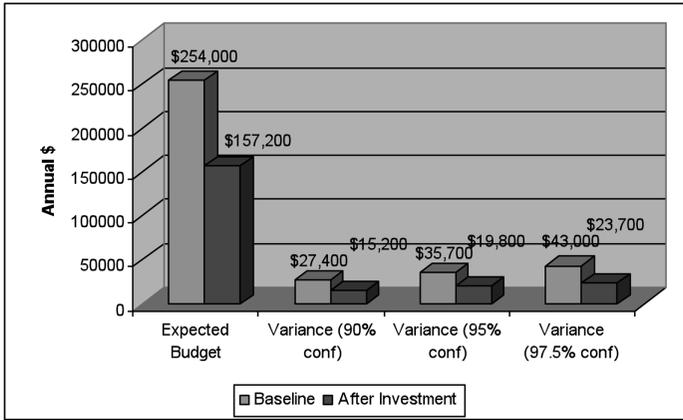
Figure 6. Expected Annual Energy Budgets Before and After the Investment

The budget variance evaluation provided above is much more important than suggested by the energy cost portion of operating expenses. Energy is typically a small part of operating costs, often representing 10% or less; however, energy costs can easily reflect 25% or more of operating cost variance and the single largest operating cost risk.

ENERGY ENGINEERS AS INVESTMENT ADVISORS

Energy engineers and managers are responsible for monitoring facility energy use, analyzing current energy use patterns, and identifying opportunities to reduce energy consumption and improve the efficiency of existing equipment and systems. They are also periodically responsible for developing capital budgeting proposals for energy efficiency investments. These proposals typically include "best estimates" of efficiency project investment costs, energy cost savings, and operating and maintenance costs associated with the investment technologies. Proposals are sometimes accompanied by alternative estimates that reflect "what if" scenarios relating to energy prices, weather, technology operating characteristics, and other factors that reduce savings associated with the investment. These alternative estimates are provided to indicate risks associated with outcomes other than those included in the best estimate. While some efficiency investment proposals include net present value and internal rate of return estimates, nearly all such proposals present payback as a primary investment criterion.

Most organization use payback results to screen energy efficiency project proposals with one-, two- and sometimes three-year thresholds applied to identify projects worthy of further consideration. As illustrated in preceding sections, payback screening provides information on only one dimension of the investment problem—the number of years required for expected savings to pay for the investment—whereas, financial decision-makers are concerned both with the expected investment return and risk associated with the investment.

Facility energy management can better be accomplished if the authority and responsibilities of facility energy engineers and managers are extended beyond the traditional role of monitoring energy use and maintaining energy systems, with sporadic submittals of energy efficiency investment projects for approval. Energy managers possess valuable information on facility energy use characteristics, energy-using equipment in the facility, information on energy efficiency options, and uncertainty surrounding efficiency investments. These resources can be used much more effectively if facility energy managers are also viewed as investment advisors who can identify and analyze the returns available with energy efficiency investments, including the reduction of annual energy budget risks.

The energy budgets at risk framework described in this article provides an intuitive interpretation like payback analysis; however, in addition to investment results based only on expected values or several scenarios, EBaR provides information on risk associated with the investment at different levels of confidence. The example presented shows that the additional information on investment risk allows decision-makers to adopt investments that would have been rejected if based only on payback analysis. Familiarity of financial decision makers with financial risk management and the widespread use of Value-at-Risk in the financial industry suggests that EbaR or a similar Value-at-Risk-based analysis can be used by energy engineers and managers to translate all relevant information on energy efficiency investments into investment analysis language used by chief financial officers (CFOs) and other financial decision makers.

SUMMARY

This article evaluates the energy efficiency investment decision-making used by most organizations. The traditional practice of applying

payback analysis to screen investments for risk is shown to potentially reject investments that would have been acceptable if both expected investment return and investment risk had been considered.

Financial risk management analysis is briefly described, and Energy Budgets at Risk, a value-at-risk-based energy efficiency investment analysis, is presented to illustrate the advantages of risk management analysis in evaluating energy efficiency projects. The case study example application illustrates advantages of applying the EBaR energy risk management approach to assess the financial, energy-savings, and budget impacts of HVAC and lighting energy efficiency investments. EBaR analysis is shown to provide the simple decision process preferred by decision-makers who currently rely on payback analysis. Rather than avoiding risk with an imprecise rule that overlooks many profitable investments, EBaR quantitatively determines investment rewards and risk for individual efficiency investments in a way that allows individual industrial firms to evaluate investments based on their budget flexibility and risk tolerance. EBaR also shows the corresponding increase in cash flow resulting from energy savings that exceed the cost of financing the investment. Finally, EBaR incorporates varying equipment lifetimes, energy price uncertainty, and other issues ignored with payback analysis.

The article concludes with the suggestion to expand traditional roles of energy engineers and managers to include providing energy efficiency and budget financial risk management analysis.

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