A Procedure for Linking Projected Energy Performance Uncertainty with Investment Decision-Making

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ABSTRACT

Energy consultants, design professionals, and property professionals have widely used building energy modeling tools to project energy performance when evaluating energy efficiency investment. These models help decision makers to explore the potential savings, estimate the simple payback (PB) and simple return on investment (ROI), compare the various energy efficiency systems and strategies (EESS), and select the most cost-effective options based on the results of their financial analyses. However, the primary issue with these financial outcomes is that they typically only focus on installation and operational costs when estimating the return on investment (ROI). Many benefits of energy efficiency investment, such as reduced risks and increased asset revenue, are beyond these analyses and ignoring them in the financial analysis may lead to poor investment decisions.

In this paper, primary challenges in evaluating the financial performance of energy efficiency investment are addressed. An eight-step procedure is proposed for a more holistic financial assessment of energy efficiency to incorporate all costs and benefits, in terms of revenues and risks, resulting from the EESS, while explicitly expressing uncertainties. This is an integrated procedure that explains how to build an accurate case-based model and address the uncertainty associated with the input assumptions, and then links the estimated building performance to financial performance indicators. It uses the Discounted Cash Flow approach and Monte Carlo simulation technique for calculating IRR and ROI in order to accommodate revenues, risks and uncertainties.

Introduction

Over the last decade, many studies, such as Summary of The Financial Benefits of Energy Star Labeled Office Buildings (Kats & Perlman 2006), have been performed to articulate the financial performance of energy efficiency investment. The majority of these studies are “case-based” which focus on the financial performance of a single energy-efficient building or “causal-comparative studies” which focus on comparison of larger sets of energy-efficient buildings versus their peer conventional ones utilizing statistical modeling techniques, such as regression analysis. They attempt to recognize the value added by investing in energy efficiency. Their results have generally shown that the financial performance of buildings with higher energy efficiency features and certifications, such as Energy-Star, may have higher rents, higher occupancy levels, lower operation costs and higher absorption rates and therefore higher market values. These studies primarily focus on new building and less clear is whether and how existing buildings, which makes up for a bulk of commercial buildings, should be retrofitted and refurbished (Miller & Buys 2008). Ciochetti and McGowan (2009) in their recent study about the payoff of energy efficiency improvements, have concluded that while data representing the impact of investing in energy efficiency improvements continues to pose a challenge, investment in these projects produce a return on investment, increase the predictability of energy consumption and add value by decreasing operating costs. The results of these studies, case-based or causal-comparative, are very helpful in providing decision makers with useful information and deeper insights into energy efficiency investment benefits and encouraging them to consider the EESS in their retrofit decision making process.

Building energy modeling programs are the primary tools used by design professionals such as architects, engineers, energy analysts, and facility managers for evaluating the energy performance, not only in designing a new building but also in evaluating existing building performance. These tools primarily provide users with forecasts of the impacts of design decisions on energy performance indicators such as electricity or gas usage. Some of them also perform simple financial evaluations. They take the building systems and strategies as inputs, and evaluate and project the building performance or simple financial performance as outputs. The U.S. Department of Energy (DOE) has developed a directory which contains information on more than 100 energy simulation tools including DOE-2, Energy Plus, etc. A short description is provided for each tool along with other information including expertise required, audience, input, output, etc. (DOE 2009). Users could go through these lists and select the appropriate tools based on the types of the decisions, building systems (inputs) and building performance (outputs) they are interested in evaluating. Currently, many minor and major retrofitting decisions are made based on the energy saving outcomes and simple financial analyses of these tools.

However, these modeling tools if not used properly could result in unreliable outcomes and may lead to inappropriate decisions about energy efficiency investment. The results of modeling tools on their own are not sufficient to rely upon for making high-quality investment decisions at the property level. In this paper, the important issues and challenges of utilizing modeling tools in existing income-producing property have been discussed and a new procedure is suggested for a thorough assessment of financial performance of the EESS investment.

Evidence of Inaccuracy/ Error of Energy Models Forecasts

Evidence shows that actual energy performance may differ from what was forecasted by energy simulation models such as e-Quest or Energy-Plus. Energy forecasting models, while assumed to be good predictors of energy performance, are subject to some level of intrinsic error ranging from 10% to 20% (Muldavin 2009). This forecasting error is interpreted as the percentage error between actual energy consumption and forecasted energy use based on a building's actual design characteristics and use profile, including actual process energy. Below, two examples of model forecast inaccuracy are presented:

Turner and Frankel (2008) in **"***Energy Performance of LEED for New Construction Buildings"* concluded that there is wide scatter among the individual results that make up the average savings. Some buildings do much better than anticipated. Measured Energy Use Intensities (EUIs) for over half the projects deviate by more than 25% from design projections, with 30% significantly better and 25% significantly worse. As shown in Equation 1**Error! Reference source not found.**, the ratio between actual and modeled EUIs for individual building ranged from 50% to 280% and the mean value was approximately 99%.

Equation 1

$$25\% < \text{Actual/Modeled} < 275\ \% \ \&\ \text{Mean} \approx 92\%$$

According to Newsham, Mancini, and Birt (2009), the average ratio between measured and designed EUI was close to unity, at 0.92, suggesting that modeled results over populations of buildings might represent a reasonable estimate of actual energy performance. However, as shown in Equation 2, the ratio for individual projects ranged from less than 0.25 to >2.75.

Equation 2

$$50\% < \text{Actual/Modeled} < 280\% \ \& \ \text{Mean} \approx 99\%$$

While the average ratios suggest that energy modeling forecasts are reasonably reliable, the estimates for an individual building are very scattered, and the distribution of results are quite varied. Thus, the degree of inaccuracy/error can be large in some cases, and the models might not be a good predictor of project-specific energy performance. It is critical for decision makers to consider the inaccuracy/error of modeling forecasts to avoid overestimating or underestimating the building energy performance when making decisions based on the predicted performance. Therefore, it is suggested to calculate ranges and distributions for reporting the energy performance outcomes with the mean of modeled forecasts in order to incorporate the errors inherent in modeling forecasts—risk of not achieving the predicted outcomes.

Calibration Process

In the retrofit analysis of an existing building, it is critical that the base case model provide accurate estimates of current energy performance in order to be able to forecast the energy performance of retrofit options reliably. Calibration methods have been suggested by many researchers as a critical part of the simulation process of existing buildings. Existing buildings are typically modeled based on the necessary data and information obtained from supplied plans and construction details, specification books and operating schedules. The results of initial simulations usually indicate that despite the careful attention in creating the models, the actual measured energy use is different from what was projected by models. This discrepancy is primarily due to the significant uncertainty or error associated with the simulation inputs. The calibration process compares actual measured performance data with those values predicted by the software and repeatedly refines the models, and reduces the errors until it closely represents the actual measured data and complies with the calibration standards. The three guidelines, which specify the acceptable tolerances for the calibration of simulation, are presented in the table below:

Acceptable Tolerance for Monthly Data Calibration

Index	ASHREA 14 (%)	IPMVP (%)	FRMP (%)
ERR_{month}	±5	±20	±15
ERR_{year}	-	-	±10
$CV(RMSE_{month})$	±15	±5	±10

EER: mean bias error; CV (RMSE): coefficient of variation of the root-mean-squared error
Source: Pan, Huang & Wu 2007, 652

Mechanisms that are typically used to identify the errors and update the inputs include: using the most accurate as-built information, site visits, surveys and interviews with building operation managers and occupants, on-site measurement, such as outside air flow, temperature or light levels measurement, and checking the utility bills data, such as electricity bills and gas bills. These methods help to reduce uncertainty associated with inputs of existing buildings' models.

Researchers have suggested several calibration methods for simulated models of existing buildings, although none of them is accepted as a standard method**.**

Westphal and Lamberts (2005) have suggested using sensitivity analysis in the calibration process, and presented six stages for calibration of building simulation models:

1. Calibration of power and schedules of constant loads, such as lights and plug loads;
2. Simulation of design days for thermal loads analysis;
3. Sensitivity analysis over input parameters related to significant heat gains/loss;
4. Adjustment of input values of high level of influence and uncertainty;
5. Whole year simulation;
6. Final adjustments.

Pan et al. (2007) have also suggested six steps for the calibrated simulation procedure:

1. Produce a calibrated simulation plan;
2. Collect data;
3. Input data and run model;
4. Calibration of simulation model;
5. Refine model;
6. Calculate energy and demand savings.

Energy Performance Outcomes

Most of the EESS, which are typically employed in retrofitting existing buildings, have more benefits than just lowering energy consumption. For example, employing a new energy efficient HVAC system may reduce the energy consumption but at the same time may improve the ventilation rate, reduce the air pollution, reduce the noise level and therefore, improve indoor environmental quality. Unfortunately, most of the EESS evaluations today are based on the simulation of energy-related systems in a single energy simulation program, such as DOE 2, and therefore, their other potential impacts on performance, such as indoor air quality, thermal performance, vision performance, acoustic performance, etc. are ignored. Rush (1986) has outlined the six building performance mandates and has examined how a building system, such as HVAC system, may contribute in different performance areas simultaneously. According to Rush (1986), the six performance mandates include spatial performance, acoustical performance, thermal performance, air quality, visual performance, and building integrity. Thus, energy-related systems' and strategies' contribution to performance are beyond the direct energy cost savings, they do impact on other building performance mandates.

These indirect-impacts on building performance or "non energy cost saving" could play a role in the financial performance of a building and therefore, are important to be considered in performance evaluation. In order to understand the ranges of impacts of the EESS on other performance mandates, it is desirable to model the subject building with multiple Building Simulation Programs (BSPs). Each BSP has advantages and disadvantages in evaluating the specific indicators. A BSP might be a great tool for predicting the monthly energy consumption, but a poor estimator of building ventilation. For example, DOE-2 is widely used in the U.S. for calculating energy consumption, Radiance Interface for evaluating the lighting and daylighting systems, and Computational Fluid Dynamics (CFD) tools for the study of building ventilation, indoor air quality, or thermal comfort. To date, no program has been developed to evaluate all the performance indicators simultaneously. However, due to the costs of software and modeling personnel, users usually model a building with a single simulation tool, and judge the building performance based on the results of this tool. In some cases, this would lead decision makers to make poor decisions. Even if it is not possible to model a building through multiple BSPs, energy consultants are expected to acknowledge other potential impacts of the selected EESS, conduct a review of available data and studies, and adjust their findings for a specific property.

Investment Decision-Making Process

Property professionals, such as real estate investors, owners, developers, managers and lenders, are becoming more interested in investing and financing energy efficiency during the last decade. The idea of energy efficiency has been around in US for a while, but it received dramatic attention among property professionals after the energy price crisis in 2006. These professionals are primarily concerned with the market value, both return and risk, that energy efficiency investment could add to their property. They need to know if the risks associated with their investment are adequately compensated by expected returns generated—risk and revenue trade off. They must truly recognize the financial return they might have received above the amount they would received when not investing in the EESS.

Historically, design professionals, such as architects, engineers, and construction consultants, would propose design options and provide property professionals with information concerning the impacts of their design suggestions (costs and benefits) on building performance. Property professionals process the cost-benefit information with their own decision-making techniques, and make the final decision about whether or not to proceed with investing in those proposed options. Therefore, it is the responsibility of design professionals to communicate the full scope of costs and benefits of energy efficiency to property professionals. Designers should be able to fully explain how their energy efficiency options impact the building performance and how those impacts could affect the property market value. This information, if presented in a reliable and understandable language, will enable real estate investors/owners to make more informed decisions about energy efficiency investment.

There are three major problems with using energy simulation programs for making major energy efficiency investment decisions:

1. These technical tools have been primarily designed to model and analyze the energy performance indicators of interactive energy related systems and their outcomes are described in technical language. Therefore, due to their technical outcomes rather than financial outcomes, these tools are not able to communicate the overall energy performance to the investment decision makers in the way they can understand and directly utilize in their investment decision making process. According to Lorch, Lützkendorf, and Lorenz (2007), “this largely technocratic approach is, on its own, not enough to bring about the necessary change. What is needed is to encourage dialogue and learning between the construction community and practitioners from the property, finance, insurance and banking industries”. Most of the current tools are well developed to deal with the complexity and dynamic interactions of building systems performance in evaluating the energy performance, but fail to properly link energy outcomes to financial performance and do not translate the technical language to financial language.

2. The financial analyses that some of these tools perform are based on both the initial and operational cost saving. Financial techniques, such as simple PB, simple ROI and Life Cycle Analysis (LCC), are utilized as the primary methods in these analyses. Traditionally, due to their simplicity, these financial techniques are used very often by decision makers for assessing the EESS investment and selecting the best options. However, they ignore many costs, benefits, and positive and negative risks of energy efficiency investment, as well as uncertainties associated with the process of achieving those benefits.

   The full costs and benefits of energy efficiency are beyond the operational cost saving and traditional financial analysis; and ignoring them, may exclude many profitable investments opportunities from consideration, which ultimately would lead to underinvestment in energy efficiency. For example, investment in the EESS in a non-green office building will decrease energy cost but at the same time may increase the benefits such as access to incentives, improve worker health and productivity, reduce electricity consumption volatility, achieving energy certification, etc. Improved worker health and productivity in an office building may contribute to the significant cost savings for employers because of lower absenteeism and recruiting costs, and also increase the ability to meet evolving tenant demand, which would lead to lower turnover rate. Reducing electricity consumption volatility would reduce the risk of budgeting and cash flow management by increasing the predictability of energy consumption. Achieving energy certification, such as Energy Star, or contributing to achieving sustainability certification, such as LEED, would increase the reputation and marketability of the subject building, which would lead to higher absorption rates. Scores of studies, mentioned previously, have confirmed that all these benefits could directly or indirectly increase the property market value. These are examples of the types of benefits that are ignored when making investment decision solely based on the results of energy simulation programs.

3. These tools are unable to deal with potential uncertainty associated with their inputs. They only take single point estimates of inputs and ignore their potential variance resulting from differences between design assumptions and actual systems performance. As a result, their projected outcomes are usually interpreted inaccurate and unreliable.

   Accordingly, the current energy assessment tools do not simultaneously incorporate all of the costs, benefits, risks and uncertainties of energy efficiency, nor represent them in appropriate terms to be understood and utilized in the investment decision-making process. Design professionals will not report the true financial performance of the EESS to their clients, if they solely rely upon the simplistic analysis of these technical tools. The outcomes of these tools on their own are insufficient for making high-quality investment decisions and often undervalue the energy efficiency investments.

   In order to better communicate to investment communities, design professionals need to understand how property professionals value their investment choices, what techniques traditionally they use to financially evaluate their options, and how they account for risk and uncertainty in their investment decision making process.

The Traditional Discounted Cash Flow Approach

One of the powerful financial methods currently used in real estate investment is the Discounted Cash Flow method (DCF). The DCF technique evaluates the present value of the projected future cash inflow and outflow over the holding period. The DCF model is able to deal with the complexity of various factors involved in real estate valuation and to incorporate its related expenses, revenues, and risks simultaneously. It is the responsibility of valuers to do as much market research as possible and forecast the DCF assumptions. DCF inputs include rent, occupancy, operation costs, tax and capital costs, absorption rate, depreciation, holding period, discount and capitalization rate, etc.

We encourage design professionals to utilize the concept of DCF approach in lieu of simple PB, simple ROI, or LCC for estimating the financial performance of energy-efficient buildings. With the DCF method, potential direct and indirect costs, benefits and risks associated with energy efficiency investment could be considered in generating the investment's revenue. Consideration of both revenues and risks in the financial analysis will allow designers to provide their clients with the true financial performance of energy efficient buildings. In the proposed procedure in this paper, DCF approach is suggested as a base model for estimating the financial performance indicators of energy efficient properties.

The Monte Carlo Simulation Model

There is a certain degree of risk and uncertainty involved in financial assessment of energy efficiency. For example, uncertainty associated with determination of design assumptions in energy modeling tools and risk of inaccuracy of model forecasts; or, uncertainty associated with determination of DCF inputs (assumptions about future factors) and risk of not achieving value or rate of return as predicted in DCF (estimation of DCF outputs).

Risk and uncertainty need to be measured and considered in assessment of energy performance; otherwise the outcomes of the evaluation process may be overestimated or even underestimated, and may lead to inappropriate investment decisions. Accounting for uncertainties inherent in the process and risks associated with achieving final financial performance indicators, such as IRR or NPV, will improve the reliability of outcomes and also the confidence level of decision-makers in their decision-making process.

In current energy modeling tools and the DCF model, inputs are included as single point estimates and therefore, the uncertainties of the input assumptions are not taken into account. Inability of the traditional technical tools and financial methods to deal with uncertainty in the energy performance evaluation process requires a more sophisticated quantitative approach to explicitly account for uncertainty.

"Monte Carlo analysis is a widely used numerical computational analysis tool that draws information from input probability distributions, applies the data in a process, and generates an outcome distribution"(Jackson 2008, 137). This technique is able to account for uncertainties by allowing for a range for each input and its correlations at the same time, perform a random probabilistic sensitivity analysis and model a range of possible outcomes. In the Monte Carlo, simulation data is processed and ranges of final outputs are estimated through the base model which describes the relationship between inputs and outputs. The results, whether shown graphically or numerically with summary of statistics, allow decision makers to better analyze uncertainty and provide them with more reliable information than a few discrete scenarios.

In the proposed procedure, the Monte Carlo analysis is suggested for modeling uncertainty and estimating the final financial performance indicators of the EESS. The base model for this simulation is built based on the DCF approach. This probabilistic model takes and analyzes the same DCF inputs and outputs but replaces single estimate points with appropriate ranges and probability distributions.

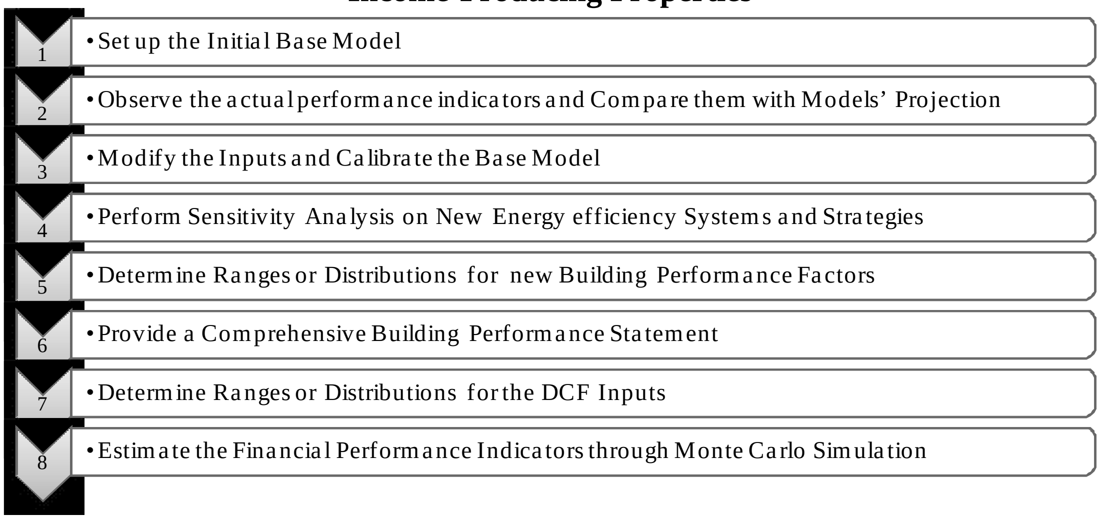
A New Procedure for Energy Efficiency Investment Analysis

One of the major problems of financial analysis of energy efficiency investment is that most of the current tools and studies in the field of energy efficiency focus on the assessment of systems performance and building energy performance outcomes, and would not directly link them to financial performance in the way that investors require. Muldavin (2010) has developed a "Green Building Finance Consortium (GBFC) Sustainable Property Performance Framework" which links the building performance to the financial performance through the assessment of market performance. The proposed procedure in this paper generally follows the concept of the "GBFC Sustainable Property Performance Framework" in order to estimate the financial performance indicators of the EESS in a major energy retrofit of an existing income-producing property. In the development of this process, emphasis has been placed on three domains including: calibration process and a more holistic energy performance evaluation, financial analysis of the EESS investment, and incorporation and communication of uncertainties inherent in the procedure.

The process begins with modeling the property with existing characteristics and conditions and building up a reliable model to serve as a base case for evaluating the energy performance and generating ranges/distributions of energy performance indicators, resulting from investing in the new EESS. The outcomes of energy performance along with other related building performance factors would then be connected to the financial/statistical models which are used by investment communities in their investment decision-making process.

Figure 1 illustrates the steps in the procedure that decision makers should follow to arrive at more reliable estimates of financial performance of energy efficiency, while risk and uncertainty have been factored in. The results of the procedure will help decision makers in addressing the decisions about "whether or not to proceed with investing in energy retrofits" or "selecting the best possible EESS in retrofitting the existing buildings".

Figure 1: A Procedure for Financial Assessment of the EESS in Retrofits of Existing Income-Producing Properties



Below, the subsequent eight steps, shown in Figure 1, are explained in more detail:

1. Set up the initial model based on available data, such as plans, construction details, specifications, operation schedule, or any as-built drawings or information; run the initial model and calculate the annual and monthly electricity and gas usage.

2. Observe the actual annual and monthly electricity and gas usage by looking at historic utility bills; compare the actual measured electricity and gas usages with those predicted by the simulation model, and calculate the annual and monthly mean bias error (EER) % and coefficient of variation of the root-mean-squared error (CV RMSE) by formulas presented in Equation 3.

   Check if the calculated EER% and CV RMSE% falls in any of the three accepted tolerances for data calibration suggested by ASHRAE 14, IPMVP, and FEMP (presented in the table). If it falls in the suggested ranges, or very close to any of those ranges, the initial model is appropriate enough for evaluating the new EESS; if not, the initial model needs to be refined, and its outcomes should be compared with the actual usages again. The process will continue until its results closely match with the actual usages observed from utility bills.

   Comments on Simulation: a) When practical, the simulation weather file should be for the actual year for which utility records are to be compared and not a Typical Meteorological Year (TMY) file. If a TMY file is used the actual monthly weather for the utility records year should be compared to the monthly TMY data as this can be a significant source of error. b) Some adjustment to the comparative data is often needed as utility records seldom correspond to the calendar month. Two possible procedures for dealing with this include: if available, sum the daily simulation values to correspond to the measured records; or normalize the measured records to correspond to the simulated monthly values.

Equation 3: EER and RSME Formulas

$$\mathrm{ERR}_{\mathrm{month}}\,(\%) = \left[\frac{(M-S)_{\mathrm{month}}}{M_{\mathrm{month}}}\right] \times 100\% \qquad (1)$$

$$\mathrm{ERR}_{\mathrm{year}}\,(\%) = \sum\nolimits_{\mathrm{year}} \left[\frac{\mathrm{ERR}_{\mathrm{month}}}{N_{\mathrm{month}}}\right] \qquad (2)$$

where M: measured electricity (kWh) or fuel consumption; S: simulated electricity (kWh) or fuel consumption; N_{month}: number of utility bills in the year.

$$\mathrm{CV}\,(\mathrm{RSME}_{\mathrm{month}})\,(\%) = \left[\frac{\mathrm{RSME}_{\mathrm{month}}}{A_{\mathrm{month}}}\right] \times 100\%$$

$$\mathrm{RSME}_{\mathrm{month}} = \left\{\frac{\left[\sum_{\mathrm{month}} (M-S)^2_{\mathrm{month}}\right]}{N_{\mathrm{month}}}\right\}^{1/2}$$

$$A_{\mathrm{month}} = \left[\frac{\sum (M_{\mathrm{month}})}{N_{\mathrm{month}}}\right]$$

where RMSE: root-mean-squared monthly error; A_{month}: mean of the monthly utility bills.

Source: Pan, et al. 2007

3. Identify the inputs with suspected high impacts on outcomes and any other possible sources for discrepancies and modify the initial model. Interviews with building operators as well as on-site measurement of systems performance could be helpful to obtain possible updated information about building systems performance and operation. Perform sensitivity analysis on each of those suspected input parameters, with a change of input value within a reasonable range, in order to specify a more accurate value for the model inputs. It will also verify which inputs have a significant influence and which are minor**.** Calibrate the model based on new inputs found form interviews and sensitivity analyses accordingly. It is probable that only those variables with greatest impacts on simulation outcomes will need to be adjusted.

4. Enter the new EESS selected for retrofitting as the new input assumptions to the calibrated model. Perform sensitivity analysis within the reasonable ranges of new inputs of each new EESS to project the new performance indicators, and finally, determine a range or distribution for each outcome based on the results of the sensitivity analysis and the model's error estimated by comparing the error statistics of the final base case model with those aforementioned standard tolerances presented in the table.

   As stated previously, it is suggested to model the subject property with new energy conservation options through different BPSs to understand their full impacts on other building performance mandates such as indoor air quality, thermal comfort, or noise level.

5. Determine a range or probability of occurrence for the building performance factors both green and non-green. Green building performance, which are the factors related to the EESS investment, include development costs, resource use, occupant satisfaction, health, productivity, contribution to green or energy certifications, achievable incentives,

reputation, marketability, cash flow risks, etc. Non-green building performance, which are the critical factors in valuation of a property and not related to the retrofits, include location, access, age, size, security, etc. Energy efficiency outcomes estimated through BPSs in the previous step are a foundation for forecasting the green performance factors. When evaluating a specific property, development and operation costs, resource use, probability of achieving certifications and incentives, can be predicted relatively easily based on available data, guidelines, regulations, and modeling tools. However, factors such as users' satisfaction, and health and productivity are more difficult to measure precisely. Scores of studies, such as "Impacts of Building Ventilation on Health and Performance" conducted by Lawrence Berkeley National Laboratory, have shown that there is a positive relationship between green building performance outcomes, such as ventilation rate or daylighting, and space users' satisfaction, and health, and productivity. Other studies, such as "The Costs and Benefits of Green Buildings" (Kats 2003) demonstrate that improved health and productivity positively impact the cost savings and property value. Currently, establishing the precise quantitative relationship between performance outcomes, health/productivity and market value seems to be almost impossible, due to limited data and difficulty in obtaining required information in a way that can be used directly in property level decision making. However, in the real estate investment world, perfect science or exact knowledge about the potential health/ productivity benefits of sustainable property is not required. What is required is appropriate caution in the use of health and productivity studies so as not to mislead decision-makers based on incorrect or incomplete presentation of results and caveats (Muldavin 2010). Forecasting ranges for health and productivity performance in a specific property will suffice. Therefore, it is particularly important that decision makers acknowledge the potential benefits to occupants and consider the occupants' response to those benefits that are results from energy efficiency investment, even if the exact quantitative data is not available.

The second type of building performance includes the non-green factors, such as location, access, age, etc. The good news about existing buildings is that most of these factors do not change after retrofits and therefore, could be considered equal in the financial analysis of energy efficiency. As a result, all changes in the final financial performance of the existing building are related to the EESS investment.

6. Provide a statement of building performance which includes all the historic financial and operation data—such as details on current rents, current expenses and current absorption rate—,all non-green factors—such as location and property quality—of the subject property, as well as new building performance information resulting from investing in the new EESS. This statement contains a summary of costs, benefits and risks of each employed option, both quantitative and qualitative information.

7. Determine a range or probability distribution for each DCF input based on quantitative and qualitative data included in the building performance statement. This step is where the technical details are connected to financial variables to be included in the financial analysis. Historically, the property professionals such as real estate valuers (appraisers, underwriters, or due diligence persons) have done this translation. They consider all the information in the statement, stated in previous step, simultaneously, assess the market

responses to those data and information in a specific property situation, and forecast the DCF inputs.

8. Set up a Monte Carlo model utilizing the DCF approach for describing the relationship between inputs and outputs. Run the model numerous times (e.g. 5000 times) and calculate the probability distributions of DCF outputs such as IRR and NPV. The resulting ranges and the shape of distributions would reflect the uncertainty related to the estimation of simulation inputs (DCF inputs) and articulate the risks related to achieving the simulation outcomes (DCF outputs), which ultimately assist final users to make a better investment decision. For example, as shown in Figure 2, the tighter distribution of outcome with smaller standard deviation represents the lower risk and uncertainty and therefore the higher level of confidence that investors will receive the predicted outcome (mean). Flat distribution with large standard deviation denotes the great degree of risk and uncertainty and therefore, less confidence investors could be in achieving the expected outcomes.

Figure 2: General Interpretation of Shapes of Normal Distribution

Lower Risk and Uncertainty
Higher Level of Confidence

Higher Risk and Uncertainty
Lower Level of Confidence

Conclusion

The traditional modeling techniques and assessment approaches used by decision makers for evaluating energy efficiency are not typically sufficient to rely upon for making major energy efficiency investment decisions. The key conclusion of this paper is that the true financial performance assessment of energy efficiency needs a new integrated approach. It cannot be done by a single group of experts. The holistic assessment requires both design and property professionals to be involved, and both technical and financial/statistical techniques to be intelligently utilized in the evaluation process.

The proposed eight-step procedure is the initial step towards the development of an integrated approach for financial assessment of the EESS. Design professionals are expected to make the model as accurate as possible, consider the uncertainty of input assumptions in evaluation process, and thoroughly communicate the impacts of energy efficiency investment on all dimensions of building performance, as stated in step 1-5 of the suggested procedure. Inputs from property professionals, such real estate valuers, are necessary for determination of DCF model inputs, as state in step 7.

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