BUILDING PERFORMANCE MODELING FOR GAINING INVESTOR CONFIDENCE

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ABSTRACT

Recent studies of the U.S. building stock indicate that scaling-up building retrofits is becoming increasingly compelling due to large cost-savings potential, attractive return-on-investment, and demonstrated savings. Deploying private capital for retrofits could prove transformational for achieving national and global energy and carbon reduction targets. Yet, a key bottleneck to accessing private capital is the lack of confidence in energy saving estimates against which lenders would underwrite loans, according to the Rockefeller Foundation and others.

An energy modeler is the service provider that is responsible for estimating energy cost savings during design. In order to build investor confidence in savings estimates, this paper proposes an expanded vision for an energy modeler's approach to their work. Current and future efforts are presented that support a modeler's ability to meet investor informational needs. Specifically, it addresses critical areas and contributions in three categories: 1) credentialing, 2) methods and processes, and 3) simulation analysis. Understanding and addressing investor concerns about modeling in these areas can help unlock the energy savings opportunities afforded by emerging financing mechanisms.

INTRODUCTION

Whole-building simulation software programs have existed for over forty years (Haberl, 2012). In the last decade however, the U.S. has seen the demand for building energy modeling services increase exponentially due to the explosion of interest in green building certification programs.

The United States Green Building Council (USGBC) first released its Leadership in Energy and Environmental Design New Construction (LEED NC) rating system in 2000. Since then it has undergone three revisions, with a fourth version under development (GBCI, 2012). To obtain critical certification points embedded within the energy-efficiency credit of LEED NC, large buildings with gross floor areas greater than 100,000 square feet (9,300 square meters) require whole-building simulation analysis. Data shown in Figure 1 illustrate the growth in projects of this size and corresponding demand for modeling services (USGBC, 2012). As a result, building simulation modeling has emerged as a valued efficiency service and practitioners are being identified as important contributors for meeting building sector efficiency targets (DOE, 2012).

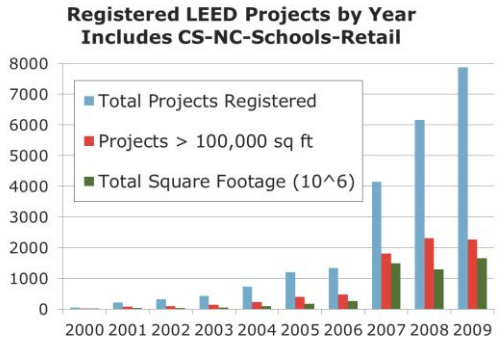


Figure 1: Increasing interest in LEED certification led to the exponential growth in the modeling service market

OPPORTUNITIES FOR EFFICIENCY

LEED NC has had a transformational impact on the demand and delivery of new commercial building modeling services. In the U.S., the modeling demand sparked by LEED has moved modeling from its research roots into a blossoming private-sector offering. However, in its current form, LEED does not built a strong bridge between design intent and achieved performance. In many instances, simulations are used for certification purposes and not for optimizing the efficiency of the building design.

LEED NC focuses on design evaluation. LEED Existing Building Operating & Maintenance (LEED EBOM) focuses on actual performance, but it does not mandate the use of whole-building modeling. As a result, LEED has fostered a demand bias in modeling services. Modelers are hired to make design comparisons to support certification. They rarely are asked to adapt the design models to inform operation or verify performance.

Evidence of radical improvements in achieved building efficiency has been published in the last few years. The New Buildings Institute in 2012 reported on the status of commercial Zero Energy Buildings (ZEB) in the U.S. (NBI, 2012). Twenty-one new buildings had sufficient documentation to be included within the study. Their energy use ranged from 9 to 35 kBtu/ft^2 year (100 to 400 MJ/m^2 year) before renewables are applied and incremental construction costs ranged from 0% to 10%. Although the size of buildings in the group are relatively small (less than 15,000 ft^2 or 1,400 m^2), they are comparable to the average for commercial buildings as reported by the 2003 Commercial Building Energy Consumption Survey (CBECS). CBECS reports the average energy use of U.S. commercial buildings at

97 kBtu/ft^2 year (1100 MJ/m^2 year). Thus buildings designed to be ZEB require only 10% to 40% of the energy of a typical existing building.

Only 4 out of the 21 buildings included in the NBI study were existing buildings, which reflect their slower uptake for achieving ZEB status. Nonetheless, the opportunities for savings in existing buildings are vast. Recently, the Rockefeller Foundation valued the U.S. commercial building retrofit market at $280 billion based on implementing improvements to achieve 30% energy savings in buildings built before 1980. The studied estimated that realizing the investment potential would yield $1 trillion in energy cost savings over a 10-year period (Rockefeller, 2012).

The study also reports on promising new financing models that can support scaled investments in efficiency. One example is an energy savings agreement (ESA). This mechanism is depicted in Figure 2. It involves a financier-developer (F-D) that funds the retrofit, owns the improvements, and takes responsibility for delivering the building's energy services. The owner makes regular payments to the F-D, typically in an amount equal to historical utility bills. With an ESA, the F-D is motivated to achieve the targeted project savings in order to meet its desired return-on-investment (ROI).

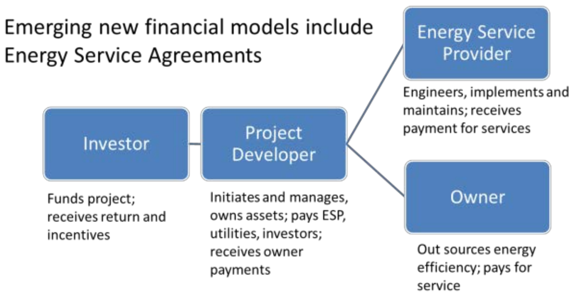


Figure 2: ESA is a new financial model that supports scaling investments in efficiency

While the ESA may appear similar to current financing schemes such as energy services performance contracts (ESPCs), it differs in several important ways. Motivated by ROI, the financier in an ESA must aggregate efficiency services with the intention of delivering a targeted performance. An ESPC is typically funded through a bank with a fixed-rate loan, which is secured based on the owner's credit rating. Through an ESA, the financier is willing to accept project risk if it might increase the ROI. This is in contrast to a project financed through a fixed-rate loan, which provides no incentive to the bank to accept additional risk for greater return. As a result, ESAs are more likely to be holistic and lead to deeper retrofits, increased savings, and higher ROI. But for ESAs to succeed, the F-D needs to identify and manage energy-savings performance risk. Taking these concerns into account will spawn a new level of rigor in efficiency services.

ESAs are one example of building energy savings mechanisms that would benefit from heightened investor confidence bestowed through improved performance modeling

MODELING FOR INVESTOR CONFIDENCE

The investment opportunities for building efficiency, along with its associated environmental benefits and job creation, have captured the interest of several influential and forward-looking organizations, including the Environmental Defense Fund (EDF).

Two years ago, EDF initiated the Investor Confidence Project (ICP) to address the issue of savings performance risk in F-D projects. The ICP objective is to set the standard of care for energy services that support investor-developer projects. Recently, a working version of the ICP protocol for large commercial buildings (Energy Efficiency Performance Protocol – Large Commercial) was released (EDF, 2013). The "Savings Calculations" section pertains to building performance modeling. It outlines nominal requirements and procedures for credentialing the modeler, development of input/output data, calibration, and reporting. Its specifications are outlined in Figure 3. In the authors' view, the requirements are not overly stringent but emphasize transparency in assumptions, methods, and documentation.

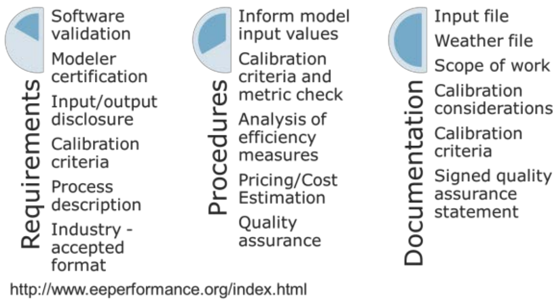


Figure 3: Specifications outlined for Energy Savings Estimates to Satisfy the EDF ICP Large Commercial Energy Efficiency Performance Protocol

These progressive efforts to scale efficiency hint at requirements that will likely emerge for modeling practitioners. We anticipate that investors' information requirements will impact the modeling market and the evolution of services as outlined in Table 1.

Modeling services for certifying an energy-efficient building design (e.g. LEED NC, Energy-Efficient Commercial Building Federal Tax Deduction, utility efficiency programs) focus on baseline model development, rating system interpretations, and credit submittal acceptance. These focus areas contrast those required for an investor-financed efficiency project, which heavily relies on savings risk assessment, transparency of methods, and third-party technical review.

Table 1: Market Drivers for Modeling Services[1]

Market Driver	Modeler Requirements and Focus Areas
Research	Deep knowledge of building science Knowledge of modeling algorithms Simulation software expertise Simulation software development Prototype building characterization Batch run analysis Pre- and post-processing Opportunity assessment
Efficient Design Certification	Basic knowledge of building science Simulation software expertise Knowledge of certification baseline Baseline building model creation Proposed design model creation Exceptional calculation procedures Credit submittal form completion Credit documentation requirements
Investor Financing	Certified energy modeler Deep knowledge of building science Knowledge of modeling algorithms Simulation software expertise Knowledge of holistic design solutions Knowledge of performance risk associated with input assumptions, modeling algorithms, and EEMs Knowledge of value beyond cost savings (e.g. comfort, health, control, reliability)

Early indicators of the changes afoot are revealed through the EDF ICP and investor financing concerns. Their requirements provide a glimpse into the future modeling market. To meet these emerging markets, the modeling offerings must start to address:

- Modeler credentialing through professional certification and review of past performance
- Documentation and associated risk assessment of input assumptions
- Specified calibration criteria
- Risk management plans for energy efficiency measures
- Assessment of value beyond energy cost savings
- Independent third-party review of analysis and findings

Modeling for investor confidence is not a new topic for the building simulation industry, but emerging market forces—along with their associated requirements for modeling services—are changing the landscape. Just as growing interest in green building certification spawned a new modeling market, investor financing will as well. It will require modelers to refocus their approach. It will necessitate modelers to ground their work in building science and be aware of simulation algorithms. Doing so will enable them to better identify and address the potential performance risk associated with estimated savings values. Addressing risk will also promote increased accountability and the designation of performance responsibility across the project. As a result, energy-service providers will need to develop clear, integrated work flows that span from building opportunity assessment to design evaluation and post-occupancy verified performance.

CREDENTIALING

Extensive quality assurance checking can help ensure that modeling methods, results, and findings are reasonable. However, if a review reveals shortcomings, there may be limited time for recourse. Therefore, credentialing a modeler may be the most effective way to incorporate due diligence that bolsters investor confidence in projects.

Certification

Modeler competence can be demonstrated through professional certifications, project experience, trainings, and education. Currently in the U.S., the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) and the Association of Energy Engineers (AEE) offer modeling certification programs. An overview of the two certifications is presented in Table 2.

Table 2: Professional Certifications for Modelers

Certification	ASHRAE	AEE
Name	Building Energy Modeling Professional (BEMP)	Building Energy Simulation Analyst (BESA)
Required experience (or equivalent)	• 4-year degree • 2-years modeling and 3-years buildings-related experience	• 4-year degree • 3-years modeling or buildings related experience
Pre-requisite	None	Three-day seminar (includes ½ day exam)
Test	• 2.5 hours • 115 multiple choice questions • AMP test center	• 4 hours • 100 multiple-choice or T/F questions • Seminar site
Member/Non-Member Cost	$295/$415	$1,350/$1,450
Number certified [2]	250	50

The purpose of the ASHRAE certification program is to “allow individuals to demonstrate mastery of a body of knowledge that subject matter experts have identified as being best practice.” The AEE designation is intended to “recognize individuals

[1] Based on the authors’ experience

[2] As of February 2013

with specialized expertise and experience utilizing building energy simulation software to assess a facility's energy performance." Each involves passing an exam. To qualify, modelers must meet requirements regarding education and work experience. The AEE exam has a training prerequisite for taking the exam.

Currently in Europe, modeler certification is not available. At a recent international meeting of simulation experts, modeler training and certification was recognized as a top priority and a "seminal step forward for the industry" (Clark, 2013).

Education and Training

Formal education programs that include building energy modeling coursework are available at approximately 25 U.S. universities within mechanical engineering or architectural engineering programs. (Tupper, 2011). In general though, much modeling expertise is learned by doing. There are some training opportunities for professionals. However, most of these are centered on the use of a specific building simulation software program. The International Building Performance Simulation Association (IBPSA-USA), in conjunction with Rocky Mountain Institute (RMI) and ASHRAE, has developed a full-day modeling training course that covers fundamental and advanced topics (IBPSA 2012). AEE offers the three-day training, which also utilizes the IBPSA training materials.

User Group Support

Resources that help modelers help themselves include electronic mailing lists. Developed for users of simulation programs, such list servers have been available for many years. They attempt to foster the development of a community of users to share questions and insights. These mailing lists can be general or software specific. A popular list is BLDG-SIM (lists.onebuilding.org), hosted by GARD Analytics. It is a helpful resource for inexperienced modelers to search for answers in its archives or by posting new inquiries. Its search features provide results for best matches or recent date based on search key words.

Recently a more sophisticated platform for user support has been proposed and initiated (http://area51.stackexchange.com/proposals/45232/). The information exchange forum utilizes the "Stack Overflow" question and answer site, which is popular with programmers and software developers. It allows authors posting questions to rank responses. Its search engine allows the best answers to rise to the top. Frequent contributors earn reputation points. These ratings are so noteworthy to the programming community that they are frequently included as part of resume qualifications.

The offerings available through the StackExchange site address some existing shortcomings of modeling mailing lists. It helps users distinguish between good and bad answers. It also identifies and rewards knowledgeable contributors.

Modeling Wiki

The Education Subcommittee of IBPSA-USA is developing a Wiki to support the collaborative documentation of energy modeling knowledge and methods (http://bembook.ibpsa.us). The initial structure has been established, content mapped from the IBPSA one-day modeling training, and initial contributions are underway. Currently, subcommittee volunteers control content. Eventually, avenues for permitting community-wide contributions will be developed after quality-assurance procedures are established.

Experience and Proficiency

The United States Department of Energy (DOE) recently published a report that identifies an energy modeler's job tasks and associated knowledge, skills, and ability requirements (DOE, 2011). Developed through an expert group consensus process, the goal of the effort is to create national guidelines, which will define a body of knowledge with which any training organization can align. DOE will also use the body of knowledge to help meet the requirements of the Federal Buildings Personnel Training Act of 2010.

The energy modeler job/task analysis (JTA) does a good job of outlining job requirements. However, most professional training opportunities available today focus on teaching software tools and not modeling methods. To meet the goal of the DOE effort, training curriculum must be developed that address the process of modeling using industry-accepted methods. As discussed in the following section, this body of applied knowledge has yet to be formally documented, vetted, and standardized.

To provide services across the building life cycle, the modeler should possess the capabilities listed below. These should be demonstrable through applied methods and actual results achieved in previous projects.

- Provide whole-building performance analysis using hourly simulation tools
- Conduct detailed daylighting studies
- Support integrated project design and delivery
- Develop minimally-code-compliant and green building certification baseline models
- Develop operational models for existing building performance assessment
- Generate synergistic bundles of energy-efficiency measures that include passive design strategies, load reducing measures, effective control strategies, and right-sized equipment
- Evaluate renewable energy systems and their impact on peak electric loads
- Assess the value of improvements beyond energy cost savings

- Identify efficiency performance risks and methods for management
- Complete life cycle cost assessment using modeling results, incremental cost data, and economic factors
- Transparently report assumptions, results, and recommendations

METHODS AND PROCESSES

Currently, detailed industry-accepted best practice procedures are not defined for the modeling process. Most modelers learn their skill on the job and applied methods are inevitably inconsistent. Developing and documenting BEM best practices will support modeling consistency and instill greater confidence in results. BEM best practices should address process issues, such as: following an integrated design approach to maximize savings opportunities, establishing aggressive savings targets, and exploring synergistic bundles of performance improvements. BEM best practices should be simulation-software-neutral but provide general modeling guidance for developing a baseline building model, calibrating an existing-building model, and sufficiently characterizing energy efficiency strategies within the limitations of simulation software.

Modeling Standard

An ASHRAE-sponsored effort for a proposed modeling standard is underway. Titled "Standard 209, Energy Simulation Aided Design for Buildings Except Low-Rise Residential Buildings," the scope applies to new buildings, major renovations, and additions. It will define nominal requirements for using modeling to support integrated design efforts. It is structured around the major design-operation building life cycle stages (pre-design, concept, schematic design, design development, and construction and operation). The main body of the standard will likely focus on demonstrable service components, while appendices will outline key best practice approaches for their implementation. The target date for producing a review draft is June 2014.

Best Practices Documentation

Resources that guide modeling methods and procedures are available in various forms. Several modeling guidelines provide direction on effectively using energy modeling for the design process (GEO, 2011; NEEA, 2010). Some are rooted in practical experience gained through applied methods (Kaplan & Caner, 1995). One of the earlier documents outlines the modeling process and provides guidance for evaluating and selecting building simulation software (CIBSE, 1998). A recently published book balances theory with practice to cover current issues in simulation modeling (Hensen & Lamberts, 2011). Directed at advanced students in engineering, it covers topics in terms of building science, computational methods, and application aspects. As modeling efforts become increasingly commonplace, we expect to see more detailed requirements being developed. For example, USGBC has developed a technical manual to clarify baseline and special-case modeling procedures acceptable for LEED Energy & Atmosphere credit 1 submittals (USGBC, 2010).

DOE is funding efforts to bridge the information gap between the modeler JTA, training opportunities, and investor needs. The collection of work is termed the Building Energy Modeling Library (BEM Library). Proposed by RMI and managed by NREL, the BEM Library supports meeting investor informational needs for energy savings estimates. Specifically, the effort involves documenting modeling best practices and developing transparent methods for communicating performance risk. We envision that the work products will be posted electronically for free access and contribution by the modeling community.

The 2013 scope includes the documentation of modeling best practice methods for three key areas: 1) quality control procedures, 2) existing building model calibration, and 3) reporting assumptions, methods, and results. The modules outline step-by-step procedures, discuss judicial decision-making, and provide supporting data (e.g. benchmark values, calibration criteria, descriptions of modeling algorithms, etc.). An example of one of the BEM Library work products is in Table 2 at the end of this paper. It is a template for reporting performance information related to an energy efficiency measure. The example is specific to high-performance windows. The form outlines information important to an investor, including: baseline conditions, measure characteristics, installed costs, estimated energy cost savings, value beyond cost savings, modeling approach, potential performance risk, and risk management strategies. Ultimately, a collection of templates describing commonly evaluated measures with example table content will be developed. Many responses will be project specific but some will draw from a consistent set of possible responses, which will be included.

The BEM Library resources will help practitioners provide information investors need. Ideally, it will help move the focus of modeling services from providing a single answer to a range of probable results accompanied by risk considerations.

ANALYSIS CONSIDERATIONS

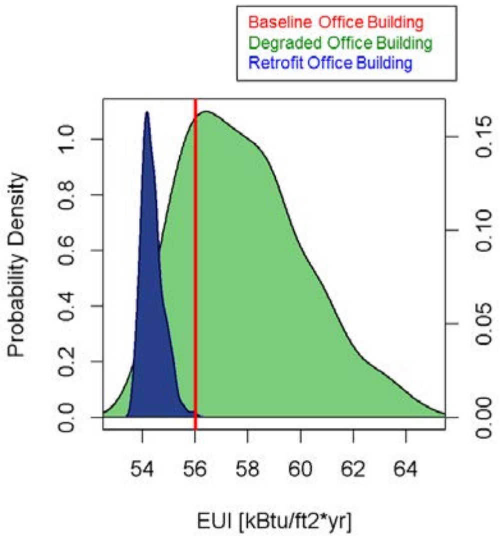
Traditional investments consider levels of risk, and higher risks usually translate into higher rates of return. Without uncertainty quantification for the energy cost savings, investors are left to estimate the risk with ad hoc procedures. For instance, published data show a range of 100% to less than 50% of cost savings guarantees made by ESCOs for their energy projects (Hopper, Goldman & Birr, 2004). When projected cost savings are reduced through derating, the anticipated profitability of the project is smaller, making some investments less attractive (Mills et al., 2003).

Uncertainty Analysis

To date the estimation of uncertainties and its associated risks for energy projects has not been widely applied. Methods are being actively researched to develop effective sampling routines for determining optimal solutions (e.g. minimum annual energy costs) for multi-variant analysis (Heo, 2012; Eisenhower, 2011). To date, these efforts have not trickled down into commercially available building simulation software used to assess large efficiency projects.

However the next release of OpenStudio, an open-source application suite and software development kit (SDK), will include options for completing uncertainty analysis (NREL, 2013). OpenStudio supports whole-building modeling using EnergyPlus and daylight analysis using Radiance. For developers, it facilitates rapid development of new applications targeting the service market and web-based analysis tools. For practitioners, it provides a workflow interface to EnergyPlus. It starts in the SketchUp Plug-In to create the building envelope and spaces, then loads applications to complete the building model characterization, and finally simulates with EnergyPlus. Version 0.10.0 provides rudimentary access to its uncertainty analysis capabilities, with an improved interface planned as part of its next release.

The OpenStudio uncertainty analysis draws from the DAKOTA project, an engineering optimization and uncertainty analysis modeling library developed by Sandia National Laboratories (SNL, 2013). It can be used to assess: the sensitivity of the output to the input parameters, those parameters that contribute the most variance, and how they interact with each other. The problem is set up by identifying the variables to perturb. For each variable, the user defines its type (continuous, discrete), distribution function (lognormal, normal), and upper and lower bounds. The algorithm for solution is also selected for generating the sample of results over the uncertainty distribution range. A variety of sampling algorithms are available through DAKOTA, including: Box-Behnken, Factorial, Latin Hyper Cube sampling, and Orthogonal Array. Once the problem and solution approach is specified, the analysis is run. Results are presented as a probability density function, as illustrated in Figure 4. In the figure, the degraded office building and the retrofit office building were modeled with a wider and narrower range of input parameters, respectively. Having this capability available in commercial-building software brings modeling closer to meeting investor needs. Nonetheless, to complete the analysis, the user needs to identify the uncertain model input parameters and judiciously assign values for their probable range. Resources are not yet available to aid the user to complete this exercise.



Note: Graphic courtesy of NREL; right axis for green curve, left axis for blue curve

Figure 4: OpenStudio can be used to provide a quasi-actuarial view of performance

Considering Climate Change

Climate change may impact future building performance. Assessing the impact requires the integration of future climates into building performance simulation. The integration requires the generation of weather files that reflect future weather conditions. The United Kingdom has developed several sets of future weather data for simulation analysis, including the Chartered Institution of Building Services Engineers (CIBSE) Future Weather Files. The CIBSE files have been generated for 14 locations. Each location has 9 files for the years 2020, 2050, and 2080. The 9 files represent low, medium, and high emissions scenarios with 10^{th}, 50^{th}, and 90^{th} probability levels. This approach results in 27 future weather files per location. A probabilistic climate profile for summer temperature in Belfast is shown in Figure 5. (CIBSE, 2012)

Recent work presented by Shamash examines the impact of incorporating future weather analysis into the modeling process (Shamash, 2012). One approach is to include the simulations of every file in the future weather dataset. This would involve batch processing simulation runs, extensive post processing of results, and increased computing time

To reduce the number of future weather files used, a methodology developed by the authors suggests narrowing the range by applying decision-making methodology. The procedure involves:

1. Choose the location.

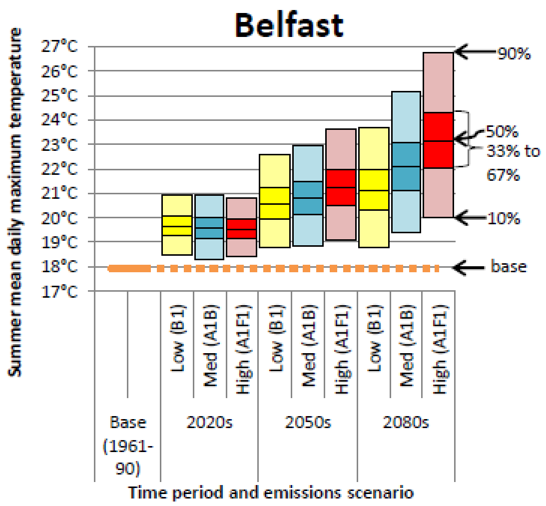


Figure 5: Probabilistic climate profile for Belfast for mean daily maximum temperature

2. Consider the purpose for using the future data, the climate variation, and the season of interest.
3. Refer to a "probabilistic climate profile" (ProCliPs) graph developed to aid the exploration of climate averages on a site-by-site basis (see Figure 5).
4. Consider the trends that the ProCliP illustrates for time period, emission scenarios, and probability level.
5. Based on these considerations, narrow down the choice of possible weather files.

The application of such procedures will reduce the risk of overheating of passive systems and under sizing of air-conditioning units. The extent to which climate change will become an issue to the investor will depend on the duration of the building performance contract.

Simulation of Controls

Deep savings in commercial buildings will be partly achieved through the use of smart building controls. An analysis of U.S. buildings energy-savings potential shows that 20% of such savings are achievable through efficient technologies. Improved controls can account for up to 20% of the technological savings potential (Lovins, 2011). But perhaps more than other technologies, smart controls bring other valuable benefits associated with improved comfort and tenant level-of-service. These extra benefits may have greater value than the saved energy in terms of maintenance costs, higher worker productivity, and better recruitment and retention of employees, retail sales, etc.

Currently, whole-building simulation programs are capable of modeling basic energy-efficient supervisory control strategies, including: economizer controls, supply-air temperature reset, chilled-water temperature reset, hot-water temperature reset, equipment sequencing, and optimal start-stop. New approaches to simulation, like those enabled by Modelica, are demonstrating expanded capabilities for evaluating buildings – including controls. The approach utilizes model reuse from design through the commissioning and operation of the building (Wetter, 2009). The approach is rooted in a separation of data (that describes the parameter of the systems, such as equipment size), the model (that specifies the system) and computation (that solves the equations). It utilizes open programming standards that allows reusing technologies (model libraries, numerical solvers, tools for code generation) that are shared across industries. This modularizes simulation efforts and facilitates collaboration with experts outside of the buildings industry. With this approach, a control strategy (or other modeling need) can be implemented and stored in a component library in an exchangeable standard format. Through modern code generation and simulation methods, the design of the control can be tested and fine-tuned, simulated and optimized within a building model, or integrated into an actual building control system. Such an approach bridges design, assessment, and implementation. Having modeling software that supports these connections will help maximize savings and minimize performance risk.

SUMMARY

The market is starting to ask for modeling services to support the ultimate end-goal for efficiency services - achieved savings. To satisfy this request, modelers need to refocus their approach now followed to support LEED certification and design assistance. To satisfy investors, modelers need to demonstrate competence through credentialing, to follow best practice processes and methods, to identify performance risk, and to transparently document assumptions and results. Investor-based services also gain from the modeler quantifying the uncertainty of savings and assessing the value of efficiency improvements beyond energy cost savings.

Besides service offerings, issues surrounding a modeler's responsibility for performance need to be resolved. For example, who is held accountable and what are the penalties for failure? The modeler does not have control over the construction and operation of the building. There must be explicit understanding of how design and construction decisions impact energy performance. Revamping approach and designating accountability are not only issues for the modeler. Other professionals involved in the assessment of efficiency opportunities and the insurance of achieved savings will be impacted in similar ways. The market may soon be asking for energy service providers to cooperatively achieve an outcome-based performance target.

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Table 2
Energy Efficiency Measure Characterization Template

High Performance Window Replacement

Description	
Replace existing single pane windows with double-glazed, low-e, high performance glazing. Calculations Based on PPG Solarban 60 Starphire	
Existing or Baseline	Single Pane. U-1.22, VLT = 40%

EEM Properties	
U-Value	0.29
VLT	0.74
SHGC	0.4
WWR%	40%

Energy Savings	
Cost Savings per Year	$15,000
% Savings	10%
Electricity Savings (kWh/yr)	96,970 kWh/yr
Gas Savings (Therms/yr)	400 Therms
Total Energy Savings (kBTU/yr)	3 kBTU/ft²/yr
Peak Reduction (kW)	5 kW

Energy Assumptions	
$/kWh	0.15
$/Therm	0.88
$/kW	$11.81
Source	CPUC
Tiered	Yes
Utility	SDG&E

Costs	
Capital Cost	$90,000
Simple Payback	6 years
Total ft² of Replacement	18,000 ft²
Cost per ft²	$5.00
Life of Measure	25 Years

Source of Costs:
Costs Based on RS Means 2012.

Relationship to Other EEMs	
Daylighting	*Improved daylight energy savings can be realized via daylight controls.*
Lighting Controls	*High VLT will improve effectiveness of daylight controls.*
Wall Insulation	*Performance glazing may be a smaller cost-add than highest insulation option*
Chiller upgrade	*High performance glazing decreases required high performance chiller size requirement*

Modeling Method
The Window 6.3 program from LBNL used to thermally characterize the glazing sytem including the framing elements. The results were matched up to a window included in the "Window Library" to represent the glazing system.

QC Checks
The following metrics were checked and compared against expected values: total energy cost, total energy use, plant cooling capacity, plant cooling use, plant heating capacity, plant heating use, system design flow, space load.

Risks			
Performance Consideration	Quantitative	Qualitative	Management Strategy
Improper Installation could cause leaks, which undermine energy savings	$15,000/year in energy costs	Draft could reduce thermal comfort	Select a qualified glazing system contractor. Commission envelope including leakage testing.
Unusually **mild weather** could reduce energy savings benefits	$7,000/year reduction in energy savings in worst-case modeled year	None	Study annual weather data by year to assess statistical advantage.
What factors could affect performance	*How Bad Could it Be?*	*Non-quantifiable Risks?*	*How to mitigate or manage the risk?*

Value Beyond Energy Cost Savings	
Improved Daylight	6% Increase in productivity, USPS Study
Improved Thermal Comfort	7.5% Increase in productivity, Ergonomics Study
Improved Moral	66% of worker's like daylight in their workspace
Higher Leasing Rates	36% Increase in rental rate, Hines Study