Energy Efficient Buildings Hub (EEB Hub)
BP3 Task and Subtask Descriptions and Performer Scopes of Work (SOW)
March 15, 2013

BP3 TASK 2 DELIVERABLE

1. Beta release of a suite of user-friendly simulation tools that will require no more than 24 hours of input time, interface with existing software, and are capable of predicting energy use in the studied types of commercial buildings with accuracy of +/-15 percent.

TASK 2: Modeling and Simulation
Lead: Jelena Srebric, Penn State, jsrebric@psu.edu, 814-863-2041

Description: This task will focus on a suite of simulation tools for predicting energy use in buildings deployed via a platform for use by architects, designers, engineers, contractors, buildings operators and others. Tools include a Design Advisor intended for the early design stages of a retrofit project, an Energy Auditing Tool to support understanding and investment decisions for advanced energy retrofit (AER) projects, and a Retrofit Manager Tool (RMT) to address needs of facility mangers that make critical decisions for building renovation and maintenance. This task directly contributes to achievement of Deliverable Number 1.

Development of multiple reduced order modeling methodologies and associated software is needed across this suite of tools because all of the existing reduced order models for buildings use standard statistical tools available from other disciplines. Therefore, major efforts in development of reduced order models for building retrofit decisions are in: (1) the provisioning of accurate building energy requirement databases, and (2) development of a scalable calibration methodology that goes beyond a single case study. At present, there is no standardized approach to either data collection or calibration methodology, because databases tend to be limited in size/scope. Further, published case studies have inherent biases that limit applicability of the proposed calibration methodologies to a large number of conditions. For example, the Georgia Tech's EFRI project generates a database using the EE-Calc method and additional auxiliary models. The study demonstrated a calibration method for an office building in UK that does not have a cooling system and uses radiators for heating, which cannot be found in U.S. office buildings. To deploy the same model to a U.S. office building for a cooling season requires significant work to either develop new or demonstrate applicability of the existing internal load models (auxiliary EE-Calc models will also need to be examined or augmented).

The research and dissemination efforts in all Task 2 projects contain a component of reduced order modeling as a first step in guiding the forward modeling deployed in subtask 2.1, 2.2, and 2.3. All these subtasks are unique due to the availability of large databases representing U.S. buildings, such as recommissioning data in subtask 2.1, Navy Yard building data in subtask 2.2, and LEED certified buildings data in subtask 2.3. Ultimately, subtask 2.4 provides a standalone inverse model as well as an uncertainty analysis tool that will channel the findings to other subtasks in Task 2. The EEB HUB currently utilizes the listed databases, while BP3 will introduce new databases into Task2 reduced order modeling efforts. Finally, the numbers of buildings that are being analyzed by all Task 2 projects provide an opportunity to develop a general calibration methodology.

More than a hundred energy simulation tools have been developed in the past several decades, but only a handful of these tools have a thriving developer and user community. One of those successful tools is certainly DOE- funded EnergyPlus with its predecessors DOE-1 and DOE-2. Overall, the most successful building energy simulation tools not only incorporated sophisticated mathematical models, but also focused on needs of specific user groups that are tightly connected to the developer groups. OpenStudio and EnergyPlus with various interface fronts, such as Simergy, SimuWatt, and DesignBuilder, have their specific target stakeholder audiences and developer groups that do not overlap with the Design Advisor and Energy Audit Tool stakeholder groups. The Design Advisor simulation tool targets the non-technical architects, while Energy Audit Tool targets engineers who can collect basic building characteristics *in situ*. Furthermore, Design Advisor will have longevity through academic research venues with potential to be commercialized, while Energy Audit Tool is already a commercial product with a company strongly invested in its longevity.

Both Design Advisor and Energy Audit Tool developers have access to an existing network of professional architect and engineer alumni from the participating schools. These stakeholder groups continuously support developers of Task 2 simulation tools. These tools are all built on existing software packages and provide functionalities that augment limitations of existing simulation tools by integrating measured data of building performance and expert knowledge. Finally, the simulation platform will provide linkages among the simulation tools developed in Task 2 as well as open opportunities to link with other simulation tools that will be identified in BP3 workshops. Please, note that the Retrofit Manger will support the OpenStudio, EnergyPlus, Contam, and Daysim connection and its software and model contributions will be openly shared with the collaborators in three national labs (NREL, LBNL and NIST).

The EEB Hub and the DOE will stay in regular contact to remain informed about the various tools under development. More specifically, the Hub will provide building data gathered to assess and evaluate actual buildings for the purposes of tool development and analysis. The Hub identify buildings in the Philadelphia area of varying types and sizes as sources of building data to support piloting of the Asset Scoring Tool that NREL and PNNL are developing. The Hub will also explore use of the Asset Scoring Tool to collect its baseline data on buildings in the Philadelphia region, and will provide verification data on energy conservation measures as it becomes available for use by the Building Component Library. The Hub has greatly benefitted from having a member of the NREL OpenStudio team stationed at the EEB Hub since April 2012 and will pursue continuation of this arrangement in some form in BP3.

SUBTASKS

2.1: Design Advisor

Lead: Leon Glicksman, MIT, glicks@mit.edu, 617-253-2233

Description: This Subtask will develop and demonstrate a simulation tool for predicting building performance based on the fundamentals of physics for use by architects, planners and engineers engaged in the early phases of an integrated design process for a new construction or retrofit project. This subtask directly contributes to achievement of Deliverable Number 1.

One of Design Advisor's advantages is its simplicity so that non-technical architects can learn to properly use it without a long learning curve. It does not offer more technical features than Simergy (and EnergyPlus), rather it simplifies and reduces the complexity while focusing on the key parameters. It is based on the fundamental building physics with a simplified model specifically developed to meet these needs. The goal is a tool that is very easy to learn and use which allows the user to input different retrofit scenarios and evaluate the relative performance against each other. The inputs are easy to understand and quick to complete. For early design of a retrofit, Design Advisor (DA) would be a tool in the early conceptual phase. When detailed design is completed, EnergyPlus can refine the energy analysis. An early version of Design Advisor has been under development and use for the past 6 years. It is presently available on line and we have users from a number of countries. The targeted users are educators of architects and practicing architects who may not have a deep level of technical training. It is also useful to more technically trained users who want to quickly execute a simulation.

One new feature we are adding is a determination of the potential energy savings from building recommissioning based on a regression analysis of actual historic recommissioning data. If we are truly interested in energy savings in Philadelphia in the next 7 years for commercial buildings, recommisioning offers the potential for the largest impact for energy savings at modest initial coasts and with immediate impact. To our knowledge, no other tool has this capability. A recently completed PhD at MIT demonstrated a novel multilevel regression technique that yields heating, cooling and lighting energy predictions that agree closely with the full Design Advisor runs for different geographic locations. This can lead to very rapid optimization offering suggested design paths to architects. In future years of our research, we envision the development of a stand-alone app of Design Advisor for smart phones and tablets.

To contrast Design Advisor with other programs, a principle feature is simplicity allowing architects with modest technical training to perform preliminary energy projections. In comparison, the Simergy web site states: "The audience for version 1 of Simergy is mechanical engineers, energy modelers, energy analysts, technical architects and technical consultants, which means it has a degree of complexity and a learning curve to it.

Performer Scopes of Work

MIT: The Design Advisor is a tool is intended for the early design stages. It is particularly aimed at architects, planners and engineers engaged in the early phases of an integrated design. There is a need for a simple accurate simulation and design program for building performance based on the fundamentals of physics: thermodynamics, heat transfer, fluid flow, optics, controls, and atmospheric science. The challenge is to develop an integrated program which retains the important building physics and at the same time is accessible to architects, planners, developers and energy consultants. This will enhance the ability of architects to take a holistic approach to design of retrofits and new buildings. The program must allow easy access to users at different skill levels. The urban weather generator will be linked to Design Advsior to provide boundary conditions for the energy flows at the building envelope. It will include simulations of performance improvements from façade retrofits and new designs

(windows, insulation), lighting upgrades (daylighting enhancements, controls), HVAC systems (continuous commissioning, hybrid systems, heat recovery, chiller upgrades). It will contain community level weather that allows simulation of energy saving controls such as night flushing and temperature setbacks.
Data from typical Philadelphia buildings, gathered from other tasks in the Hub will be also used to assess accuracy in predicating overall energy use. The goal is the capability of predicting energy use in the studied types of commercial buildings with accuracy of +/- 15% for the parameters included in Design Advisor and the Urban Weather Generator.

Penn: The T.C. Chan Center will support the activities of subtask 2.1 EEB Hub Design Advisor by supplying information and analysis regarding the characterization of building systems, such as HVAC and lighting, to assess and improve the accuracy of the new simulation tool being developed. The T.C. Chan Center will assign one research associate to the support of Subtask 2.1. Supported activities will include literature review, review and support of fellow task members' work, and energy modeling as required.

CMU: CMU will conduct parametric modeling for a series of generic HVAC systems in the high order building simulation program of EnergyPlus, using Philadelphia, PA as the environmental boundary conditions, to derive accurate reduced order models for the Design Advisor tool of MIT. CMU will also conduct high order whole building energy simulations to verify and calibrate the building and HVAC simulation of the Design Advisor tool so as to support the achievement of the required +/- 15 percent accuracy. This team will also develop a web-based user-friendly GUI for the customizable visualization of detailed simulation results generated by the Design Advisor with varying temporal and spatial resolutions.

2.2: Energy Audit Tool

Lead: Robert Leicht, Penn State, rmleicht@engr.psu.edu, 814-863-2080

Description: This subtask will develop and demonstrate a rapid, reliable building energy audit tool and its accuracy in at least 20 buildings with at least 20 percent reduction in required level of effort for operation compared to similar tools currently in use or available. This subtask directly contributes to achievement of Deliverable Number 1.

The EEB HUB audit tool is targeted at a facilitating an initial walk through (Level I) audit through rapid data collection and analysis. The analysis is targeted (and trending) within 15% error to annual energy consumption when uncalibrated, and similarly 5% for calibrated data based on very limited data input (10-100 parameters). The development of the analytical engine was originally supported by a previous SERDP project and an ongoing ESTCP project. The targeting of Level I audits coupled with automated screening of energy conservation measures are the critical differentiators – with more than 30 pre-built Energy Conservation Measures already incorporated into the tool for energy analysis, the pre-screening capability is intended to provide a more thorough and rapid (1 minute) analysis of options for energy savings for the minimal data collected. In addition to the energy savings, the tool has incorporated cost analysis to provide both energy and costing evaluation for the audited projects, to focus on providing direction to owners for proper considerations of Advanced Energy Retrofits. The energy audit tool does not directly compete with any other programs, and two face to face coordination meetings have already taken place with the SimuWatt team.

Performer Scopes of Work

Penn State: The efforts in BP3 for the Energy Auditing Tool will focus on three areas. These are: 1) refinement and validation of the accuracy of the energy modeling performance, notably through extended data collection; 2) developing a cloud infrastructure to improve the information flow from the field data collection to the analysis, with return of the analysis to the iPad for presentation of results; and 3) improvement to the presented outcomes, notably for economics, to support understanding and decision making for capital investment planning for AER projects with the intent of moving toward clearer ROI decision making support. BP3 denotes a shift in the focus for the energy auditing tool toward a deployment phase, with the first half of the year dedicated to validating the core functions and embedding advanced modules, and the latter half working to develop the support and examples necessary to move the tool into the market. The Penn State team will be involved in all three aspects of the project in BP3, with emphasis on improving the data flow focused on the mobile device integration and supporting the development of improved data presentation for the economic and energy results to support decision-making. Penn State will oversee the effort for integrating the presentation of energy analysis and economic results into the iPad application, expecting to have core features developed by the end of Q1 with refined presentation per work with Balfour Beatty by Q2. Penn State will also lead the development of the visualization for the data outputs to support decision making. Penn State will play a supporting role in the refinement and validation, with a focus on the assessment of the data collection reliability through interface testing in conjunction with the ongoing validation and case study effort. Penn State will also facilitate the establishment of the protocols and methods needed for the broader range of mixed mode and envelope mode dominated building.

UTRC: UTRC will lead the development, verification and validation of an integrated audit and retrofit analysis process to provide buildings total energy demand and savings with accuracy of +/- 15%. In particular, UTRC will test its modeling approach when integrated with other tools and methods including parameter calibration tools and methodologies (e.g. the uncertainty quantification and sensitivity analysis tools), the economic analysis tool and ECM costing, and potentially with tools that enable levels II and III audits (e.g. NREL's Concept 3D audit tool). The team shall also deliver analysis tools critical for rapid, cost effective advanced energy retrofit (AER) design that enables building stakeholders to identify sources of uncertainty and to predict results within 15% error in energy savings. Focus of proposed BP3 work will be on standard work, improving tool usability and expanding analysis capabilities. The UTRC team will also deliver analysis tools critical for rapid, cost effective advanced energy retrofit (AER) design. The analysis tools will enable building designers to identify sources of uncertainty, pinpoint modeling errors, and ensure design intent is met and maintained during building operation. This capability is critical to ensure Task 2 target is met and simulation prediction is within ±15% of actual building energy performance, given model inputs uncertainties. The team will leverage this capability for risk analysis to enable more aggressive investments in retrofit solutions. Analysis tools will also provide automated model calibration and optimization capabilities. Analysis tools have interface that allows for seamless integration with any simulation platform (TRNSYS and EnergyPlus integration demonstrated in BP2). In terms of scale, features, automation and interfaces, analysis tools delivered in BP2 provide game changing technology that has not been available to building practitioners. Focus of proposed BP3 work will be on improving usability and developing interactive user interface for analysis tools. Audit Tool will be used as the prototyping platform for the analysis process flow and user interface. Target for BP3 is to deploy analysis tools to at least three projects within the Hub and one A&E firm, and measure impact on processes there. Accuracy of methods employed will be demonstrated by calibrating AER model for a Navy Yard building with respect to sensor data, and demonstrating improved predictive capability. Analysis tools will be available for widespread dissemination in BP4.

Balfour Beatty (BB): BB will lead the methodology for lifecycle costing and capital investment planning with the goal of improving integration of energy conservation measure adoption within strategies for evaluating AER projects and leveraging the data developed in the Energy Audit to feed the integrated design process. To develop this capability, BB will lead the methodology development for including initial cost, lifecycle energy cost, and operations and maintenance costs into the decision process. In addition, BB will develop a tool framework to accept the analytical output from the audit process and carry that data forward into an integrated design process using target value design principles. BB will support the case study validation through the performance of pilot data collection and energy analysis through parallel comparison of the traditional process with the process performed with the Energy Audit Tool for five pilot projects in the Philadelphia region. BB will also focus on the owner value proposition and conduct an owner driven workshop to identify key value drivers from Owner's perspective that move energy retrofits forward from energy audit – this information will be used to inform the Energy Audit Tool outputs to increase percentage of audits that lead to AERs.

2.3: Retrofit Manager Tool

Lead: Jelena Srebric, Penn State, jsrebric@psu.edu, 814-863-2041

Description: Activities: Develop and demonstrate the Retrofit Manager Tool (RMT) with and accuracy range of +/-15 percent for at least 10 buildings to estimating building HVAC energy, lighting loads, and infiltration rates. This subtask directly contributes to achievement of Deliverable Number 1.

Performer Scopes of Work

Penn State: A new simulation tool, called Retrofit Manager Tool (RMT), is under development to address needs of facility mangers that make critical decisions for building renovation and maintenance. The Greater Philadelphia region includes several different groups of facility managers that are being recruited to provide feedback for RMT development. The tool has five distinct areas of development: 1) simple interface that requires only a few parameters for a particular building; 2) middleware to connect the interface with three simulation engines; 3) energy simulation engine; 4) daylight simulation engine; and 5) air flow/quality simulation engine. The work that is already underway in BP2 is creating the main dataflow structures for the first three. This initial effort is to be expended to include daylight and air flow/quality simulation engines. The tool will be demonstrated for Navy Yard renovation projects in BP3. A retrofit of the existing lighting system and related control devices offers a significant opportunity for energy savings in many AER projects. This work will incorporate an array of lighting retrofit options into the RMT while expanding and applying the Daysim modules that were developed in BP2. The following project activities are envisioned:

- Coordinate the lighting/daylighting development work for the RMT.

- Conduct one or more workshops or webinars to collect information from facility managers regarding the features they would like to see in the RMT.
- Research, evaluate, and finalize the existing lighting and daylighting retrofit options that will be included in the initial version of the RMT.
- Study and determine what input quantities and modeling processes are necessary to assess the impacts of the available retrofit options in the lighting and daylighting systems to the desired level of accuracy, and implement these within the RMT.
- Validate the lighting and daylight modeling predictions against available case studies.
- Develop a simple interface to OpenStudio for Daysim that can also serve as a standalone interface to study and optimize photocontrolled electric lighting systems.
- Further enhance Daysim with automated layout and design decision tools, such as automated zoning, photosensor placement, etc., and implement the forthcoming five-phase complex fenestration modeling algrorithms/programs from LBNL into Daysim.

The RMT tool will address building classes currently under development based on the USGBC database. The building classes have sets of attributes that will be default inputs into energy simulation engine. This approach allows for a quick asset rating and scanning for retrofit opportunities in each of the building classes. RMT tool will be demonstrated in renovation projects to take place at Navy Yard in BP3. The main efforts will include:

- Development of the web-based interface
- Debugging of the connection with OpenStudio which is the middleware for RMT
- Identification of building class attributes crucial for achieving the 15% accuracy of energy consumption predictions
- Demonstration of RMT tool and feedback from facility manager focus groups
- Identification of framework for use of all three simulation engines on a retrofit project

Proper whole-building simulation requires correct handling of airflows, both intentional (HVAC) and unintentional (leakage, infiltration). Interactions of air flows, contaminant sources, and heat transfer can be significant, but few energy modeling packages offer complete, coupled simulation capabilities. OpenStudio does not support airflow modeling, and available airflow modeling tools are not easy to use. Goals for BP3 are to add necessary facilities to OpenStudio to support single-model airflow simulation and cosimulation with CONTAM, and to continue development of a simplified airflow modeling user interface ("PrjBuilder") ultimately capable of generating calibrated models. OpenStudio offers a unique opportunity for the integration of many simulation tools in a single, open source platform. Addition of airflow modeling capabilities will enable better whole-building energy modeling. Addition of high-level airflow objects to the OpenStudio software development kit (SDK) will support multizone airflow simulation and make it more accessible to non-specialist users who may be unfamiliar with multizone modeling. Unlike NIST's ContamW interface, which targets all users of CONTAM, PrjBuilder is an "express" interface for inexperienced or non-specialist users. A simplified interface will allow more users to become familiar with the underlying techniques, and will support transition to the use of the full CONTAM package.

2.4: Simulation Platform

Lead: Jelena Srebric, Penn State, jsrebric@psu.edu, 814-863-2041

Description: Develop a web page featuring the three simulation tools and their components available for commenting and review by future stakeholder groups. This subtask directly contributes to achievement of Deliverable Number 1.

Performer Scopes of Work

Penn State: The simulation tool platform will be part of the existing EEB Hub web page to feature the simulation tools under development in Task 2. All of the tools will be cloud-based tools that will be hosted on a virtual machine, so future users will not need to install software on their local machines. It will be sufficient to have access to internet and browser to run simulation stools currently under development in Task 2. This approach will enable for an easy access to software as well as an easy way to collect inputs from stakeholder groups while the tools are still under development. All of the demonstration simulations can be collected into a database of examples available for future developments of training materials. Srebric will manage this subtask and the whole Task 2 from the perspective of simulation tool platform development where ultimately all successful Task 2 projects will be featured. To deliver packaged products resulting from Task 2 research activities, the following three functions will be performed: energy modeling for retrofit projects; web programming for a simulation tool platform; and data management among simulation tools and simulation databases. Professional staff are being recruited to perform these functions and will provide vital services to EEB Hub performers and stakeholders and will speed up the technology transfer process while at the same time supporting the ongoing Task 2 projects.

Purdue: The objective of this investigation is to integrate Fast Fluid Dynamics (FFD) with an existing energy simulation software, Modelica. The FFD can be used to consider the impact of advanced ventilation systems on building energy use. The FFD will be further developed to have a better accuracy and a computing speed of up to 100 times faster than CFD. By collaborating with LBNL, the FFD will be integrated with Modelica through a data exchange module. The integrated programs will be validated by the measured energy data from Purdue Living Lab or energy data obtained from a commercial building in Philadelphia region approved by the EEB Hub with an accuracy range of □15%. The main deliverables are: 1) a reliable and fast FFD for achieving better accuracy of energy simulation by considering the impact of air distribution on energy; 2) an integrated FFD+Modelica platform to ensure that the input time will be no more than 24 hours; and 3) validation of the integrated program for a building with high quality data.

IBM: IBM will lead the cloud implementation of the tools with focus on the design and deployment of the infrastructure leveraging progress in BP2 from efforts with the inverse modeling analysis. This work includes the following activities:

- Design and implement a cloud-based IT architecture for supporting web-based tool of inverse modeling of building enclosure and a framework for data interface with other simulation tools that will be developed in Task 2 n BP3
- Develop a cloud-based web application tool for inverse model for building enclosure with data interface and decision support user interface. In parallel, the IBM team will enhance its inverse model capabilities by enabling the tool availability on the cloud as a service,

automate building performance evaluation and cross-validation in the auditing process with the forward modeling approach

- Further integrate the inverse modeling of building enclosure data with the interface and forward modeling through refined clustering values which align the data collection from the field with clustering indicators and forward modeling inputs
- Develop an integrated quantification method for computing uncertainties associated with thermal parameters recovered from the inverse model and estimated energy savings for improved decision making
- Develop a cloud-based, user-friendly simulation (what-if) capability for predicting energy savings of building envelope related retrofits and set points changes within +/- 15% accuracy using basic utility data, building geometry and weather data and providing decision support for retrofits

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