INTRODUCING A FRAMEWORK FOR ADVANCING BUILDING ENERGY MODELLING METHODS & PROCESSES

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ABSTRACT

Current interest in building energy efficiency is driving an increase in demand for building energy modelling (BEM) services. Yet practitioners are challenged to deliver BEM services effectively and consistently. Contributing to this is an expansive knowledge requirement, the lack of standardized methods and the absence of defined processes. This paper introduces the concept of a BEM methods and processes (M&P) framework. The effort involves examining modelling M&P tasks across modelling applications, creating a structure for organizing them, and specifying the detailed development of shared components. Ultimately, the defined M&P components will be referenced in modelling application guidelines.

INTRODUCTION

Confined to tight meeting quarters, we arranged our chairs in a circle and replaced writing tables with end tables. The meeting commenced with attendees introducing themselves, sharing their motivations for attending and personal stories. After the final introduction was made, one lively participant succinctly characterized the scenario by exclaiming, "Hello Ellen. Welcome to the group!"

This sounds like one of many support groups whose members meet to work collectively through their pasts in order to move forward with their futures. I admit that the group provided an outlet for my own modelling angst but the meeting served a broader purpose. Our group was comprised of thirteen professionals working within the building energy industry. We were the Building Energy Modelling (BEM) Methods & Processes (M&P) break-out group, which came together during the Building Energy Modelling Summit (BEM Summit) held in Boulder, Colorado in March 2011. The Summit was developed, organized and hosted by the Rocky Mountain Institute (RMI). RMI is a non-profit organization whose mission is to reduce the U.S. dependence on fossil fuels. The Summit, considered by some die-hard building scientists to be the ultimate party event, brought together about 60 stakeholders within the BEM industry for a 2-day workshop. The intent of the gathering was to address major issues facing the U.S. energy modelling community that hindered modelling to best support widespread solutions for low-energy buildings. Participants included BEM industry professionals employed as: practitioners, educators, researchers, policy makers, software developers, and customers of services. Break-out groups were formed to identify issues, discuss solutions and develop actionable work plans (Tupper, 2011a, Tupper, 2011b).

I facilitated the BEM Summit M&P break-out group with the help of Ron Nelson of the Institute for Market Transformation (IMT). The scope for our group included examining current BEM methods and processes and identifying major issues. We developed a business-as-usual (BAU) statement to characterize BEM services in the U.S., which stated the following.

- A variety of BEM methods and processes are being applied without differentiations being made between applications (e.g. modelling being done to make design comparisons, to meet certification/code requirements, or to predict actual consumption).
- The above approach contributes to customers' expectations being mismatched to service offerings and diminished credibility for BEM.
- There is a lack of feedback and continued use of models over the building life cycle.

The BAU led us to identify the top challenges for M&P, namely:

- A variety of methods are being applied
- No differentiation in methods are being made across applications
- There is a lack of defined methods for performing key tasks, including: sensitivity analysis, M&V, and design feedback.

Our ensuing discussion could have focused on advancing a single, key BEM method. However, it did not. Instead, we delved into broad considerations for meeting challenges to advance methods. Our work plan outlined critical M&P needs, including:

1. Developing a customer brochure that defined scopes of work for three categories of modelling

applications (comparison, compliance, or prediction),

2. Creating a BEM M&P Framework to direct the development of BEM methods,
3. Producing a white paper describing the Framework, and
4. Seeking funds to get standardized methods and modelling guidelines developed.

Since March, we've gained traction on several items. Linda Morrison (Ambient Energy) incorporated suggested content for the customer brochure into a document being prepared for the Colorado Governor's Energy Office (CO GEO). It has been published as "Energy Modelling: A Guide for the Building Professional" and is available on the CO GEO website. Tom White (Green Building Services) recorded ideas from our discussion in the form of a draft white paper. I championed the BEM Framework – pledging to develop the concept further until it can become absorbed into industry efforts. This paper presents the original concept for the Building Energy Modelling Framework and new considerations for its future development.[1]

A VISION FOR THE BEM METHODS AND PROCESSES FRAMEWORK

Over the last few months while contemplating the BEM Framework, I have been involved in some other efforts for improving modelling effectiveness that are proving to be quite complementary. They include: organizing an industry review for COMNET[2] through IBPSA-USA, being an active member of the COMNET quality-assurance committee, contributing to a modelling education plan through IBPSA-USA, developing an education curriculum with the Northwest Energy Efficiency Alliance (NEEA) for achieving deep savings in existing buildings, and creating in-house modelling tools to improve RMI's modelling process. Recently, I've come to appreciate that the BEM Framework has the potential to pull together, leverage and direct all of these efforts. Specifically, it can go beyond defining modelling methods and also address: 1) the modelling process, 2) modelling quality control/assurance efforts, 3) modelling tools and 4) modelling training. A vision for a new and improved way to conduct modelling through this expanded view of a BEM Framework is presented below.

Imagine providing modelling services by following a modelling path comprised of defined, sequential tasks. For nearly all modelling applications, an effective modelling process is defined. Tasks that are common across paths are detailed in a single library of BEM procedures and industry-specified methods. As part of this, the nature of each task is recognized. The approach outlined to address some tasks involves judicious assessments. Other tasks that encompass mindless repetition are automated in tools. Modelling training is available that is consistent with the defined processes, tasks, procedures and methods. Firms no longer have to develop these resources independently since the groundwork is laid and the basic tools are available for providing modelling services.

If this vision is adopted as the end goal for the BEM Framework then we will need a broad and coordinated effort to define and implement it. Specifically, we will need to define the tasks comprising different modelling applications, identify the common tasks across modelling applications, create methods to address all key tasks, and develop guidelines that reference the accepted methods. We'll also want to ensure that these processes are being referenced by customers in scopes of work. A series of steps proposed for accomplishing this is outlined below.

1. Define sequential tasks for carrying out modelling applications
2. Identify tasks shared across applications
3. Define core procedures and deviants associated with shared tasks
4. Define core methods and deviants associated with shared tasks
5. Create BEM Framework that shows commonalities of shared procedures and methods across modelling applications
6. Define industry-accepted shared procedures
7. Develop industry-accepted shared methods
8. Make shared procedures and methods available through a BEM M&P Library
9. Update and maintain the BEM Framework and BEM M&P Library as new approaches, techniques and tools are developed
10. Define Minimum Analysis Requirements for a given modelling application that outlines nominal scope, level of detail, quality control/quality assurance considerations.
11. Develop modelling application guidelines that group and address related modelling applications and draw from the BEM Library and Minimum Analysis Requirements
12. Develop scope-of-work templates that users of modelling services can draw from to define their project modelling requirements

The steps stem from a collective view of a handful of professionals that gathered at the BEM Summit regarding the modelling industry and its most pressing needs. The approach has been informed by

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[1] This work has been supported through funding provided by RMI and the Energy Foundation.

[2] Efforts for automating the creation of an ASHRAE 90.1 baseline building within simulation software are being addressed by COMNET (see http://www.comnet.org/).

the experiences I have had delivering modelling services in today's exciting but challenging environment. This is a big effort, which has spawned from the minds of a few. However, it is my hope that introducing it to industry will start a dialogue and lead to the development of an integrated action plan that can be adopted by a broader group of BEM stakeholders

Definition of Terms

An elaboration of the BEM Framework will benefit from a clarification of terms. Discussing its concepts involves making distinctions between modelling elements, task characterizations and subtle differences in definitions. Table 1 outlines useful terms and lists my interpretation of their meaning as applied to this discussion.

Table 1
Explanation of terms

DESCRIPTOR	MEANING
Judgment	A modelling task that requires opinion or discernment to complete
Procedure	A modelling task that can be defined through a series of steps
Method	A modelling task that is complex and requires following an industry-accepted technique
Process	A series of modelling tasks completed to achieve an end result, e.g. integrative design modelling process
Modelling Application	A modelling process specific to a particular use for modelling, e.g. integrated design assistance
Quality Control	Activities incorporated into a modelling task undertaken to ensure adequate quality
Quality Assurance	Activities following a modelling task undertaken to ensure adequate quality
Bridging Tool	Simplified tools that fill modelling needs not yet supported by a simulation tool
Support Tool	Simplified tools that fill modelling support needs not directly related to whole-building modelling
Simulation Tool	Detailed, whole-building simulation analysis tool

Task Characterizations

The first step proposed for this ambitious undertaking is to characterize modelling applications as a series of sequential tasks. Just recently, a solid list of modelling tasks emerged as part of an energy modeller job characterization in a public review draft compiled by the National Renewable Energy Laboratory (NREL), a U.S. Departmentof Energy (DOE) research laboratory, through an expert group consensus process. DOE is sponsoring this project to develop 1) the job task analyses and 2) knowledge, skills and abilities for six commercial building job categories, including building energy modeller. The goal is to create national guidelines, which will define a body of knowledge that any training organization can align to. The General Services Administration and the Department of Energy will also use the body of knowledge to help meet the requirements of the Federal Buildings Personnel Training Act of 2010.

I've slightly modified the published DOE modeller task list to address modelling tasks commonly completed to deliver integrated design assistance services. The task list is provided in Table 2.

In the table, I've also made an initial characterization of the nature of the task based on my experience and indicated a general approach for addressing them. The characterization indicates the level of codification appropriate for the task and the nature of its library component. This categorization is helpful since it can inform the need to develop new procedures or methods. For example, we may agree that:

- No attempts to codify tasks requiring judgment will be undertaken although general considerations for addressing them may be included within published BEM guidelines.
- The tasks that are characterized as procedures will be outlined as a series of steps agreed upon by industry experts. These will be library components.
- The tasks characterized as methods will require the development and vetting of industry-accepted techniques before being included as a library component.

I've included two more task attributes to the table that I believe also distinguish the best approach needed to address each. They include the applicability of QC/QA and the benefit of using a tool to accomplish the task. Based on my experience, I've indicated which tasks would benefit from having a QC/QA element. For these tasks, their results could have significant impact on the project direction, outcome and/or accuracy. Thus, their formalized, developed approach should include procedures for performing self-checks and/or reviews by senior modelers. If the task includes a tool consideration, it has the potential for some or all of its completion to be incorporated into simulation software or a support or bridging tool.

The task characterizations listed in Table 2 provide a reasonable starting place for envisioning the basic content and nature of a shared library of BEM procedures and methods. The characterizations can become more refined with time, which will inform the nature of their associated approach and specifications for their refinement.

Procedures and Methods Characterizations

The original idea behind the BEM Framework was to identify common methods (e.g. benchmarking, calibration, uncertainty analysis) across different modelling applications and define them once for others to reference in published BEM guidelines.

During the Summit, the M&P break-out group explored project characteristics that play a role in differentiating methods across common modelling applications as a starting place for identifying common methods.

To undertake this, the group performed a modelling applications "slicing and dicing" exercise. This included developing a list of common applications and describing attributes that might indicate overlaps in methods. I added a new field to the original matrix - the basis for making analysis comparisons. Table 3 summarizes the attributes considered. Table 4 outlines the results of the initial slicing and dicing effort. As organized in Table 4, the patterns for identifying and grouping common methods across applications are not immediately apparent. However if we identify the influence (see Table 3) that these attributes have on the modelling process, it reveals some important considerations for grouping.

The attributes of the applications and nature of their associated tasks suggest an initial form for the Framework that includes:

- The definition of core procedures and methods that apply across all/most modelling applications
- The definition of deviant procedures and methods that apply to a few modelling applications

In an attempt to improve my ability to categorize core and deviant attributes for methods across applications, I added some simplifying conventions to help better distinguish them. These conventions resulted in an improved organization and clearer categorization of the methods, as outlined in Table 5.

- Divide the applications that spanned design phase to operation into separate design and operation component.
- Perform a strict interpretation of the modelling objective to bound the analysis scope. For instance, LEED modelling was considered to be compliance modelling even though it is often accompanied by modelling that supports an integrated design approach. These efforts were considered to be distinct from each other and addressed in two separate applications.

From this cleaner discretization, new patterns emerge that inspire an approach for making distinctions between core and deviant method components. I have depicted this approach graphically in Table 5 and used Benchmarking as an example method. As shown in the table, the key attributes considered for distinguishing the modelling applications are: 1) modelling objective, 2) life cycle phase, and 3) basis for making performance comparisons. I also surmised that all modelling applications rely on making some sort of performance comparisons. Thus, the core methods are rooted in meeting this analysis requirement. It follows that deviants from the core methods are expected for compliance and prediction applications. Of course the deviant considerations for

Table 3
Attributes of Modelling Applications

APPLICATION CHARACTERISTIC	**POSSIBLE VALUE**	**INFLUENCE**
Modelling objective	Comparison, Compliance, Prediction	The level of detail the model requires
Project phase	Schematic Design, Design Development, Construction Documents, Construction, Operation	The sources of information available for characterizing model input; the way the model is used to inform
Basis for input data	Standardized, Projected, Actual, Adjusted Actual	The level of detail the model requires, the sources of information used for characterizing the model input
Basis for making comparisons	Proposed versus Standardized Baseline, Design Baseline, Actual, or Sector	The level of detail the model requires, the sources of information used for characterizing the model input

these two different objectives are different from each other. Table 5 shows with colors and cross-hatching the range of core and deviant methods that need to be defined across the applications listed. Core methods that take into account different analysis needs that occur across the building life cycle are shown by a change in color intensity. Since five design phases were considered, five variations of core methods are depicted. The deviants to the core methods are shown by different types of cross-hatching. In the table, two types of cross hatching appear for those deviant methods to be applied to compliance and performance prediction applications. Thus, five variations in core methods and two flavors of deviants of each core method appear to define methods for benchmarking across all modelling applications. However, a benchmarking task may not occur in the modelling process during each life cycle phase for each application. Thus, another filter should be applied to Table 5 to take this into account. For example if benchmarking is only completed in schematic design, construction documents and operation, there will need to be only 3 core variations and two flavours for deviants applied across the core methods.

The process can be repeated for other modelling methods and procedures. The resulting categorization of shared methods/procedures can direct the specification of methods, their creation and the development of the BEM M&P library.

MOVING FORWARD

Achieving this grand vision will undoubtedly involve a multi-year effort requiring substantial developing, vetting, and testing. Thus, it will not provide a short-term solution for current BEM M&P needs. However, many BEM Framework elements can serve as useful stand-alone resources and be shared as developed. They can support interim efforts for advancing modelling methods. Some applications for BEM Framework products include:

- Use task outlines for different modelling applications to inform training curriculums
- Develop customer templates for outlining project modelling requirements
- Develop minimum requirements for providing different types of services (e.g modelling to support energy conservation measure evaluation, integrated design assistance or deep energy savings in existing buildings)
- Identify the existence of and need for new BEM bridging and support tools
- Drive the development of the needed new BEM bridging and support tools
- Encourage the sharing of BEM bridging and support tools through creative commons licensing agreements
- Develop a formalized process for vetting new BEM methods and getting industry acceptance
- The continued development of the BEM Framework concept will support a coordinated standardization effort for BEM methods and processes. The concepts presented in this paper are a starting point for this effort. They are intended to generate discussion and further thoughts on the topic. RMI welcomes the opportunity to work with interested individuals and organizations motivated to further this effort.

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Table 2
Characterization of Integrated Design Modelling Tasks

Tasks		Approach			Elements	
		Judgement	Procedure	Method	QC/QA	Tool Support
Define project objectives	Perform preliminary climate and site analysis		X		X	X
	Perform benchmarking			X	X	X
	Perform conceptual energy analyses		X			X
	Review Codes, standards, and protocols	X				
	Review project requirements	X				
	Develop internal project work plan	X				
	Research codes, standards, and protocols	X				
	Set target goals	X			X	X
	Set baselines	X				
	Select analysis method	X			X	
Gather project data	Define modeling data requirements	X			X	
	Compile information resources	X				
	Resolve data gaps	X				
	Collect onsite data (existing building)	X				
	Assess existing conditions (existing building)	X			X	X
Specify baseline building	Recognize baseline methodology			X	X	
	Specify baseline building envelope system		X			X
	Specify baseline lighting system		x			X
	Specify baseline HVAC system		X			X
	Specify baseline domestic water system		X			X
	Specify baseline process loads		X			X
Develop project alternatives with design team	Brainstorm facility improvement measures	X				
	Package measures into project alternatives		X		X	X
	Identify supplemental modeling requirements	X			X	
	Collect incremental costs	X				
Construct models	Develop and record key project assumptions		X		X	X
	Divide building into thermal blocks	X			X	
	Specify project simulation analysis parameters	X				
	Specify site conditions	X				
	Construct model geometry		X			
	Build opaque constructions		X			
	Build fenestration constructions		X			
	Specify internal lighting load		X			
	Specify occupancy loads		X			
	Specify process loads		X			
	Specify infiltration loads		X			
	Specify schedules		X			
	Specify ventilation		X			
	Develop HVAC systems		X			
	Specify service hot water loads/systems		X			
	Specify onsite generation systems		X			
	Specify performance curves		X			X
	Specify control sequences		X			X
	Specify building site electric/gas loads		X			
	Integrate supplemental customized calculations		X			X
	Specify utility rates		X			X
	Create models that reflect project alternatives and baselines		X		X	
Evaluate model results	Run simulations		X			
	Perform quality control			X	X	X
	Calibrate model against measured data			X	X	X
	Compare project alternatives		X			X
	Perform economic analysis		X			X
	Develop recommendations	X			X	
Communicate analysis results	Create report	X			X	X
	Guide decision making of stakeholders	X				
	Complete compliance documentation		X		X	X
	Record project take aways					
Finalize Design Model	Review construction documents, specs, cut sheets		X		X	
	Update model	X				
	Update compliance documentation		X		X	X
	Create final report	X				

Table 4
Characterizing Modelling Applications

Application Name	Description	Applicable Project Type	Applicable Lifecycle Phase	Modeling Objective			Basis for Model Input Assumptions				Basis for Proposed Design Comparisons			
				Comparison	Compliance	Prediction	Standard -ized	Projected	Actual	Adjusted Actual	Standardized Baseline	Design Baseline	Existing Building	Building Sector
Asset rating	Assess performance based on components specified in design	NC	SD, CD	X			X							NC
Design ECM evaluation	Evaluate energy efficient design alternatives	NC, EB	SD, CD	X			X					NC	EB	
Integrative Design Assistance	Evaluate integrated strategies for improved performance	NC, EB	SD, CD	X			X					NC	EB	
LEED D&C Compliance	Evaluate design performance relative to a certification baseline	NC	CD, C		X			X		X	NC			
Efficiency Investment	Verify contractual requirements met per financing agreement	NC, EB	SD, CD, O		X			X	X	X		NC	EB	
Measurement & Verification	Verify energy efficiency savings relative to a normative baseline	NC, EB	O, SD, CD, C, O			X			X	X	NC	NC	EB	NC
Commissioning	Support diagnostics of components and systems	NC, EB	C, O			X		X	X			NC	EB	
Performance Rating	Assess performance based on the post-occupancy energy use	EB	O			X	X							EB
Operations	Evaluate impact of control and operational changes	NC, EB	O			X			X			NC	EB	
Outcome-based code	Assess performance relative to an outcome-based target	NC, EB	O			X				X				NC, EB
Integrated Project Delivery	Assess performance improvements attributable to design team, operators, tenants	NC, EB	O			X						NC	EB	

Notes: NC - new constructon, EB - existing buiding, SD - schematic design and design development, C - construction documents, O -operation

Table 5
Characterizing Core and Deviant BEM Methods

	Categorizing BEM Methods	Description	Life Cycle Phase	Modeling Objective	Comparison Basis	Model Input Basis	Benchmarking				
							SD	DD	CD	C	O
Modeling Applications	Core Methods										
	Design ECM evaluation	Evaluate energy efficient design alternatives	SD, DD, CD	Compare	Proposed vs Alternates	Projected					
	Integrative Design Assistance	Evaluate integrated strategies for improved performance	SD, DD, CD	Compare	Proposed vs Alternates	Projected					
	Additional Considerations - Design										
	LEED D&C Certification	Evaluate design performance relative to a certification baseline	SD, DD, CD	Comply	Proposed vs Baseline	Standard					
	New Construction Measurement & Verification - Design	Determine energy efficiency savings relative to a normative baseline	SD, DD, CD	Predict	Proposed vs Actual	Projected					
	Additional Considerations - Operation										
	Commissioning	Support diagnostics of components and systems	C	Predict	Actual vs Proposed	Projected					
	Efficiency Investment	Verify savings requirements are met per financing agreement	O	Predict	Actual vs Proposed	Projected					
	New Construction Measurement & Verification - Post Install	Determine energy efficiency savings relative to a normative baseline	O	Predict	Actual vs Baseline	Actual					
	Existing Building Measurement & Verification - Post Install	Determine energy efficiency savings relative to an existing baseline	O	Predict	Actual vs Existing	Actual					
	Performance Rating	Assess performance based on the post-occupancy energy use	O	Predict	Actual vs Sector	Actual					
	Operations	Evaluate impact of control and operational changes	O	Predict	Actual vs Existing	Actual					
	Outcome-based code	Assess performance relative to an outcome-based target	O	Predict	Actual vs Baseline	Actual					
	Integrated Project Delivery	Assess performance improvements attributable to design team, operators, tenants	O	Predict		Actual					

Note: SD - Schematic Design, DD - Design Development, CD - Construction Documents, C - Construction, O - Operation
Solid color - core method distinguised by project phase; Single hatch - core method plus additonal details related to compliance Double hatch - core method plus additonal details related to attempting to predict actual performance