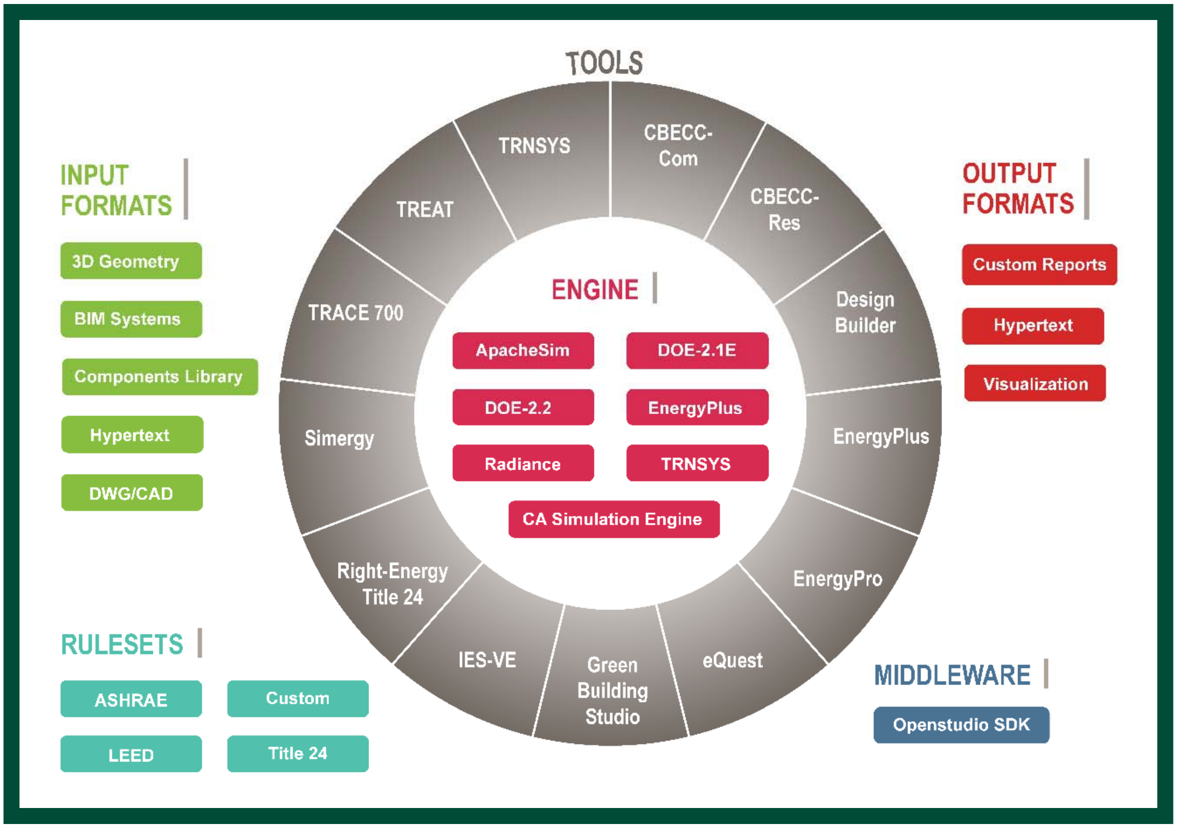
SCE Building Energy Modeling Roadmap

ET14SCE7050



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Disclaimer

EXECUTIVE SUMMARY

Southern California Edison (SCE) is a California leader in the subject of building energy modeling (BEM); having previously commissioned and provided industry training for tools such as eQUEST, EnergyPro, AGI32, SPOT and Dynamic Radiance. In turn, SCE's customer programs have long relied on BEM tools. SCE's programs use modeling tools to demonstrate energy code compliance, calculate margins of compliance for customized programs such as Savings By Design, calculate energy savings for deemed programs, and evaluate new emerging technologies.

Now, statewide policy changes and industry demands are quickly transforming California's BEM landscape. The California Energy Commission (CEC) recently modernized Title-24's refernence engines for demonstrating code compliance, the State continues to aggressively push for new construction to be Zero Net Energy (ZNE), and the building industry's dependence on predictive modeling continues to increase. The American Institute of Architects boldy proclaimed in their 2013 Progress Report that: "…design responsive to energy simulation is the solution to meeting current and increasing carbon reduction goals."[i]

At the same time, the US Department of Energy (DOE) is in the process of laying a foundation for BEM nationally by prioritizing initiatives that will further increase the use of BEM. The BEM industry in general show a trend towards open-source, developer-neutral, and computationally sophisticated tools. Software built-as-a-platform allows for iterative updates and improvements. Yet this also means that the BEM market is constantly evolving and the need to support customers in this space is growing. All of these developments, among others, have created a timely opportunity for SCE to assess involvement with BEM tools and to strategically plan towards optimized programmatic investments to support SCE customer needs.

Accordingly, SCE contracted with TRC Energy Services (TRC) to create this SCE BEM Roadmap (Roadmap). The primary goals of this work are to promote transparency and cross-collaboration amongst SCE's customer programs, optimize future expenditures and resources on BEM tools, and identify alignments with regulatory requirements, statewide policies, and industry trajectories. To develop the Roadmap, TRC interviewed key members of SCE's staff, industry stakeholders, attended DOE workshops, and incorporated findings from parallel industry-wide planning efforts. TRC conducted a total of nine separate in-depth interviews with SCE program staff, as well as two industry focus groups with nationwide leaders on the subject of BEM.

Based on extensive market research, TRC created a decision-making framework to guide SCE's future investment in BEM tools. This framework aligns with larger industry trajectories, seeks to create the clear value proposition to customers, and leverages SCE's existing CP&S Product Governance Process (a process for incorporating new ideas, technologies and measures into SCE's portfolio of customer programs). The pillars of this decision-making framework are as follows:

- **SCE Product Governance:** SCE should use the existing CP&S Product Governance Process for determining future involvements with BEM-related projects. This process promotes transparency, accountability, and supports methodical coordination across SCE's portfolio of customer programs.
- **SCE BEM Sub-Committee:** Upon submittal to the CP&S Product Governance Process, BEM-related projects should be reviewed on an as-needed basis by a BEM sub-committee, consisting of SCE subject matter experts (among others). This includes referencing the project in question with SCE's existing portfolio to help optimize expenditures and avoid duplicate work. Members of the BEM sub-committee should be up-to-date with industry trajectories and significant BEM-related efforts relevant to SCE.
- **Leverage Market Momentum:** SCE seeks to participate in BEM projects and developments that have the largest ratepayer benefit. One way to do this is by leveraging market momentum and contributing to BEM markets that have upstream policy and industry support. For example, EnergyPlus™ is a free, open-source simulation engine that is federally funded and is the workhorse for a variety of existing BEM tools – including CA's energy code compliance tool CBECC-Com. Supporting software frameworks that use EnergyPlus broadens the opportunity for a larger number of end-users to benefit.
- **Open Source, Non-Proprietary:** SCE BEM-related projects that are used to support customers should be open-source and non-proprietary. Source code and calculation methodologies should be made publicly available to support transparency and on-going incremental developments by an open market, and to avoid SCE dependencies on vendors with black box developments.
- **Avoid Commercialism:** User interfaces change frequently and operate in a highly competitive market, thus development contributions to individual user interfaces are likely to become quickly outdated. Supporting interface developments may also result in unintended endorsements of specific commercial vendors.
- **Encourage Interoperability:** SCE should seek to participate in projects that help to close the gap between engine capabilities and the end-user (customer) experience. A great way to do this, without favoring any particular commercial developer, is to invest in projects that support interoperability: the ability to work across multiple tools with minimal effort from the end user. Standardizing input and output files formats and streamlining incentive program requirements would encourage design teams to further incorporate BEM into their design processes.
- **Educate:** SCE provides free industry-leading education and training on BEM tools at their Irwindale and Tulare Energy Education Centers. As has been historically the case, these courses should evolve to reflect the latest needs of SCE customers. Web-based resources and forums for crowd-sourced reviews (such as IBPSA-USA's BEST Directory[ii]) are also examples of ways education can support customer experience with BEM tools.

Additionally, this report organizes 40 actionable recommendations based on specific needs from SCE's portfolio of programs (Table 1). SCE stakeholders can gauge and prioritize these recommendations to develop new BEM projects that are in alignment with the findings of this roadmap.

ABBREVIATIONS AND ACRONYMS

ACM	Alternative Compliance Method
ALCS	Advanced Lighting Control Systems
API	Application Program Interfaces
BCL	Building Component Library
BEM	Building Energy Modeling
CAHP	California Advanced Home Program
CASE	Codes And Standards Enhancement
CBECC	California Building Energy Code Compliance
CEC	California Energy Commission
CP&S	SCE's Customer Programs & Services
CPUC	California Public Utilities Commission
CSE	California Simulation Engine
CTA	Calculation Tool Archive
DEER	Database For Energy Efficiency Resources
DG	Distributed Generation
DOE	Department of Energy
DR	Demand Response
DSM	Demand Side Management
EE	Energy Efficiency

ES	Energy Storage
EUI	Energy Use Intensity
GHG	Green House Gases
GUI	Graphic User Interfaces
HERS	Home Energy Rating System
HVAC	Heating, Ventilating, and Air-Conditioning
IDSM	Integrated Demand Side Management
kW	Kilowatt
KWh/yr	Kilowatt-hours per year
LEED	Leadership in Energy & Environmental Design
LPD	Lighting Power Density
NREL	National Renewable Energy Laboratory
NRNC	Non-Residential New Construction
PCM	Phase Change Materials
PLS	Permanent Load Shift
RNC	Residential New Construction
SAAS	Software as a Service
SBD	Savings By Design program
SCE	Southern California Edison
TDV	Time Dependent Valuation
TPI	Third-party Implementer

TRC	TRC Energy Services
VRF	Variable Refrigerant Flow
XML	Extensible Markup Language
ZNE	Zero Net Energy

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INTRODUCTION

Southern California Edison (SCE) contracted TRC Energy Services (TRC) to prepare a company-wide roadmap on the subject of building energy modeling (BEM) tools. The roadmap laid out in in this report is designed to provide a detailed needs assessment for BEM tools and processes used by SCE's existing demand side management (DSM) programs, and to propose a decision-making framework for BEM-related efforts in the future.

This BEM Roadmap addresses two major objectives for SCE. The first objective is to identify, summarize, and prioritize both the immediate and long-term energy simulation needs as identified by SCE Program Managers. In order to determine SCE's specific needs for BEM tools, TRC conducted in-person interviews with SCE program managers. These in-person interviews provided rich data to document a range of immediate, short-term and longer-term requirements and requests from the perspective of various SCE programs. The needs assessment presented in this report balances this first-hand commentary with the available BEM tools available today. This report provides high-level summaries of major calculation methods and comparisons between methodologies rather than specific recommendations as to the best simulation algorithm for a given calculation. To provide additional detail, references for major calculation methods, as relevant to the assessment are provided. Inventory, analysis and review of existing proprietary, commercially available tools is out of the scope of this report; these tools and their capabilities are abundant and change frequently.

The second objective, builds on Objective 1 to develop a decision-making framework to offer clear guidance for future SCE investments and program planning with regards to BEM tools. BEM tools support both DSM incentive programs and code enhancement efforts for SCE's DSM portfolio. Informed investment in BEM tools can improve program cost-effectiveness, customer satisfaction with programs, and foster better communication between established program activities and code enhancement efforts. The roadmap incorporates industry trends and state efficiency policy drivers, in order to identify which future BEM developments are most likely to support achieving DSM goals. Smart development of BEM tools provide a valuable opportunity for SCE to cost-effectively realize business and policy targets. This framework is designed to support both informed investment and smart development decisions for SCE's consideration.

BACKGROUND

Today, software developers create platforms integrating various components into one package or tool; users can be easily confused as to the purpose and function of the various components. BEM tools components include data inputs, physics engines, rulesets, middleware, data outputs (and reports), and graphical user interfaces (GUI). BEM tools are used to establish project baseline and savings within the boundaries of computation time, thermodynamics simulation algorithms, and California energy code requirements. TRC gathered feedback from SCE program managers and industry experts to establish the history and context of BEM tool development.

SOFTWARE PLATFORMS

Since the early 2000's, software development in general has transitioned from one developer building an entire tool, to a team of developers coordinating development across complementary pieces of the tool.[iii] The complementary pieces of software development coined a new term, software stack.

A software stack is a group of programs that work in tandem to produce a result or achieve a common goal. Software stack also refers to any set of applications that works in a specific and defined order toward a common goal, or any group of utilities or routine applications that work as a set[iv]. Software platforms integrate collaborative software components into a functional end-user tool that can exchange data with one another. In BEM tools, the components can be categorized as follows:

- **Data Inputs:** The mechanism(s) by which a tool can receive data about a project or building. The most common data input mechanisms are manual data entry through the GUI, automated generation of inputs through input processors such as OpenStudio® for EnergyPlus, gbXML (a data exchange protocol for green building built with XML), and ASCII text files (a data exchange protocol that is similar to, but less powerful than gbXML).
- **Calculation Engine:** The collection of algorithms used to approximate thermodynamics, illumination, ventilation, and other energy-related calculations within buildings and to capture the energy performance of various systems and equipment.
- **Rulesets:** The set of assumptions referenced in a particular simulation (e.g., assumptions for weather, time-dependent energy use, schedules of operations, reference building baselines) that are neither part of the engine's core algorithms, nor part of a graphic user interface. California's Title-24 energy code compliance software, CBECC-Com. and CBECC-Res, are examples of rulesets.
- **Middleware:** Middleware is a software term originally developed to denote the software layer that allows newer applications to work on legacy operating systems but has since evolved to be defined more as a 'glue' that binds the other software layers together. In that sense, middleware enables two separate programs to interact with each other. Alternately, middleware is a software layer inside a single application that allows different aspects of the program to work together. An example in BEM applications is the OpenStudio SDK which is a core component of EnergyPlus.
- **Graphical User Interface:** The f*ace* of the platform, this is the component most often referred to by the user as *the BEM tool*. The GUI is the component

most often identified by the users as the platform. For example, when a user runs a simulation in DesignBuilder, the engine running the simulation is EnergyPlus, but because the GUI is DesignBuilder, the user may misunderstand that the entire platform is unique to DesignBuilder.

- **Data Outputs (and reports):** The mechanism(s) by which a tool can export data from a particular simulation. The most common outputs are: display through the GUI, gbXML, ASCII text files, and PDF summary reports.

Programmers can improve each component individually, however each component must interact with the rest of the software stack using consistent routines, protocols and tools. Software stack components are individually modifiable through the use of application programming interfaces (API). The software stack and APIs enable programmers to develop discrete components of software tools, while leaving the rest of the stack unchanged.

The platform and the individual components are often interchanged when referred to by BEM tool users. Figure 1 shows the complexity of some of the most used BEM tool platforms (and their components). One example of component integration is that EnergyPlus is both a platform by itself that includes the EnergyPlus engine, and it is used as an engine by other platforms (CBECC-Com, EnergyPro Non-Residential, DesignBuilder and Simergy).

An example of a BEM software platform is EnergyPlus, which is funded by and maintained by the US Department of Energy. The DOE leverages the stack architecture (Figure 1) to focus on engine refinement while creating a platform for others to develop various end-user tools. EnergyPlus engine development is open source and publicly-funded. The EnergyPlus architecture allows users to easily build new features, interfaces, and middleware to interact with the engine through APIs.

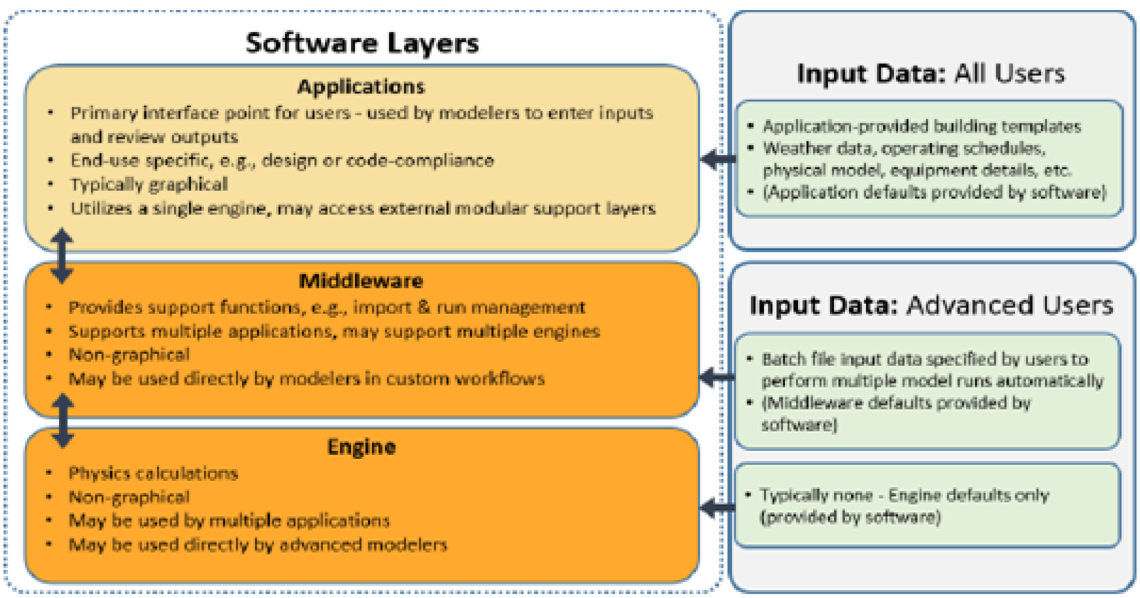


FIGURE 1. EXAMPLE BEM ARCHITECTURE

Incorporating new building components into the physics engine is conducted through the building component library layer of the EnergyPlus architecture. As the development team identifies new components or changes to existing component simulation algorithms, the DOE will introduce new measures into the building energy modeling software through the

Building Component Library (BCL)[v]. The BCL is separate from the underlying physics engine and the user-case specific apps. Apps, new building components, and physics engine rules are all developed and implemented independently. This division of development resources ensures that EnergyPlus will continue to be the industry leading simulation software.

BEM Tools in SCE Programs

Out of a market of over 115 tools and platforms, SCE programs engage with 13 platforms with 7 unique engines, 4 unique rulesets, 5 unique input formats, 3 unique output formats, and 11 unique GUIs. Figure 2 shows the array of BEM tools and components that comprise the short list of commonly used tools by SCE programs.

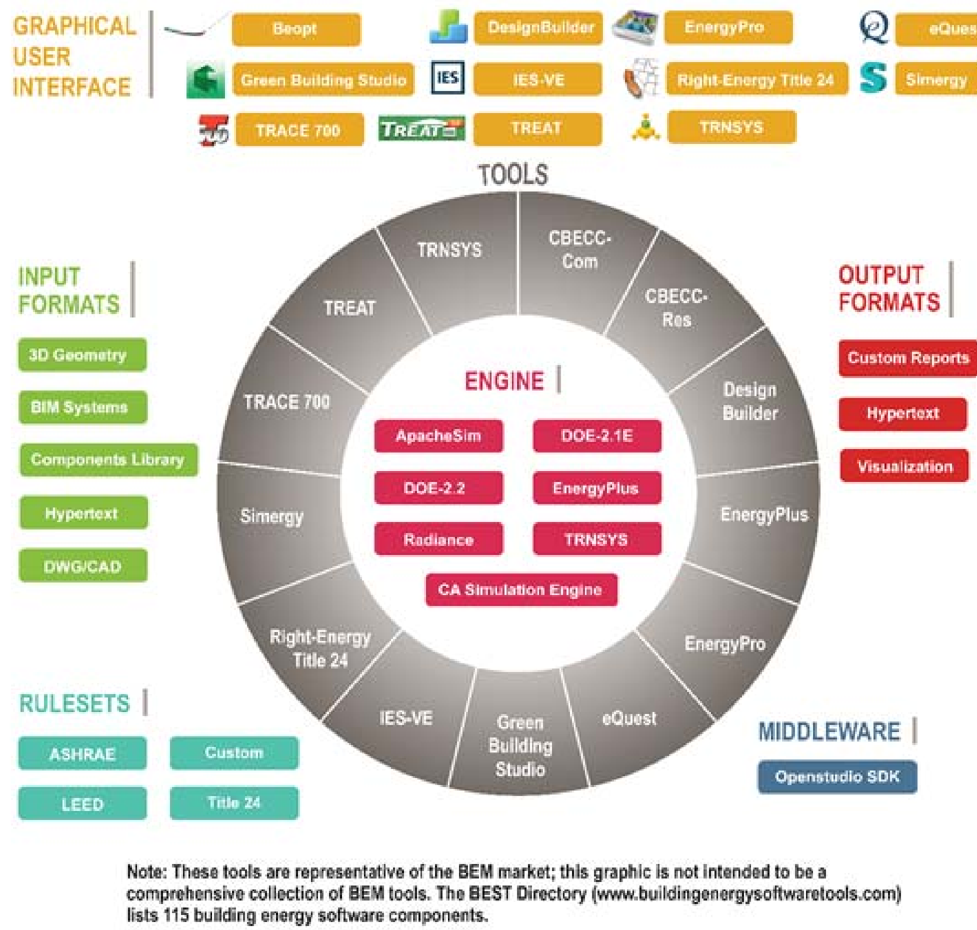


Figure 2. Example of BEM Tools Associated w/ SCE Programs

Note that from the perspective of the users, there is often no distinction made between a simulation engine versus GUI or rulesets, but in reality any given BEM tool has several components including graphical user interfaces, inputs and outputs, rulesets and middleware. (Refer to the tools listed in the gray doughnut in the middle of Figure 3.) For example, users often confuse whether EnergyPro is a BEM tool unto itself or simply a GUI of the underlying engine. (California Simulation Engine (CSE) for residential, EnergyPlus for non-residential).

Further, many BEM tools share various components of the software architecture. For example, all compliance software share a common ruleset and simulation engine since those are managed by the California Energy Commission (CEC) (Figure 3).

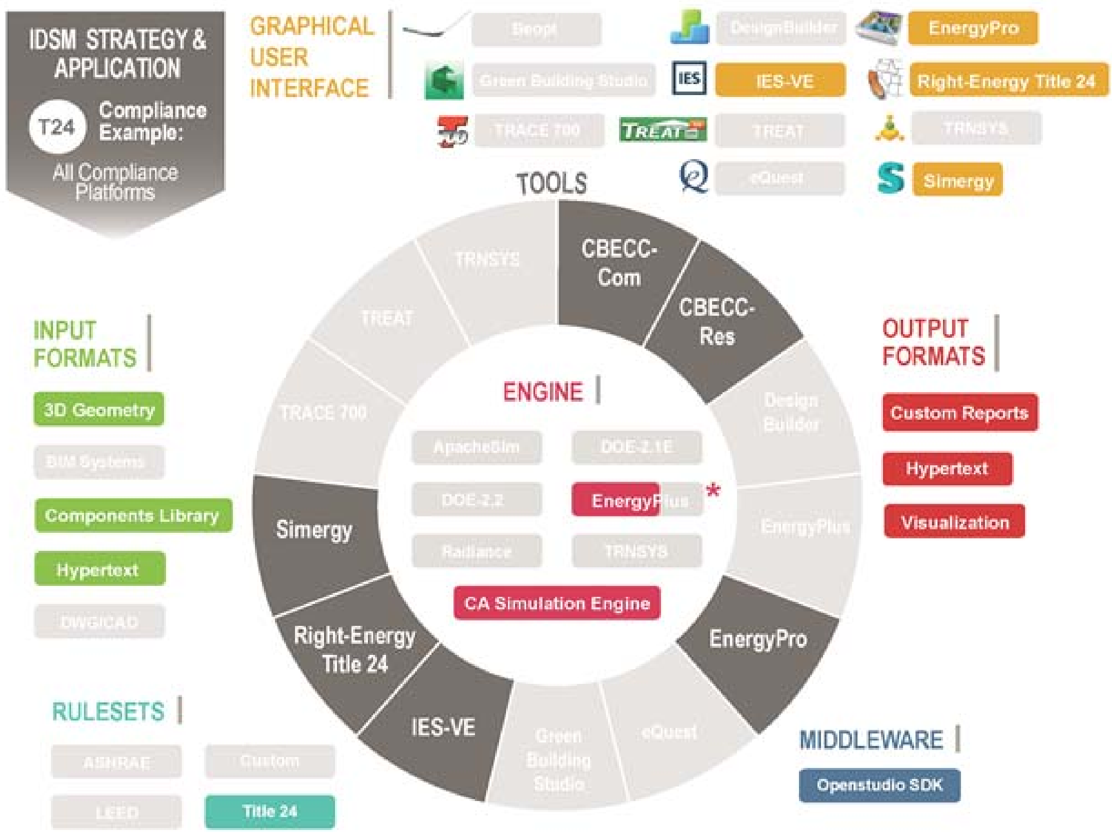


FIGURE 3. EXAMPLE OF BEM TOOLS ASSOCIATED W/ CA CODE COMPLIANCE

Title 24 performance calculation does not employ the complete EnergyPlus engine (for non-residential projects) since the capabilities are limited by what the CEC has implemented through the compliance rulesets. As shown in Figure 3, only six tools are approved for compliance (for residential and non-residential) simulation in California. It is important to note that when a user uses a tool not called EnergyPlus (e.g., CBECC-Com, EnergyPro, DesignBuilder or Simergy), the underlying calculation engine may in fact be EnergyPlus.

In contrast to compliance, the integrated design community uses separate BEM tools, Graphic User Interfaces (GUIs), rulesets, and accepts more input formats. Figure 4 shows BEM tools and components available to users that elect to use EnergyPlus. Notice that the full suite of algorithms of the EnergyPlus engine are available for use in integrated design applications of BEM tools.

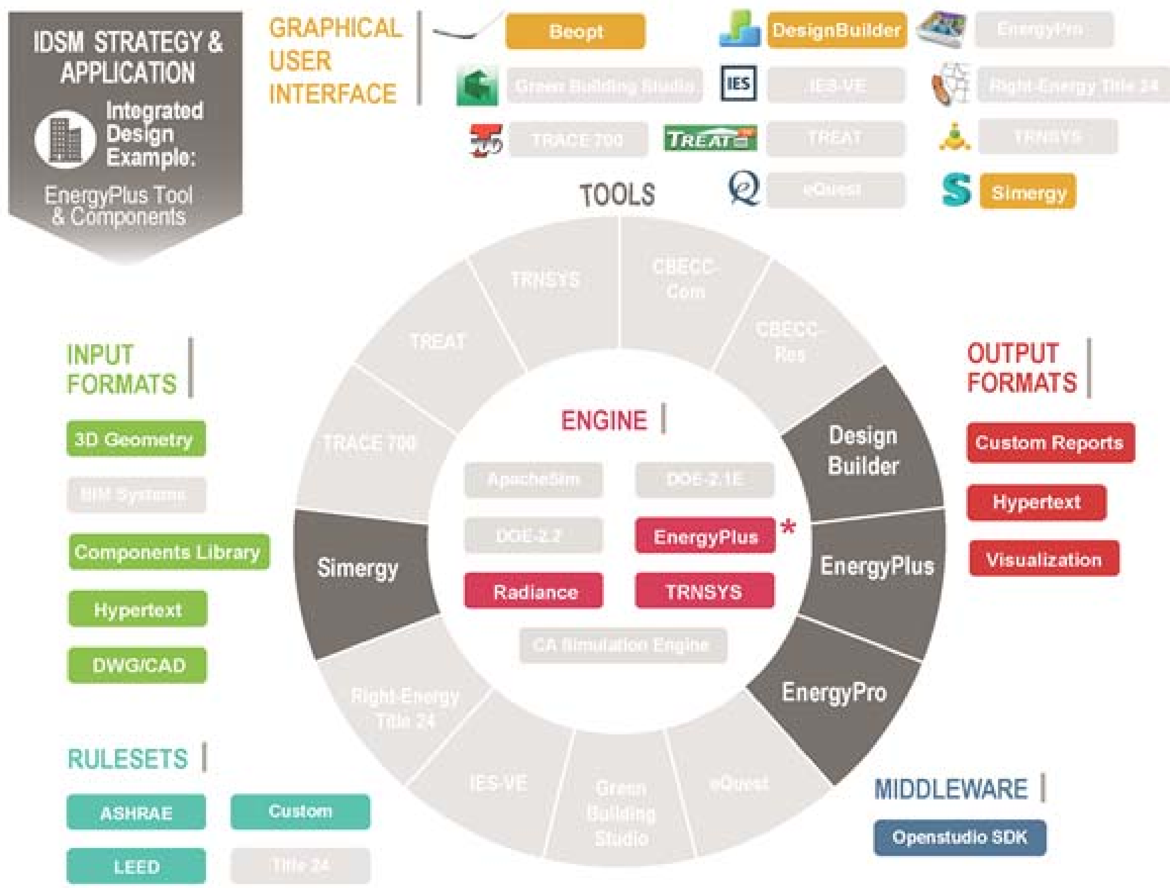


FIGURE 4. EXAMPLE OF BEM TOOLS ASSOCIATED W/ ENERGYPLUS USERS

EVOLVING BEM LANDSCAPE IN CA

CHANGING METRICS

Since the adoption of the first energy code in California, building performance has been mostly measured by the percentage better than code baseline. Historically, comparing a building to a minimally energy code compliant building has allowed building officials, incentive program managers, and project teams to compare project performance relative to predetermined baselines. Some prominent statewide energy efficiency programs, such as Savings by Design (SBD), use this comparison to determine levels of cash incentives to California ratepayers. However, as buildings become increasingly energy efficient, building performance is more accurately comparable to absolute metrics such as energy use intensity (EUI), instead of a relative “percent better than code” metric. As the California energy code becomes more stringent and buildings become more efficient, the room for calculated savings using the relative metric of “better than code” is reduced. Additionally, the CA energy code updates every three years, making it more difficult to compare building performance over time. Building professionals often state that a building is X percent better than the 20XX building code; this can be tedious and confusing to a majority of the building industry. Therefore, as buildings become more efficient, EUI becomes a more informative and understandable metric of building performance rather than percent better than code.

Both the residential and nonresidential new construction program administrators interviewed for this roadmap identified a need for an EUI metric, especially as energy codes move toward zero net energy (ZNE), and emphasize that a EUI metric can actually indicate how close a building is to zero energy, while a "percent better than code" metric does not. The EUI metric will be especially helpful on the residential side, where several end-uses are unregulated, such as lighting and plug loads.

Similarly, in interviews with SCE's codes and standards program administrators, it was mentioned that current certified energy compliance tools do not translate into real energy savings. California's compliance tools convert calculated energy savings to a statewide time dependent valuation (TDV energy), which attempts to better account for the time, location, and fuel type of the energy being used on an hourly basis[vi]. Though helpful for policy and planning purposes, this metric generated by energy compliance software does not translate directly to energy bills. As a result, customers engaged in SCE programs cannot relate to a *percent better than code* or *percent improvement TDV* metric.

CHANGING ENGINES

In California, Title 24 performance path projects show compliance by creating a building simulation model within one of the approved software platforms. Historically, the CEC would post the calculations to be performed in the Alternative Compliance Method (ACM) manual that also contained specific tests for software to be performed in order to be certified for use in energy code compliance. Software vendors then applied for certification as approved simulation software by performing a series of simulation tests and passing benchmark performance tests as described in the ACM. There have been separate tools/engines for compliance depending on whether the building was residential or nonresidential. The residential compliance engine has been developed by the CEC over a number of code cycles and has alternately been an open-source and/or proprietary tool that has been implemented independently in various compliance tools. For the nonresidential buildings, the compliance engine has been based on the DOE2.1E software and the ACM was explicitly tied to the capabilities (or lack thereof) of the DOE2.1E engine.

As part of the 2013 Title 24 update, the CEC invested in explicitly defining the engine and middleware that must be used by software platforms in order to become certified compliance software. The CEC defined separate software platforms for residential and commercial projects; these include California Building Energy Code Compliance (CBECC) Res and Com.

CBECC-Res builds on the history of residential calculation engine improvements performed by the CEC over the past 20+ years, but adds a series of complementary features/tools to develop a fully developed software stack. A key feature of the new software architecture is that the core engine, rulesets, and report generator are shared across any approved software used for compliance analysis. Thus EnergyPro can use the same engine, rulesets, and report generator as native CBECC-Res. This avoids the problems seen in the past where different software provided different results for the same inputs.

CBECC-Com made a significant change to the nonresidential compliance calculations by making the following two key decisions:

- Changing the compliance engine from DOE 2.1E to EnergyPlus.
- Using the OpenStudio/EnergyPlus software stack to generate building models.

Proprietary, Open-Source, and Licensing

The open source definition[vii] specifies the following licensing terms for open source software (there are 10 terms that comprise the open source definition):

- Free Redistribution: The license shall not restrict any party from selling or giving away the software as a component of an aggregate software distribution containing programs from several different sources. The license shall not require a royalty or other fee for such sale.
- Source Code: The program must include source code, and must allow distribution in source code as well as compiled form. Where some form of a product is not distributed with source code, there must be a well-publicized means of obtaining the source code for no more than a reasonable reproduction cost preferably, such as downloading via the Internet without charge. The source code must be the preferred form in which a programmer would modify the program. Deliberately obfuscated source code is not allowed. Intermediate forms such as the output of a preprocessor or translator are not allowed.

In comparison, proprietary software is owned by an individual or company and that entity maintains restrictions on the use of the tool, the content of the source code, and the ability of third parties to modify the source code.

Since the first iteration of the Title 24 energy code in 1978, energy simulation tools have been developed to provide buildings a software mechanism to show compliance with Title 24's performance path. Over the history of Title 24, these software packages were approved by the California Energy Commission (CEC) by comparing the simulation results against expected results. The California residential BEM algorithms (engine rules) have always been open source, and in many cases explicitly defined within Title 24. The residential software middleware, inputs, outputs, and GUIs were proprietary.

Thus, each residential software platform needed to be certified separately because each software produced different simulation results. The two most often used compliance software in CA were Micropas and EnergyPro. The CEC wanted to remedy the fact that different software produced different results for the same project, but the proprietary nature of each software platform limited the CEC's ability to ensure consistency between compliance software platforms.

The California non-residential algorithms were proprietary and locked due to license issues of the engine (DOE2.1E). Development on the non-residential engine (DOE2.1E) was stopped for almost a decade, resulting in many efficiency measures not being modeled. The lack of ability to change the engine was the primary reason to move to EnergyPlus. For non-residential compliance, EnergyPro was the only software approved for compliance and it used the DOE2.1E engine.

These limitations influenced the California Energy Commission's decision to invest resources into an open source platform for energy code compliance simulation. Each open source license shares common elements (as defined at the start of the Proprietary, Open Source, Freeware, Shareware, and Licensing section), however many software platforms have nuanced differences in the complete software license terms. For example, EnergyPlus is open to use by anyone, however if edited, the user must either provide the changes to DOE so they officially incorporate edits into the main EnergyPlus engine, or the user needs to give the program a new name.

Each platform CBECC-Com and CBECC-Res is open source, and the nonresidential and residential compliance tools use different simulation engines. CBECC-Com (nonresidential) uses EnergyPlus, whereas CBECC-Res (residential) uses a CEC developed simulation engine called the California Simulation Engine (CSE).

CBECC-COM[viii]

The energy simulation stack for the nonresidential Title 24 compliance software is organized as follows:

- **Graphical User Interface (GUI)**: Allows users to enter details about a proposed building's design. Certified options currently are CBECC-Com, EnergyPro, IES-VE, and Simergy.
- **Middleware:** Intermediate software or set of rules used to generate outputs beyond the core capabilities of a simulation engine.
- **Compliance Manager:** The core of CBECC. Uses middleware to assess whether the building complies with the energy code.
- **Connection to the U.S. Department of Energy's EnergyPlus Simulation Engine**: Performs energy simulations to determine the building’s heating, cooling, ventilation, lighting, plug, or process loads.
- **Report Generator:** Generates forms and other reports to summarize the building's compliance characteristics. Forms may be submitted for building permits, or as documentation for other programs.
- **Application Programming Interface (API) Documentation:** The purpose of this document is to provide information needed to link software interfaces to the CEC Compliance Manager.

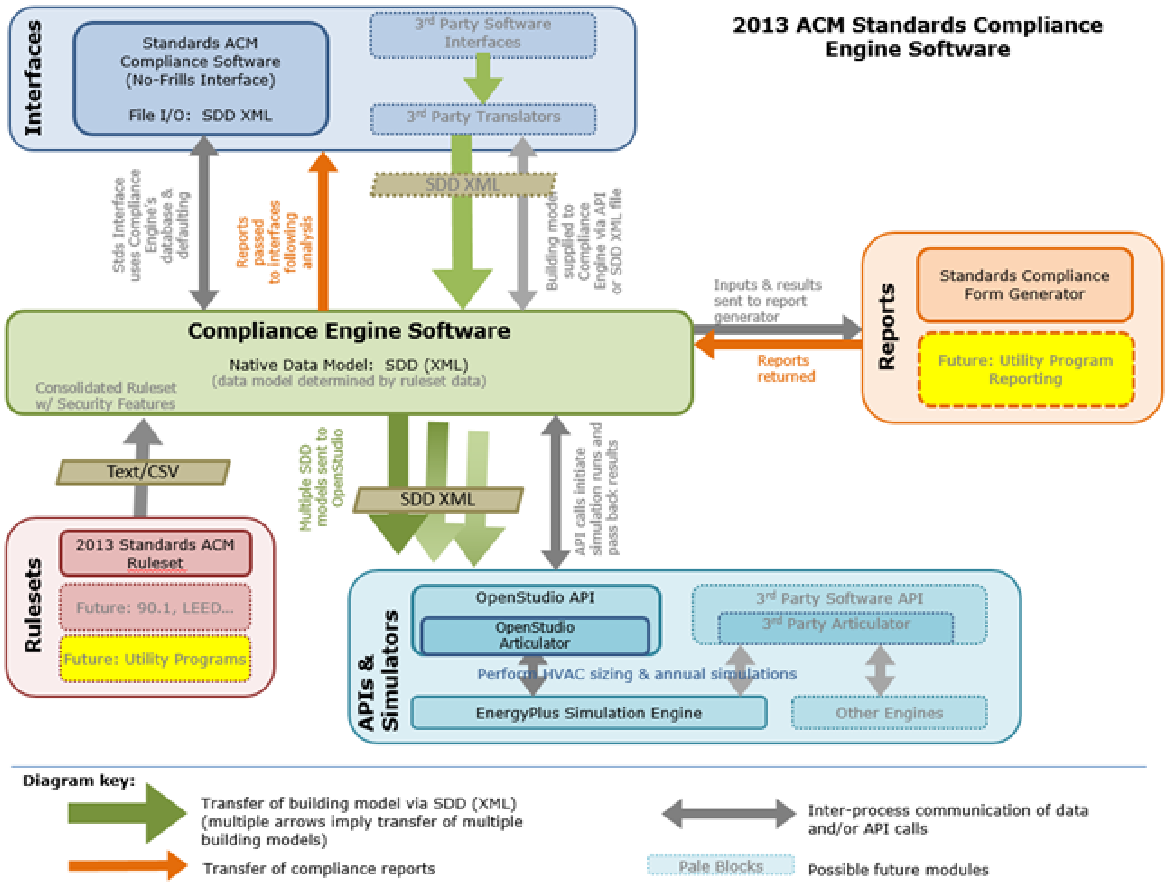


FIGURE 5. CBECC-COM SOFTWARE ARCHITECTURE

CBECC-RES[ix]

In California, the energy simulation stack for the residential Title 24 compliance software is organized as follows:

- **Graphical User Interface (GUI):** Allows users to enter details about a proposed building's design. Options currently are CBECC-Res, EnergyPro, and Right-Energy.
- **Middleware:** Translates the building energy code prescriptive requirements into software rules.
- **Compliance Manager:** The core of CBECC implements the middleware to assess whether the building complies with the energy code.
- **Connection to CEC Developed California Simulation Engine (CSE):** Performs energy simulations to compare proposed building energy consumption to the energy code 'budget'.
- **Compliance Report Generator:** Generates reports and certification forms to summarize the building's compliance characteristics. Forms may be submitted for building permits, or as documentation for other programs.
- **Application Programming Interface (API) Documentation:** The purpose of this document is to provide information needed to link software interfaces to the CEC Compliance Manager.

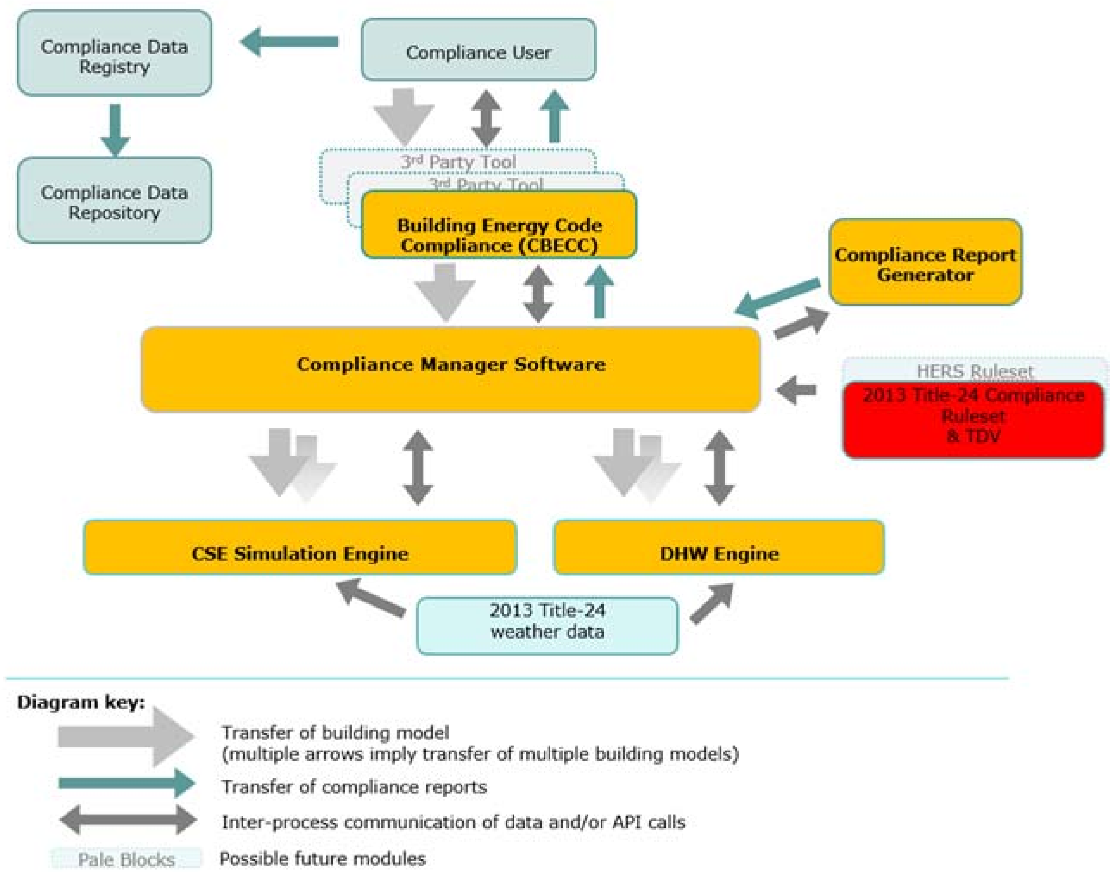


FIGURE 6. CBECC-RES SOFTWARE ARCHITECTURE

BEM FOR COMPLIANCE IN EE PROGRAMS

Energy simulation for code compliance and SCE program implementation are currently not aligned with the recent changes to code compliance software. Starting with the 2013 Title 24 code, the CEC code compliance software for non-residential buildings is now based on the EnergyPlus engine. The IOU program ex-ante (predicted based on energy analysis) and ex-post (measured or observed based on actual installation and operation) savings are still based on the DOE-2.2 engine included in eQuest. This is due to the fact that most IOU savings claims and program offerings are based on the Database for Energy Efficient Resources (DEER), which is a compilation of energy savings estimates based on eQuest energy simulations.

Programs typically document energy savings from a code baseline. However, the code baseline threshold for retrofit projects appears to be changing, as AB 802 (signed into law in October 2015) potentially allows projects to count retrofit savings from existing condition to code (beginning in September 2016 based on regulatory rules).

The California Public Utilities Commission (CPUC) requires non-residential new construction (NRNC) program projects to use operating schedules based on the actual occupants of the building, as opposed to using code default schedules. SCE worked with EnergySoft (creators of EnergyPro) to create a special module within the program to meet SCE program needs. The software takes a two-pronged approach; compliance (% better than Title24) is used to qualify for incentives, while a non-compliance simulation is used to calculate energy savings and DEER peak demand (the values that the program pays incentives on). This solution has resolved the specific problem around schedules.

There are still challenges with modeling innovative technologies that program participants want to use, such as advanced daylighting, chilled beams among many others. Current compliance software based on CBECC-Com has limited capabilities to model those features. And in many cases, the DOE-2 based simulation software preferred by CPUC, such as eQuest, are unable to model these features adequately.

BEM Tools used by Third Party and Non-Resource Programs

Third party implementers (TPIs) play a key role in SCE's programs. The third party programs have the second highest overall savings impact in SCE's portfolio behind Codes and Standards (C&S), and third parties tend to focus on large projects. As a result, the accuracy of the third-party savings estimates is critical to SCE's overall program portfolio. Third parties document project savings according to the proscribed rules of each program. The software needs of third-party energy efficiency programs are a subset of BEM tools needs identified in this study.

Non-resource programs (programs whose funding are not tied to quantitative energy metrics such as kilowatt (kW) and kilowatt hour/year (kWh/yr) savings), distributed generation programs, and demand response programs differ from energy efficiency programs, and so do the BEM tool needs for these programs. For example, SCE's Demand Response (DR) program implementer uses proprietary tools to calculate demand reduction for the DR and permanent load shift programs (PLS). Similarly, non-resource programs have more flexibility in the tools they are able to use. For example, the Sustainable Communities program relies on outside consultants who run tools such as BEopt (a GUI that uses the EnergyPlus engine), and customized calculator tools. The Sustainable Communities program chose to implement the program using BEopt, whereas most of SCE programs do not have any influence in BEM tool selection.

Non-resource, demand response, or distributed generation capacity programs rely on different BEM engines than energy efficiency programs. Moving forward, SCE has an opportunity to modify BEM tools rulesets, and data input/output protocols to integrate non-resource, DG, DR calculations and projections with energy efficiency simulations.

SCE's CP&S Product Governance

SCE's Customer Programs & Services (CP&S) administers SCE's Intake and Evaluation Process to help incorporate new ideas (of DSM technologies, process improvements, customer engagements, program offerings) into the programs portfolio. The CP&S Product Governance Process is used for external and internal ideas alike, and filters ideas through multiple stages:

- **Discovery:** where all submissions are assigned to members of SCE ET team who will work with you throughout the entire process. Ideas must be cost-effective, benefit customers, and align with SCE's strategy to be considered for adoption.
- **Ideation:** where the submission will receive a more detailed review. This includes evaluating the proposed energy savings, customer benefits, risks, value proposition, target market, and potential adoption rate.

- **Concept Development:** where SCE will begin working on ways to test and validate the submission. This can include industry research, lab and field testing, or a pilot with customers.
- **Product Development:** where SCE will ensure all processes and systems are mapped out, and compliance requirements are met. SCE will also begin to prepare employees and communicate with customers.
- **Launch:** where SCE periodically evaluates all the offerings in the customer portfolio to ensure that the products and services we provide are working as designed, and delivering to expectations.

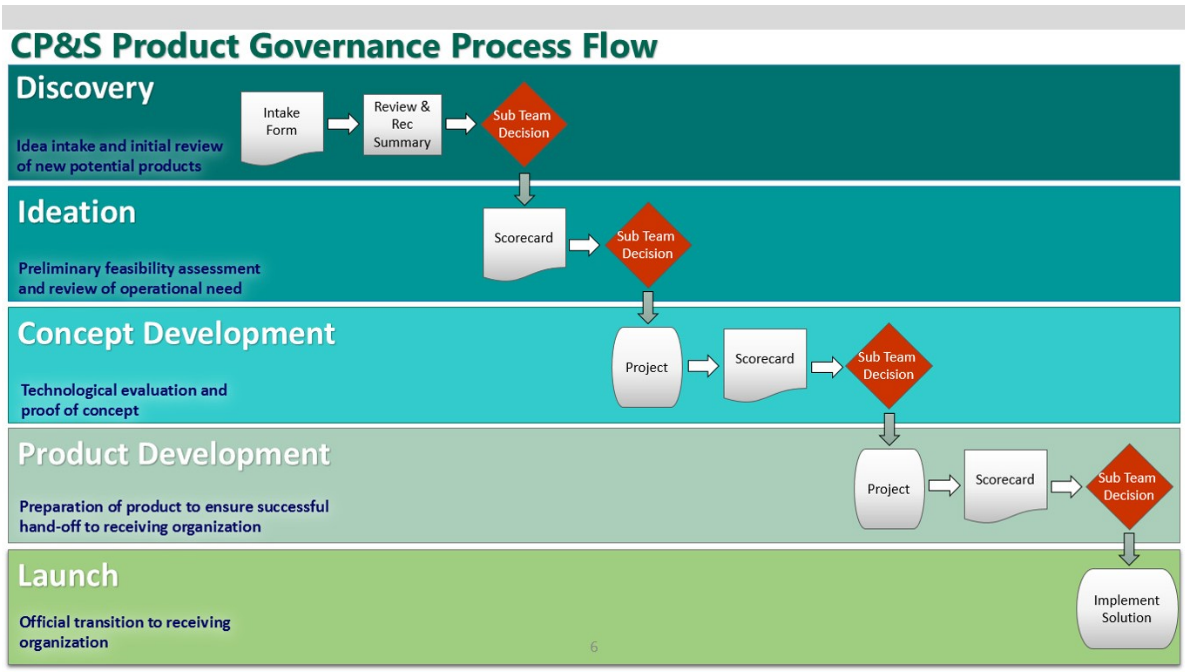


FIGURE 7. SCE'S CP&S PRODUCT GOVERNANCE PROCESS

BEM ROADMAP DATA COLLECTION

TRC conducted in-depth interviews with SCE program staff and key decision-makers, BEM tool developers and facilitated focus groups with industry leaders in BEM tool development. Our work builds upon the considerable effort to date by SCE to identify BEM tools used in various SCE programs, as well as technical analysis related to EnergyPlus and CBECC-Com.

INTERVIEWS WITH SCE PROGRAM MANAGERS

The interview guide is available in Appendix D – SCE Program Manager Interview Script. TRC conducted eight separate in-depth interviews with SCE program staff, covering the following programs:

- Codes and Standards
- Emerging Technologies
- Custom Programs

- Demand Response
- Permanent Load Shift
- Demand-Side Management Engineering
- Nonresidential New Construction
- Residential New Construction including single family and multi-family

Each interview focused on the particular needs of the program, as well as the following topics:

- List of BEM tools used
- Types of measures modeled, and use cases
- Frequency of use
- Technical gaps in BEM tools
- Areas of need
- Current plans for tool development/improvements

INDUSTRY FOCUS GROUPS

TRC conducted an industry focus group to collect additional insights into BEM tools, and to gauge views from beyond the IOU market and outside of California. The focus group shared insights about BEM development outside of the CA policy perspective, energy simulation as a demonstration of the physics of heat transfer. A key insight from the focus group was gained from the engine development discussion. The focus group attendees stressed that while SCE may want to be involved in engine and algorithm refinement, the developers feel that SCE can best support developers by providing actual project data and utility data use feedback to engine developers. This feedback is a major missing component in BEM tool development today. The complete discussion notes are available by request.

CURRENT BEM TOOL OPTIONS

Most whole building BEM tools can provide users with a simulation of energy use for a building. The choice of BEM tool depends on regulatory factors including: baseline assumptions, code requirements, weather data, simulation engine capability and energy use accounting (TDV, site, source). While there is not an ideal BEM tool, the question of which BEM tool is the correct choice can be answered by considering the application of the BEM tool (apply to programs or comply with code, energy efficiency or integrated demand side management (IDSM), whole building or one-off measure). And the choice of BEM tool differs drastically for users outside of California because of the various differences in regulations (program rules and energy codes).

As part of program design, SCE must determine the appropriate tool or tools for calculating savings for each program's eligible measures. Certain programs (upstream manufacturer incentives, direct install, and prescriptive incentives) can leverage statewide approved averages ("Deemed") for energy savings, and do not need to use BEM tools on each project application to document program energy savings.

Whole-building programs such as Savings by Design and the California Advanced Homes Program rely on BEM tools to calculate energy use and savings based on the unique location and characteristics of a project building.

Sometimes unique project parameters dictate that a project's energy savings cannot be accurately captured by either deemed savings or by whole building analysis tools. In these cases, SCE's DSM Engineering Team builds and verifies custom tools for these special projects.

DEEMED MEASURE TOOLS

Deemed measures are energy savings measures that have a pre-defined quantity of energy savings per widget and deemed measure programs typically install in large quantities of widgets (e.g., lighting, low flow fixtures). SCE programs that want to implement high volume upgrades benefit from automatically calculated deemed savings because the program can document the average savings for each item replaced and then scale the savings based on the number of items installed. To develop deemed savings estimates, SCE currently uses READI tool to download pre-defined eQuest models to develop new deemed measure baselines based on DEER data.

Although an individual measure-level energy savings calculation appears to be straightforward, complications arise from the assumptions about base case, operating schedules, and other factors. In cases where program implementers use tools to determine energy savings, they must identify the tools and the calculations used. Tools range from simple spreadsheet tools to whole building annual simulations.

SCE program managers must verify each tool and the inputs and assumptions that went into the calculations. They can call upon the DSM Engineering team for technical assistance. In addition, any measure based on the energy code requires the use of a CEC-certified tool, and any measure SCE wishes to implement as deemed must meet DEER criteria. New measures introduced into the deemed programs require work papers documenting savings if they are not using standard DEER assumptions, and therefore energy simulations. Since many program baselines are based on code, every time code changes, SCE has to determine whether to continue, change, or retire each deemed savings program.

When a measure is proposed that cannot be modeled in existing DOE-2 (DEER approved) models, a non-DEER work paper is developed to document the base case and savings calculations. For these specific measure types, the BEM tool is irrelevant. SCE must claim energy savings for each project based on the calculations outlined in the work paper.

WHOLE BUILDING ANALYSIS TOOLS

A wide variety of programs utilize whole building energy modeling tools, and each program has unique simulation needs. For example, any measure that results in interactive effects, requires a whole-building simulation. Most programs that require whole building energy analysis use code as a baseline and thus need to use BEM tools that are able to generate the code baseline (e.g., BEM tools that conduct compliance analysis). However, compliance analysis tools typically lock certain features such as operation schedules, equipment power densities, system efficiencies, among others. This is done to avoid any intentional or unintentional *gaming* of the compliance calculation by using *wrong* assumptions. However, in the case of energy efficiency programs, the whole building energy analysis may involve measures that do change these default assumptions. In the past, compliance tools have allowed a non-compliance mode where program participants can use custom schedules and other assumptions as long as they are well-documented. Currently, the non-residential and residential compliance tools lack the non-compliance mode, thus causing issues with determining accurate program savings estimates.

For NRNC, the program team is primarily concerned with the following CEC/CPUC approved tools: EnergyPro v6, CBECC-Com, SimCalc, and IES-VE. NRNC program managers would like tools that design teams understand and can model savings accurately, while balancing the complexity and resources necessary to conduct the analysis. For certain measures in non-residential new construction, such as package systems, windows, or insulation measures, the program team uses SimCalc, a simplified BEM tool, to create a simple whole building model to estimate the savings; SimCalc is not an approved compliance calculation tool for 2013 Title 24. The NRNC team also reported that many major design teams are using IES-VE, and would like to be able to submit their integrated design IES-VE models for NRNC program incentive consideration, since that is the design team’s preferred tool. It should be noted however that the IES-VE tool uses different simulation engines depending on the use case. For normal design process, IES-VE uses the ApacheSim engine that allows for design optimization. For code compliance however, IES-VE uses the CBECC-Com engine and rulesets which lack the capabilities that are otherwise available in the ApacheSim engine.

Similarly, the residential new construction (RNC) program only uses the tools that the CEC has certified for compliance: EnergyPro, CBECC-Res, and Right-Energy. Some members of the RNC program team would like to see a compliance tool that can also be a design resource such as BEopt, which provides for greater granularity, and allows multi-run parametric modeling to compare outcomes from different strategies. Currently, design teams are reluctant to use tools such as BEopt to optimize energy efficiency because they still have to build a separate model in an approved compliance tool.

CUSTOMIZED MEASURES

In addition to the deemed and whole building tools described above, there are also customized tools that support the custom programs, as well as other specialized measures. All non-DEER measures are calculated and vetted by SCE then uploaded to the calculation tool archive (CTA). The CTA is an archive of all generic energy tools used in calculating ex ante values for customer measures, and is updated on an ongoing basis as tools are publicly revised.

The emerging technologies group at SCE has used a variety of methods for estimating savings. However, they report that many are based on spreadsheet tools, while some are based on EnergyPro with a module developed in collaboration with Electric Power Research Institute (EPRI) and the National Renewable Energy Laboratory (NREL). In general, the emerging technologies team prefers to use industry-approved tools, to better align with the market.

In some cases, where code baselines are not clearly defined, the non-residential new construction team has had to develop their own tools. These measure-specific tools are typically spreadsheet calculations, developed for measures that are in high demand such as parking lot lighting and kitchen equipment.

For the PLS program, customers typically use Trane Trace to provide all of the necessary information about the thermal energy storage system. Some customers have used eQuest for the PLS program, but in those cases they need to submit additional data to the program which eQuest does not currently provide. There is also a pre-audit tool that is currently in beta that will help customers understand their thermal energy storage potential before the feasibility study phase of the PLS program.

The Residential New Construction team also supports some specialized tools associated with the Sustainable Communities program, including a water energy calculator, and a tool to test the benefits of a “shower-tower” for evaporative cooling. However, since that is a non-resource program, they have more flexibility with their modeling tools.

The Custom Program team maintains a list of preferred and trustworthy tools. Although there is no policy on tool selection, the preferred list is meant to encourage customers to use the best-in-class tools. The preferred list is geared towards contractors who are just starting to participate in the program, and need guidance on where to begin. As of June 2015, there are approximately nine tools on the preferred list, and the list only includes fully functional BEM tools. The preferred list does not include any of the spreadsheet tools that the Custom Program team also uses. The Custom Program also maintains a website with a variety of simple calculator tools that can help provide customers with quick estimates of energy savings. However, customers are free to use their preferred tools, as long as the tool is not specifically disallowed by the CPUC.

The Custom Program prefers to use simple tools when feasible, while CPUC policy is pushing customers toward whole building simulation. Whole building simulations are most often used for projects with heating, ventilating, and air conditioning (HVAC) measures, control resets, or retro-commissioning. Typically, projects with multiple measures will require a whole building simulation. However, if most of the measures are already in the express programs, customers may only need to use a spreadsheet.

SCE is in the process of developing specialized tools to meet specific needs, such as a tool that will help predict savings for each measure, help inform annual utility-wide energy savings potential, and plan for the future of the programs. SCE is also developing a greenhouse gas tool that will translate certain reach code measures into a “cars taken off the road” equivalent. At the moment the tool has limited scope, but it is something that local governments have been asking for in order to address their greenhouse gas reduction goals.

Each program team must validate any new tools that customers use. As a result, the team generally avoids any tools that are not explicit or clear about their calculations. Customers frequently use customized spreadsheets for projects, but basic spreadsheets (without “inputs” or “outputs”) are not considered BEM tools by the SCE program team or by the CPUC.

To support specific program needs, the custom team has also developed specific tools for measures that are not addressed or accommodated by other software tools such as supermarket whole building, industrial refrigeration, and lighting calculators. The lighting calculators are a hybrid tool, in that they use both DEER data for buildings, and LPD requirements for code baseline.

BEM NEEDS ASSESSMENT RESULTS

TRC conducted 16 hours of interviews with SCE program managers to better understand the unique BEM tool choices of each program. The findings of the interviews illuminated the many shared needs across programs. The needs assessment results document interview findings and draws comparisons between different programs sharing similar challenges. TRC categorized these needs into:

- **BEM Related Policy Needs:** These are the statewide energy policy and regulatory limitations that SCE programs experience. These challenges generally will require advocacy of policy change.
- **Communication Needs:** These refer to the challenges of communication with customers regarding program eligibility, program rules, and project results.
- **Software Development Needs:** These document the BEM capabilities that cannot be modeled because of algorithm limitations or lack of rulesets.

Note that this section contains information that may be dated as the BEM tools in question have continued to be improved since the time TRC conducted these interviews. TRC presents these findings with the understanding that either BEM tool vendors, IOUs or the CEC may currently address some of the specific needs below but they are still important to document since they represent the types of needs that may arise in the future as well as policy goals shift, and SCE programs evolve.

POLICY NEEDS

CODE COMPLIANCE VS. ABOVE CODE PERFORMANCE

There is a fundamental difference between performing an energy model for code compliance where there is a fixed baseline (prescriptive code requirements), and an energy model for an energy efficiency program that promotes optimal energy efficiency. For the former, the model needs to provide a comparative guidance on whether the given building meets the code. For the latter, it is more important to know how much real-world energy savings will be achieved by the given design. Current code compliance software rules prevent ‘gaming’ by fixing several assumptions about the building operation such as operation schedules, equipment performance, and behavioral factors. These are appropriate for code compliance that assesses whether the asset (building) can be legally built. However, for an energy efficiency program that is targeting increasingly ambitious energy savings goals, the target is not just asset efficiency but also operational efficiency. To address operational and behavioral issues, the BEM tools must allow the users to make different assumptions than what the code prescribes.

ASHRAE 90.1/189.1 has tried to address this divide by developing an industry standard performance rating method, called “Appendix G” for short. Appendix G is designed for higher efficiency buildings and programs such as LEED and incorporates standard practice as well as code requirements. It also allows more discretion by the “Rating Authority”, which in the context of IOU/SCE programs would be the CPUC.

SCE should advocate and support development of an ASHRAE Appendix G style approach to model actual project baselines for programs.

CPUC Guidance on BEM Investments

SCE program managers have some uncertainty about CPUC regulations governing whether and how they can spend program funds updating or improving BEM tools. Yet updating BEM tools is seen as a necessary function to improve customer participation and experience in SCE programs. Many SCE program managers stated their preference to make the process more streamlined, but were unsure whether they had the authority/budget to do so. This confusion about how SCE can invest in updating BEM tools limits SCE's activities about significant BEM software changes. SCE should seek direct guidance from the CPUC regarding how program funds can be used to support development of BEM tools.

Program Rules Consistency

SCE reported that while programs rely on BEM tools to generate savings estimates, the assumptions, defaults, and BEM tool inputs vary from project to project within a given program. For example, as of June 2015, Savings by Design is still working to update the technical reference manual (to outline reasonable assumption parameters, and expected efficiency ranges) for comparison against the new Title 24 code requirements.

According to DSM Engineering, one aspect of building simulation that the technical reference manuals could better address is operating hours. The CPUC requires Non-residential New Construction to use actual hours, based on Title 24 acceptance documents for savings estimation, as opposed to CEC default operating hours. These assumptions must be estimated based on how the building is going to operate, even though the building tenants might not be known at the time of application to NRNC.

The technical reference manual development provides an opportunity to implement consistency across projects in the program, as the manual is written for program implementers. To better serve a wider audience, SCE should integrate program specific rules and data input ranges into BEM tools natively. Also, the information can be written in a format that is accessible to program participants and energy consultants developing the energy models, so that they are clear on the rules, guidelines, and procedures for the programs.

Leverage Industry Efforts

The DOE and various DOE National Laboratories lead development of the EnergyPlus simulation engine. Development and refinement of simulation engines depends on good data. For emerging technologies (e.g., chilled beam cooling) and existing technologies (e.g., direct expansion split system air conditioning), the researchers developing the simulation engine need data to compare simulated results to real-world results. SCE program managers provided many examples that show that SCE has access to rich sets of aggregated data for real-world project results. SCE should continue to support energy simulation advances by providing experienced feedback and real-world data towards the improvement and calibration of simulation assumptions and results.

BEM Tool Transparency

SCE reported that program managers reviewing custom tools struggle to review these tools for confidence, accuracy, and precision due to lack of available supporting documentation or access to calculation assumptions. Without transparent documentation, SCE program managers have to review projects using these tools case-by-case, increasing program administration cost. Beyond cost considerations, SCE cannot conduct quality control on custom proprietary tools without tool methodology documentation.

Proprietary tools can be used, in specific instances, to support new measures in SCE programs but that the developers of these tools have a responsibility to justify savings claims and tool assumptions. To significantly increase overall program and calculation transparency, SCE's programs should consider moving towards, primarily or exclusively, using non-proprietary open source tools such as EnergyPlus based tools.

LEGACY VERSIONS

SCE program administrators enroll projects and approve savings based on whichever version of the BEM tool is certified at the time of project enrollment. However, BEM tool updates occur on an independent cycle, and sometimes hotfixes are implemented between new version releases. When the software is updated, all previous versions are decertified. This can cause significant complication for SCE programs when a BEM tool is updated (sometimes multiple times) within one program cycle. Two projects implementing the same measures may document different savings results solely because of BEM tool version changes. SCE should develop consistent program implementation strategy regarding BEM tool version control. TRC recommends that new construction programs use the most current version of approved tools, and existing construction programs use one version generation previous (than the most current version) of the approved BEM tool for each program.

ALIGN ENERGY EFFICIENCY AND DEMAND RESPONSE

In order for SCE to continue to succeed in an evolving market, SCE programs need to continually streamline creative solutions towards customer satisfaction. Accordingly, SCE would like to encourage more integration between DR and energy efficiency (EE). At the moment, these two activities are regulated differently by the CPUC. If a customer is participating in both EE and DR programs simultaneously, SCE programs cannot verify DR potential until EE measures are installed. In these cases SCE must first wait to understand the impacts of the EE measures on the project before establishing a DR baseline.

SCE can improve program participation by building a DR module for EE customers to estimate DR potential. There is precedent for this activity; the Sustainable Communities Program incents ZNE-ready new construction, and the SCE Residential New Construction Program processes these projects such that the customer's EE and DR funding is combined into one program acceptance document. SCE then performs the back-end accounting to document which incentive money came from which program. This accounting could be streamlined and integrated into the BEM tool workflow, and SCE should consider investing resources for that development.

SCE can consider investing in a CBECC-Com calculation module to estimate DR potential as a generator. One program manager suggested an example for how SCE can process EE and DR combined projects. The suggested workflow is as follows:

- Project submits EE simulation model.
- EE simulation model is verified by SCE.
- SCE exports hourly kWh and kW usage estimates.
- SCE provides hourly use estimates and actual project utility use to DR program implementer.

DR program implementers compare actual project usage with simulated use after EE to generate a DR potential estimate for projects.

SCE Specific Program Criteria Needs

SCE expressed that as the loads that are not regulated in code increase (e.g., plug loads), program models and actual performance results differ more significantly. For example, the RNC program reported that ZNE homes submitted at the time of interviews (June 2015) receive the least incentives, and the most cost-effective ZNE homes are only 15-20% better than the 2013 Title 24 code baseline.

SCE should explore opportunities for incentivizing projects on different metrics than percent-above code, such as using a whole-building EUI that addresses non-regulated loads, even for new construction programs where the goal is to incentivize above code projects.

Communication Needs

In addition to the policy needs identified during the interviews, TRC identified the following needs for improved communication with customers, consultants, regulators, and vendors.

Align BEM Results with Actual Project Impact

SCE program managers expressed the difficulty with comparing actual performance with modeled margin of compliance and communicating this difference to customers. BEM compliance tools' accuracy depend most significantly on the quality and accuracy of the data inputs and user's experience with simulation. Often energy simulation results do not reflect actual energy use. Without accurate inputs and well-trained energy simulation users, BEM compliance tools are primarily useful for comparing the relative impact of various scenarios.

BEM compliance tools are not generally accurate in predicting the absolute value of energy-use of a proposed simulation scenario. BEM compliance tools are restricted by rulesets that pre-define certain inputs and cannot capture real-world operation due to standard input assumptions (e.g., schedules of operation). These restrictions require designers and energy consultants to create two separate energy simulations: compliance simulation analysis and actual design conditions analysis. SCE should consider developing rulesets that enable users to complete a compliance simulation and actual design conditions simulation simultaneously.

Code Change Communication

SCE program managers explained that regular code changes affect program results drastically because of confusion about what measures changed, and what the overall impact of measures will be on regular business processes. SCE program managers understand that when a suggested change to code occurs, through Codes and Standards Enhancements (CASE) reports, the studies generate an impact analysis demonstrating that the given measures will prove cost-effective as required by the CEC. This information is helpful for SCE program managers to give customers confidence about code change impacts.

SCE can leverage BEM tool development to help customers understand and feel confident about code changes. Introducing small prompts into BEM tools provides information,(seamlessly integrated into the energy model), and can help improve customers' understanding of baseline code changes, and potentially improve project performance within SCE programs. Energy Code ACE already translates archaic code language into easy to read "trigger sheets" and code-change fact sheets.

Documentation and Validation of Custom Tools

At the moment, SCE does not receive positive confirmation when custom BEM tools and associated work papers are approved by the CPUC. For example, SCE developed, reviewed, and submitted a parking lot lighting energy savings tool. The tool was uploaded to the CPUC tool repository (e.g., the calculation tool archive [CTA]). The tool was used for more than one year on projects before the Energy Division (ED) reviewed the tool and provided explicit feedback about the tool.

To help increase the transparency and effectiveness of this workflow, and to improve the workflow leading to CPUC approval, SCE should document and provide validation data for the custom BEM tools at the time of upload to the CTA.

SCE can develop an internal custom tool database to improve tracking of the custom measures database and work paper updates.

Communicate BEM Tool Input Requirements

SCE program managers expressed the need to better communicate BEM tool preferences or limitations to customers enrolling in programs. For example, SCE has developed a preferred list of tools for the Customized Solutions program to encourage customers to use the best-in-class tools. There are approximately nine tools on the preferred list, however this list is incomplete as it does not include recent software programs such as EnergyPlus, CBECC, IES-VE and other whole building energy modeling tools.

Separately, SCE program managers have expressed concerns about the CPUC requiring use of more sophisticated and complicated BEM tools than necessary, and disallowing certain simpler tools. As an example, the CPUC has expressly disallowed POST (Programmable Occupancy Sensor Tool), a Microsoft® Excel-based tool used for heat pumps in hotels, and BOA/C-BOA (Building Optimization Analysis) tools (also Microsoft Excel-based) that are intended to simplify analysis for existing building commissioning projects. SCE program managers have expressed their concern that disallowing simple tools and requiring more complex tools deters program participation. During an energy modeling webinar hosted on September 18, 2015, the CPUC echoed this statement. There is alignment between the CPUC and SCE that many projects do not require whole building simulation to develop energy savings estimates.

While a preferred tools list is useful for selecting the tools, in order to conduct energy analysis that meets SCE and CPUC needs, customers also need better guidance on appropriate tool selection. Often, the customer billing data may not reflect results provided by approved BEM tools, and customers are unclear why there are differences.

Program rules navigation is a challenge to communicate and to clearly set expectations with customers. SCE has an opportunity to communicate BEM tool requirements more clearly by maintaining an updated approved tools list for each program on each program's website (or each program's area on SCE.com). This update would require significant input from SCE corporate and marketing teams in order to reorganize SCE's web presence.

SOFTWARE DEVELOPMENT NEEDS

TRC identified various measures and project categories that are underserved by SCE programs. TRC sees many opportunities for SCE to impact and guide development of BEM tools to resolve these challenges. These include the following:

- Project Cost Effectiveness and Parametric Analysis: Parametric analysis is a mechanism that allows BEM tool users to evaluate a range of project scenarios, and helps to ensure that customers have the information to make the most cost-effective choices about their building. SCE program managers expressed concern that current CBECC interface options do not include the capability to perform parametric analysis. This feature is essential for design consultants to forecast the relative performance of various scenarios. For example, the BEopt GUI provides parametric scenarios so customers can evaluate different options to get the most cost-effective package, based on project specific costing parameters. The RNC program cited a desire to be able to provide project cost-effectiveness feedback to program participants either as a service to customers, or if the customers have costs or bid information.

  Based on this feedback, TRC suggests that SCE advocate that the CEC or vendors develop a GUI to support parametric analysis capabilities in CBECC-Res and –Com.

- CBECC Missing Functionality: SCE program managers reported that missing features, performance bugs, and computational time needed for analysis with the new CBECC simulation software have negatively impacted SCE's ability to meet program savings goals for both residential and commercial new construction programs. Bugs in CBECC prevented potential program participants from complying with Title 24 using the performance path which is a pre-requisite for program participation. When projects utilized the prescriptive compliance option for Title 24, the additional effort to build and submit a whole-building performance simulation was too costly, and SCE's performance program incentives did not justify the extra efforts. As a result, program managers from both residential and non-residential new construction programs reported that fewer users submitted applications in 2015 than in previous years. SCE reported that 2015 project submissions are lower than 2014, and only 30% of annual savings goals were realized as of June 2015.

  Based on this feedback, TRC suggests that SCE has an opportunity to be a more active stakeholder with the CEC, and proactively identify performance issues and bugs with the CBECC software. SCE should identify bugs and recommend updates to CBECC engines to address program needs.

- BEM Engine Needs: SCE program managers expressed the need for BEM tools to better accommodate analysis of certain emerging technologies and building types, as well as support additional assumptions, schedules, and outputs. SCE has an opportunity to advocate for these issues in the development of future BEM tool iterations. Details on requested emerging technologies, building types, parameters and narrative descriptions can be found in Appendix B – Specific BEM Improvement Needs.

- Building Types: SCE program managers expressed the need for BEM tools to better accommodate analysis of building types currently not well-served by the BEM tools in use for SCE programs. These building types include sports fields, supermarkets, data centers, jails, and hospitals.

- BEM Assumptions, Schedules, and Outputs: SCE program managers expressed the desire to include various rulesets, assumptions, scheduled and output variables in BEM tools, including the ability to have equipment degradation factors for modeling existing equipment, greenhouse gas (GHG) estimates, embedded energy savings results for water savings, and controls and commissioning modeling.
- Building Simulation Registry Issues: The CEC designed and implemented CBECC with the expectation or creating a registry of building simulations completed within the software. The registry is intended to provide program implementers with a database to track the results of projects, and to certify that models were run correctly for compliance. However, SCE program managers reported that as of September 2015, the registry for CBECC-Com is not operating.
- SCE Firewalls: Since the CBECC-Res compliance tool requires access to third-party servers for certifying simulation results and generating compliance and home energy rating systems (HERS) documentation, program managers for RNC have to leave work (exit the SCE network firewall) in order to be able to complete their work (process compliance models). Similar firewall issues were reported by the Codes and Standards team in teaching the software on SCE campuses. Students cannot perform simulation while in training because the SCE network firewall prevents communication with external servers. Similar issues are likely to be faced by the non-residential programs when using CBECC-Com when/if the non-residential registry is in place.
- Processing Speed and Design Time: SCE program managers and customers have expressed concern and frustration about the amount of time and effort needed to conduct non-residential building simulation using CBECC-Com. The non-residential simulation model requires three separate programs with SketchUp to build the model, OpenStudio® to translate geometry into CBECC readable file, and CBECC to process the simulation using EnergyPlus. If the user wishes to change the geometry of the building (for parametric analysis of architectural features, or to correct an error), the user must repeat all of the transfer and translation steps of the process. TRC suggests that SCE advocate for future improvements to CBECC-Com that enables users to perform simulations and modify building architecture more rapidly.
- Develop BEM Tools to Serve SCE Programs: SCE expressed frustration that CBECC-Com is not meeting program needs because the tool is made for compliance, not for calculating above-code savings. SCE worked with EnergySoft developers to resolve the issue temporarily, but there are still limitations to the tool in terms of their capabilities to model innovative technologies commonly employed by program participants. SCE explained how output results from BEM tools are not always useful. Some tools do not provide hourly results, or require the user to go through extra steps to manually collect hourly results. Other tools have limited options for reporting, forcing SCE program administrators to take a screenshot or hand copy the results. It is critical for any model to provide a high level report of results, and provide access to more detailed results. TRC suggests that SCE develop program-specific model outputs (e.g., DEER peak demand results) and reports (including program-specific incentive calculations and savings claims).
- Align BEM Tools with ZNE goals: SCE has an opportunity to help align BEM tools with ZNE goals. The ability to forecast renewable generation is available as some tools have sun angles already. However, new construction models do not

forecast renewable generation, as renewable generation is not a factor in complying with Title 24. To predict ZNE performance requires analysis of all building energy end-uses not just those allowed by current program rules to be claimed for savings. For example, current new construction program rules do not allow for savings claims based on plug loads or appliance efficiency, but for a ZNE building those end-uses are critical in order to maximize energy efficiency and cost-effectiveness of the ZNE package. Current program rulesets and BEM tools used for programs do not offer those capabilities, neither do code compliance tools that use defaults that cannot be changed by the user.

- Simplify and Streamline Quality Control: DSM Engineering would benefit from an automated diagnostic review process for energy models. These diagnostic automated evaluations exist already in EnergyPlus. DOE staff have created scripts to check for whether a given project lighting load is within the expected LPD range for the project. Similarly, SCE could develop building unique model evaluation steps (and protocols) for each program or building type to speed up review and to ensure consistent assumptions across program projects. As an example of streamlined quality control (Figure 8), the DOE published a description of a data-driven approach to identify measures, evaluate the acceptable ranges of inputs and outputs, and to calibrate energy models.

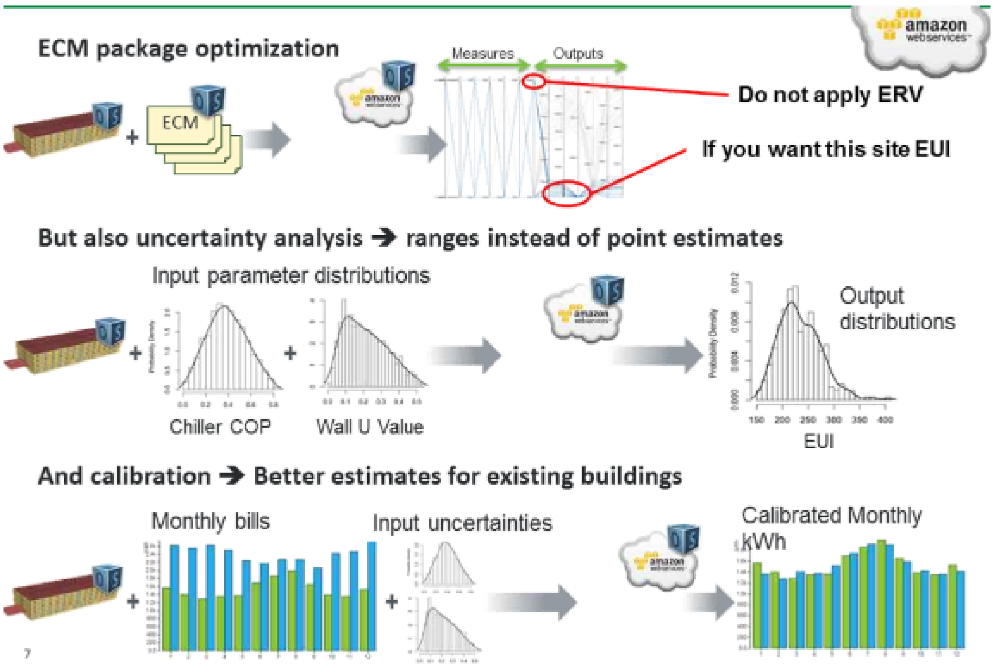


FIGURE 8. BEM OPTIMIZATION, UNCERTAINTY RANGES AND CALIBRATION

BEM Decision Making Framework

Based on findings from SCE program manager interviews, BEM tool research and industry focus group findings, TRC developed the decision-making framework to guide SCE's future BEM activities. The goal of this framework is to help SCE identify and prioritize recommendations for future BEM tool decisions beyond the term of this project.

BEM Decision Making Process

TRC proposes the decision-making process outlined in Figure 9 (enlarged version provided in Appendix A – BEM Tools Decision Making Framework). This decision-making framework is intended to align with SCE's Customer Programs & Services (CP&S) Product Governance Process.

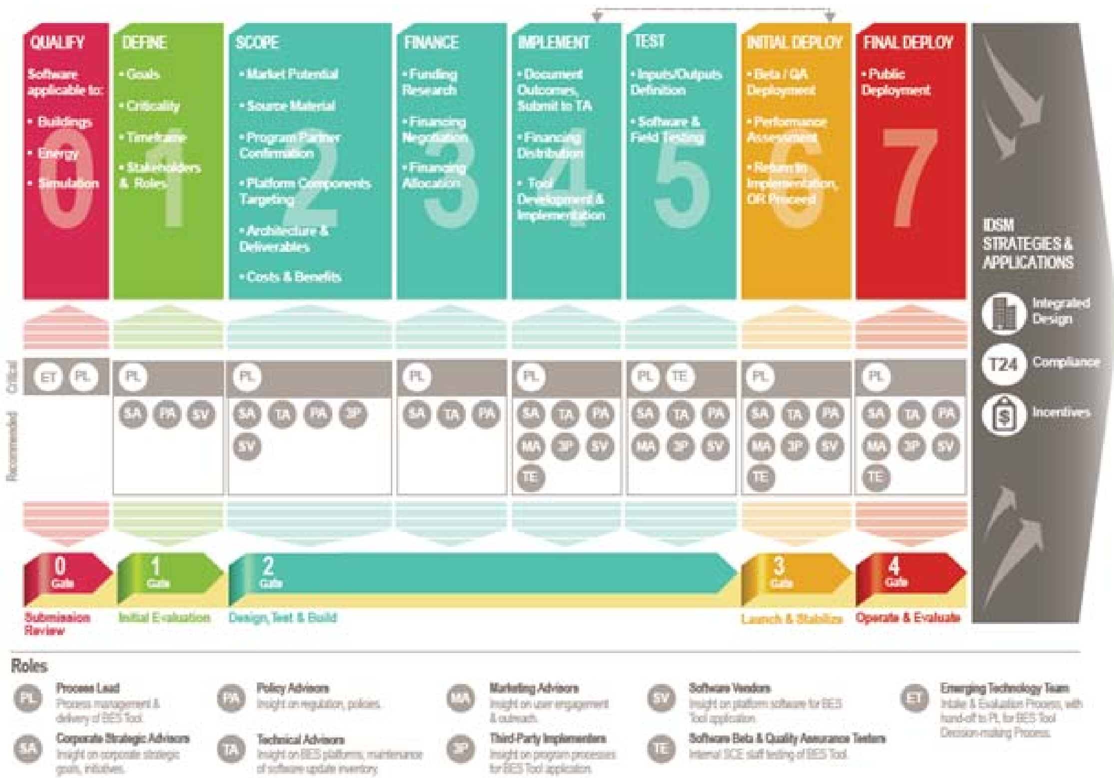


Figure 9. Proposed BEM Tool Decision-Making Process

The decision-making process is composed of seven (7) steps as outlined at the top of Figure 9. These correspond to the stages in the CP&S Product Governance Process as outlined at the bottom of Figure 9. The responsibilities section of Figure 9 outlines the persons or entities that are deemed to be critical or recommended to be involved in each of those seven steps. The goal of this decision making process is to support IDSM strategies from the perspectives of supporting integrated designs, conducting code compliance calculations, and calculating appropriate incentives for proposed measures through SCE programs.

STEP 0 – QUALIFY

Findings from the interview and focus groups identified a variety of challenges for SCE related to BEM tools for energy efficiency programs. However, not all of these challenges can be resolved through updates or improvements to BEM tools. Therefore, the initial step in the decision-making framework is identifying whether the issue is directly related to the BEM tools themselves. To help guide the decision-making process, the following list of questions need to be asked for each of the proposed efforts or needs identified for BEM tool related work:

- Is It BEM Software?

  Confirm that the software being proposed or requested meets the definition of BEM software identified in this roadmap.

- Is the change to simulation engine, rulesets, inputs/outputs, or the GUI?

  If the issue in question is directly related to BEM tools, it is then necessary to identify which part of the BEM tool(s) is the source of the challenge.

  Additional BEM tool criteria are outlined below in Step 1.

- Which SCE program(s) benefit?

  In addition to identifying the root causes of the challenge, it is also necessary to identify which SCE programs are most impacted by challenges with BEM tools, and which programs would benefit from any changes or improvements to those tools.

  A detailed discussion of program-based criteria is included below in Step 1.

- Does a similar tool or any precedent exist?

  Once the above details are identified, SCE should consider whether there are precedents for addressing the issue, or other similar tools that address the issue.

- Is a funding source identified?

  Identifying a funding source is critical to the implementation of any BEM tool efforts, but SCE should use the findings from the previous steps to inform how any efforts are funded.

- What are the deliverables and are they valuable by IDSM as a whole?

  Finally, and perhaps most crucially, for each BEM tool effort, SCE should clearly define the final deliverables, and identify if they are valuable to the broader IDSM team.

Step 0 aligns with Gate 0 of the CP&S Product Governance Process.

STEP 1 – DEFINE

Once SCE determines that a new idea qualifies for further BEM tool development, SCE faces the challenge of prioritizing and explicitly defining the changes needed. Therefore, the next step in the BEM decision-making process is defining the goals, criticality, timeframe, and stakeholders.

The program goal(s) should define the required data inputs for project processing within the program. One question to consider is if the program targeting demand, generation, efficiency, or integrated demand side management? Depending on the program target, SCE can identify which BEM tools can serve the program needs.

The timeframe will change and adapt over time to internal goals and external requirements. In the short term, SCE should consider three milestones, along with internal business and strategic milestones, when reviewing the timeframe of BEM tool needs this decision making framework:

- 2015 immediate (short term): These needs identified are widespread issues that require attention immediately and should be resolved as soon as possible.
- 2016/2017 rolling portfolio (medium term): These needs are going to help SCE make smart decisions about BEM tool-use during the transition from three-year program cycles to rolling program cycles.
- 2020+ ZNE (long term): These needs must be addressed in the next 4+ years in order to prepare SCE programs to incentivize customers to meet statewide policy initiatives beginning in 2020.

Step 1 aligns with Gate 1 of the CP&S Product Governance Process.

Step 2 – Scope

After SCE qualifies and defines the BEM tool development needs, SCE stakeholders should develop a scope and impact assessment. As part of the scoping process, SCE decision makers should focus on what needs can be realistically implemented to improve BEM tools support of SCE programs. The scope must consider what the market potential impact could be for the investment, as well as the source material availability. (Read: whether the tool can be modified easily.) SCE can evaluate the implications of BEM tool choice and modifications based on the following criteria at a minimum:

- **BEM tool proprietary engine:** Is the tool proprietary? Does the proprietary nature of the tool limit SCE's ability to meet its desired outcome?
- **Cost:** SCE needs to weigh the cost of purchase (for both SCE and customers), as well as the cost to conduct quality control review on projects and the cost to train staff to use the tool.
- **Market acceptance:** SCE should consider how the tool is perceived by users and staff.
- **Modification capability:** In addition to whether the tool is proprietary, SCE should consider the level of effort required to modify the tool.
- **User-friendly interface:** Clunky, frustrating interfaces will turn customers away from BEM tools.
- **Comprehensive component library:** Determine whether the tool has building components pre-defined to reduce modeler decision differences.
- **Approved by regulators or likely to be approved by regulators:** SCE should determine whether the tool is already approved by regulators or if strong likelihood exists that the tool will be approved in the short to medium term, and if that approval timeline meets SCE desired outcomes.
- **Program partner confirmation:** Are program partners engaged in and supportive of proposed BEM tool changes?

Step 2 aligns with Gate 2 of the CP&S Product Governance Process.

STEP 3 – FINANCE

Based on an initial definition of the need, and a detailed scope assessment of the impact of the BEM tool investment, SCE must propose the BEM tool investment to SCE corporate strategic advisors, technical advisors, and policy advisors for a determination regarding whether to fund the BEM tool investment. Whenever possible, SCE should ask the following questions: Is this BEM tool development need shared among many programs? Can SCE cost share investment among various programs?

Step 3 aligns with Gate 2 of the CP&S Product Governance Process.

STEP 4 – IMPLEMENT

Once a BEM tool investment is financed, SCE should begin implementation with the following considerations:

- Align program outcomes with customer experience. (e.g., Change new construction program rulesets to allow projects to model efficiency and generation in the same model.)
- Improve the transaction ease (or cost) for each project to collect data and document results. (e.g., improve a BEM tool to provide organized/reportable electricity savings for each project).
- Evaluate the customer experience to document project targets. Is there any activity SCE can implement to reduce customer burden?
- Review the program process to identify each customer, administrator, third-party, and regulatory involvement throughout the program. SCE should attempt to reduce data transfer hassles at each step of the program.
- Consider whether SCE should develop rulesets internally or guide development of rulesets by engaging a third party developer?

BEM tools can export data in transferrable data formats (XML, CSV) to improve data transfer between BEM tools and SCE databases. SCE can leverage its online relationship with customers to conduct all applications, program forms, and project milestone tracking online, reducing administration communication burden. SCE can build custom program report outputs for BEM tools to reduce project review time. SCE can implement automated quality control from within BEM tools to reduce the administration time needed to verify accuracy of BEM models. And all of these program improvements can be shared across the SCE program portfolio and should be considered during the implementation phase of the BEM decision making process.

Step 4 aligns with Gate 2 of the CP&S Product Governance Process.

STEP 5 – TEST

Testing of any BEM tool modification requires significant early forethought to set expectations for user experience, tool performance, tool accuracy, program transaction ease, and consistency of results. SCE should document the test procedure for every BEM tool investment so developers can understand the expected performance of the tool, and to provide guidance to future BEM tool investment projects. The considerations for testing are:

- **Inputs:** Are the various potential data input processes addressed? (e.g., manual data input, automated data import, data screening process to filter bad data)

- **GUIs:** Are the various user cases addressed? At a minimum, tools should be tested in Windows and Mac environments. In addition, SCE should consider developing a short list of potential GUI testers. These testers should be people unfamiliar with BEM tools so SCE can test the intuitiveness of the interface.
- **Outputs:** Do the output formats meet the program needs? SCE should pay careful attention to the layout and attractiveness of all output reports.
- **Rulesets:** Do the rules changes address the scope as defined in Step 2?

Step 5 aligns with Gate 2 of the CP&S Product Governance Process.

STEP 6 – INITIAL DEPLOYMENT

After the major kinks are identified and resolved during Step 5, SCE should identify a select group of users to further refine and test the tool. The group of users included in the initial deployment should be a subset of the anticipated users. The SCE program manager(s) requesting and driving the BEM tool change should identify the persons to include in the beta testers group. SCE should develop a standard questionnaire or interview script to collect feedback from beta testers. SCE should develop a criteria to evaluate feedback from the beta testers (e.g., If overall rankings of the BEM tool are less than 3/5, return to Step 4 – Implementation.). If the feedback from beta testers meets or exceeds pre-defined expectations, SCE should recommend that the BEM tool investment is approved for Step 7 – Final Deployment.

Step 6 aligns with Gate 3 of the CP&S Product Governance Process.

STEP 7 – FINAL DEPLOYMENT

SCE will need to announce the BEM tool to the users impacted. SCE should engage marketing advisors in this process from Step 4 through Step 7. Before SCE can launch the BEM tool change, SCE's marketing team should develop outreach materials to explain the changes and benefits to end users. SCE should engage key stakeholders identified in Figure 9 to ensure that all affected programs, users, and stakeholders are coordinated on the final deployment status and schedule.

Step 7 aligns with Gate 4 of the CP&S Product Governance Process.

DECISION-MAKERS

The initial list of stakeholders and decision makers identified in Figure 9 are defined below. SCE should periodically review and revise these roles as staff responsibilities change and as the BEM decision making process matures:

- **Process Lead (PL):** Manages the BEM tool investment, drives the process.
- **Corporate Strategic Advisors (SA):** Person(s) who can provide oversight and approval of BEM tool changes with regard to SCE corporate initiatives.
- **Policy Advisors (PA):** Person(s) well-versed in Title 24 requirements as well as CPUC program evaluation rules and regulations.
- **Technical Advisors (TA):** Person(s) capable of translating PL needs into more technical jargon; someone with some experience revising and modifying software.
- **Marketing Advisors (MA):** Person(s) involved in marketing and branding of SCE.

- **Third-Party Implementers (3P):** Representatives from third party implementer organizations that will be impacted by the particular BEM tool under development.
- **Software Vendors (SV):** Representatives from companies that build, supply, or modify software who are not employed by SCE.
- **Software Beta and Quality Assurance Testers (TE):** Group of users, program staff, third-party staff, and other necessary person(s) that can be tasked with testing and providing feedback about BEM tool changes.
- **Emerging Technology Team (ET):** The person(s) identified by SCE to support the coordination between the CP&S Product Governance Process and the BEM decision making framework.

CONCLUSIONS

The conclusions summarize the common themes discovered through interviews and industry research regarding BEM tools and their use within SCE programs. BEM tool engines are misunderstood to be the root cause of inaccuracy and inefficiency, when uncertainty and variability of data inputs, rulesets, and decisions ultimately limit the accuracy of results.

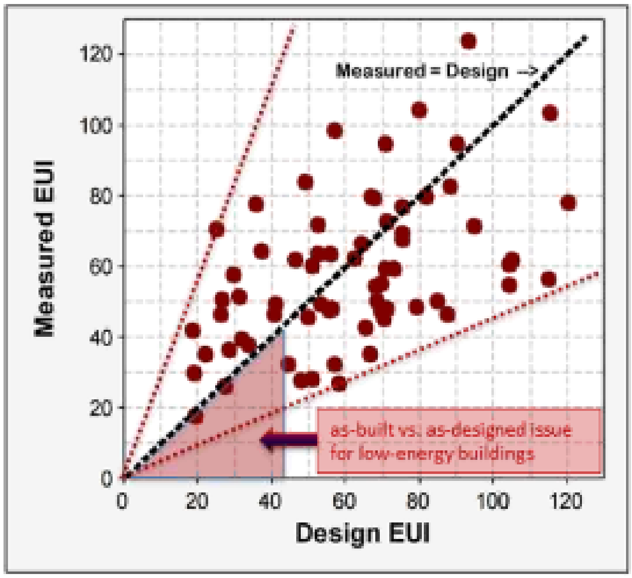
The BEM roadmap report outlines the market of BEM platforms and the interchangeable components that support various platforms. SCE has an opportunity to influence BEM tool development to support integrated demand side management (IDSM) goals: integrated design, improved Title 24 compliance, and market transformation incentive programs.

SCE program managers provided extensive feedback and insight about program needs. BEM tool investments can help address some issues that are shared among programs. For example, program managers most commonly expressed needs, that related directly to the BEM tools. These needs include:

- **Accuracy:** BEM tool produces accurate results for all projects within a program.
- **Predictability:** BEM tool produces simulation projections that precisely predict measured project performance.
- **Ease of use:** BEM tool requires minimal training (of users and SCE staff) which usually is a tradeoff with accuracy and predictability.
- **Cheapest transaction cost:** BEM tool inputs are easily captured, results are easy to conduct quality control on, and outputs are well organized for SCE programs processing.
- **CPUC approval:** BEM tool has regulatory approval and SCE can confidently claim savings with approved BEM tool. Alternately, SCE is confident about eventual CPUC approval of a tool that has not been previously approved by the CPUC.

Some of the challenges program managers identified are related to regulatory frameworks or internal SCE policies that cannot be resolved through the BEM tools, nor addressed by the BEM decision making framework.

According to a study conducted by the New Buildings Institute, there are six sources of differences between BEM tools simulation results and real world outcomes. The study compared the simulation performance to measured performance for buildings built to LEED-NC standard. Figure 10 shows the comparison between design EUI and measured EUI for the study buildings[x]. These results highlight that BEM tool usage differences can generate incorrect simulation results, and that the model algorithms alone do not ensure accurate BEM tool results.



Source: Energy performance of LEED-NC buildings, NBI, 2008

FIGURE 10. LEED-NC BUILDINGS, SIMULATED VS. MEASURED

The differences that created the wide range of results in Figure 10 can be categorized as sources of uncertainty and sources of variability. Drawing a distinction between uncertainty (user misinformation) and variability (user choices) casts light on the underlying causes of these differences, and can help SCE make decisions about how to minimize each source of error.

The three sources of uncertainty are:

- Model algorithms
- Input parameters
- Modeler decisions

SCE can address uncertainties with BEM tools through better communication about input parameters and documentation of correct modeling decisions.

The three sources of variability are:

- Weather
- Occupancy
- Operation (e.g., controls)

SCE can limit the variability of BEM tool inputs through better communication about program rules, improved software workflow, and streamlined QC review.

SCE can develop solutions to minimize the errors caused by five of these sources of differences, while also improving customer experience and BEM tool data transfer. Separately and in parallel, SCE can support refinement of model algorithms by providing project data feedback to model algorithm developers (DOE).

RECOMMENDATIONS

The recommendations outline three suggestions to refocus SCE BEM investment decisions. First, SCE should leverage engine development efforts led by other entities (as opposed to specifying engine development changes). Second, SCE investments should primarily fund open source (non-proprietary) tools that bridge the gap between simulation enginer and GUIs. Third, SCE should invest BEM tool development time and energy into improving program processes, BEM rulesets, input processers, output processers.

Table 1 identifies 40 actionable suggestions identified during interviews with SCE program managers and subsequent discussions. The matrix outlines the category of the recommendation, the BEM tool component impacted, and recommendations for internal and public stakeholders.

SCE should focus BEM development efforts on: support of CEC, DOE and industry efforts to improve BEM tool environments; investment in open source, publicly available (not proprietary) software platforms; improvement in program processes, rulesets, input processers, output processers and user education.

LEVERAGE INDUSTRY EFFORTS

SCE should minimize direct spending on engine development, but rather leverage efforts by broader industry groups and the DOE to ensure that the leading BEM tools can serve SCE needs. The following engines should receive the most SCE support and investment through the provision of data, test standards, and performance curves for measures:

- Integrated Design; EnergyPlus
- Compliance Improvement: CBECC-Res, CBECC-Com

SCE can rely on the tool developers to improve simulation engines and can certainly lobby/champion the need for changes, but SCE should not spend their own monies developing engine algorithms to the extent feasible. Instead, SCE should focus on providing measured project performance data through laboratory or field studies, developing test standard, and developing performance curves to facilitate the refinement of BEM engine algorithms.

SCE can lead customers, program implementers, and the market towards statewide policy ZNE goals of:

- All new residential construction in California will be zero net energy by 2020.
- All new commercial construction in California will be zero net energy by 2030.
- HVAC will be transformed to ensure that its energy performance is optimal for California's climate.
- All eligible low-income customers will be given the opportunity to participate in the low-income energy efficiency program by 2020.

Meeting these aggressive goals requires that SCE help customers build and retrofit projects using advanced technologies, underserved building types, and real-world simulation of building operation. TRC has identified many opportunities for SCE to improve program offerings by supporting DOE and LBNL to improve BEM engines. All

CBECC simulations create a building data structure in a transferrable code called extensible markup language (XML). These XML outputs contain all data that users input, and simulation results from the model. The advantage of these files is that SCE can aggregate many projects together and perform large scale data review.

As an example, SCE could collect BEM models from the Permanent Load Shift (PLS) program. These projects will contain various solutions to thermal energy storage. SCE could provide XML files for all the simulation models, along with customer utility data, in order for BEM engine developers to refine simulation algorithms. During a webinar hosted by the CEC on September 18, 2015, the DOE announced a new project to leverage this activity.

Supporting model algorithm validation will help SCE meet CA statewide policy goals by engaging engine developers to implement emerging technologies, underserved building types, and real world building operations. (Identified in the Software Development Needs section.) With advanced technologies, SCE can incentivize customers to install very efficient building systems, engage new customers (e.g., sports complexes and jails), and better support their customers by more accurate modeling of building operations (e.g., advanced lighting controls, equipment degradation factors).

SCE should help support model algorithm validation to support further engine development and new simulation algorithms for under-utilized, under-analyzed, or new emerging technologies and strategies. To that end, SCE can:

- Develop a process to absorb and document XML (or other output files) from all BEM files processed through SCE programs.
- Continue to collect data to justify new measure baselines (miscellaneous electric loads) through the Emerging Technologies Team's efforts.
- Develop algorithms to calculate impacts from non-DEER measures.
- Identify lead/stakeholders within SCE to communicate data collection results to external interested parties (DOE, CEC, Software Vendors, and CPUC).

The burden of engine improvement resides with BEM tool developers, especially for proprietary and privately owned tools. The nature of BEM tools enables SCE to support engine development efforts and focus on software workflow, customer communication, and program transaction streamlining.

INVEST IN OPEN SOURCE, NON-PROPRIETARY

The BEM tools industry is coalescing around software that is updatable, scalable, and stacked. The mixed ownership between federal (DOE), states (CEC), and private entities allows SCE to engage directly with the level of the software stack to develop solutions to SCE needs. To further support collaboration and development, TRC feels that SCE efforts are best spent on open source and non-proprietary tools where they are available.

Open source tools offer SCE the ability to modify the BEM tool workflow to suit each program need; as well as modifications to improve the reporting capability for one program, which can be shared across SCE's portfolio. Based on the interviews and focus group findings, TRC identified the following software workflow improvements.

Close the Gap Between Engines & GUIs

SCE can leverage the open-source software platform model to support strategic SCE needs. The BEM improvement needs vary by the user and by SCE program. As an example of how each IDSM strategic user can benefit from BEM tool development:

- **Integrated Design:** Operating schedules, passive heating and cooling systems, operational ratings, and operational efficiency.
- **Compliance Improvement:** Energy design Rating, calculating whole-building EUI, move away from % above code, and integrate/include PV, battery storage, DR.
- **Incentives Programs:** Program unique rulesets, program unique reports (show California Advanced Home Program (CAHP) report), program unique data input templates, list of desired program measures identified in this report (e.g., chilled beam cooling, advanced daylighting).
- **BEM Experts:** Identify team of BEM experts to be included in BEM decision making process (SCE internal or third parties) to help review BEM needs of new measures identified through the CP&S Product Governance Process.

Program Specific BEM Processing Recommendations

SCE should review each program process and to determine whether program-required data is generated, transferred, or aggregated manually. For example, SCE computes peak demand manually outside of the design and compliance models. The open source nature of CBECC enables the software to calculate and export peak demand automatically.

As part of program review and decision making, SCE should determine program data outputs. (e.g., SBD may want kBTU/sf whereas CAHP may want CAHP score.) The proposed program review process outlined in the BEM Decision Making Process section will identify: all program data requirements, whether certain data are generated already or if BEM tools need modification to generate program results, and determine who can make the necessary BEM tool modifications.

Rulesets and Output Generator Recommendations

The CBECC engines are customizable and SCE can develop rulesets for each program with high-project volume to streamline program workflow. The rulesets can create and define:

- New variables (e.g., CAHP Score)
- Output variable calculations (Cannot modify the underlying simulation algorithms.)
- Input requirements (highlight required fields, grey-out unnecessary fields)
- User interface customizations (program-tailored results displays)
- Simulation result reports (PDF outputs documenting incentives and simulation results)

For programs with high project volume (e.g., SBD and CAHP), SCE should consider reviewing the program process for opportunities to reduce transaction costs and streamline customer experience.

SCE can engage the CEC to develop a library of operation schedules approved for each program. If customers are able to choose from program-approved pre-defined building schedules (when building a simulation performed within the specific SCE program rulesets), program customers may submit BEM tools with fewer incorrect schedules.

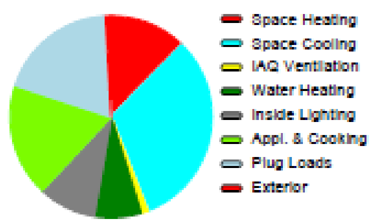
The rulesets can also define the templates for project results reports. Instead of each SCE program using one standard report output (Util-1), each SCE program can create tailored reports, reinforcing SCE programs' brand with customers and streamlining program workflow. The report can provide incentive details along with the program eligibility criteria (e.g., EUI or DEER peak demand).

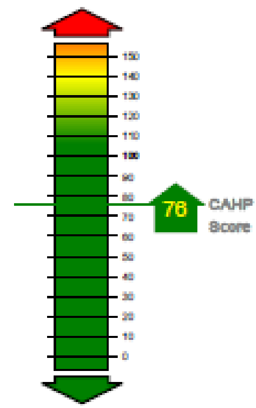
SCE can invest resources to define program specific reports from BEM tools. Previously, programs used the "Util-1" and the "CF1R" forms to extract project results. (See Figure 12). However, because these forms are used by various end-users, changes to the forms are not dictated by SCE but have a direct impact on SCE program operations.

TRC worked with the statewide residential new construction team (CAHP) to develop tailored program reports. This document is generated directly from a BEM simulation in CBECC-Res so customers, energy consultants, and program implementers have access to a standard template of information. This report reduces program administration because implementers can output this report for each project application without any additional work. Other programs (e.g., non-residential new construction) have to post-process project data from a standard output report. SCE should develop templates and identify report data needs in order to leverage the CBECC report generator capability.

CAHP Incentive Report (CIR) — **Home Incentive: $ 1100**

Project Size and Location		Orientation and Type	
Conditioned Floor Area	2017 sq. ft.	Project Type	Single Family
Climate Zone	CZ11 (Red Bluff)	Front Orientation	North





Kicker and Incentive Summary	
CAHP Score Initial	79
DOE Zero Energy Ready Home (3 possible)	- 0
Future Code Preparation (5 possible)	- 0
High Efficacy Lighting Credit (3 possible)	- 3
Low Energy Use Home (5 possible)	- 0
Ultra Low Use Home (5 possible)	- 0
CAHP Score Final	76
Total Project kTDV Energy	244,118
Incentive Amount	$ 1,100

Project Savings Margins	
Project Savings (kW)	-0.1
Project Savings (kWh/yr)	-92
Project Savings (therms)	170

Energy Use Summary				
End Use	Savings (kWh/yr)	Savings (therms)	CAHP Std (kTDV/ft2)	Proposed (kTDV/ft2)
Space Heating	77.00	116.70	28.16	14.89
Space Cooling	-169.00	0.00	52.96	36.45
IAQ Ventilation	0.00	0.00	1.33	1.33
Other HVAC	0.00	0.00	0.00	0.00
Water Heating	0.00	53.30	13.42	9.15
Inside Lighting	0.00	0.00	11.18	11.18
Appl. & Cooking	0.00	0.00	21.91	21.91
Plug Loads	0.00	0.00	22.98	22.98
Exterior	0.00	0.00	1.14	1.14
PV Credit				0.00
Compliance Total			95.87	63.82
TOTAL	-93.00	170.00	153.06	121.03

Name of Model File:	Plan 2017
Date and Time of Analysis:	11:27, Thu, Sep 03, 2015

FIGURE 11. CAHP REPORT GENERATED FROM CBECC-RES

The CBECC report generator is a server run by Rasent Solutions, LLC, which communicates with any compliance model and serves two functions: generates reports and digitally signs the project simulation to certify that the simulation is valid and acceptable. The CAHP report (Figure 11 is built into the report generator server process for all CBECC-Res projects. CBECC-Com operates in parallel to CBECC-Res with the report generator server. SCE can leverage existing report templates and integrate new report templates into the report generator, so that all programs do not have to rely on one standard output report (Figure 12).

CERTIFICATE OF COMPLIANCE - RESIDENTIAL PERFORMANCE COMPLIANCE METHOD CF1R-PRF-01

Project Name: Plan 1698 **Calculation Date/Time:** 10:34, Mon, Dec 08, 2014 **Page 1 of 9**

Calculation Description: Plan 1698 **Input File Name:** Plan 1698.ribd

GENERAL INFORMATION					
01	Project Name	Plan 1698			
02	Calculation Description	GJG 1698			
03	Project Location	TBD			
04	A City	Selma, CA	05	Standards Version	Compliance 2014
06	Zip code		07	Compliance Manager Version	BEMCmpMgr 2013-3b (685)
08	Climate Zone	CZ13	09	Software Version	CBECC-Res 2013-3b (685)
10	Building Type	Single Family	11	Front Orientation (deg/Cardinal)	Cardinal
12	Project Scope	Newly Constructed	13	Number of Dwelling Units	1
14	Total Cond. Floor Area (FT^2)	1698	15	Number of Zones	1
16	Slab Area (FT^2)	1698	17	Number of Stories	1
18	Addition Cond. Floor Area	N/A	19	Natural Gas Available	Yes
20	Addition Slab Area (FT^2)	N/A	21	Glazing Percentage (%)	10.6%

COMPLIANCE RESULTS	
01	Building Complies with Computer Performance
02	This building incorporates features that require field testing and/or verification by a certified HERS rater under the supervision of a CEC-approved HERS provider.
03	This building incorporates one or more Special Features shown below

FIGURE 12. STANDARD "CF-1R" REPORT GENERATED FROM CBECC-RES

INPUT PROCESSORS AND GUI RECOMMENDATIONS

SCE can minimize BEM tool errors while improving customer experience by leveraging BEM tool modifications to better communicate program expectations. BEM tool choice, guidance about system modeling rules, input parameter ranges, occupancy schedules, and data outputs can be defined and communicated within BEM tools. Further recommendations include:

- Support customers in choosing the correct tool for each application.
- Increase collaboration between customers and SCE. Program thresholds of participation and system modeling requirements will help customers and SCE programs work together more effectively.
- Translate the technical reference manual assumptions into prompts built directly into CBECC.

If the inputs to the BEM simulation gave feedback about input ranges, program customers would submit BEM models with fewer mistakes. SCE programs have unique rules and expectations for systems data. Where one program may allow users to model existing conditions as found on site as the baseline, another program may require Title 24 code as the baseline. Explicitly defining these rules and expectations is possible in CBECC-Res and CBECC-Com, and will reduce SCE program transaction costs by minimizing data input errors.

As a simple example to illustrate data input guides, the following is a screen capture of the CBECC-Res water heater system input screen. SCE can build functionality into the tool, such that when a user requests the model run for a particular SCE program, the user will be prompted with allowable data ranges.

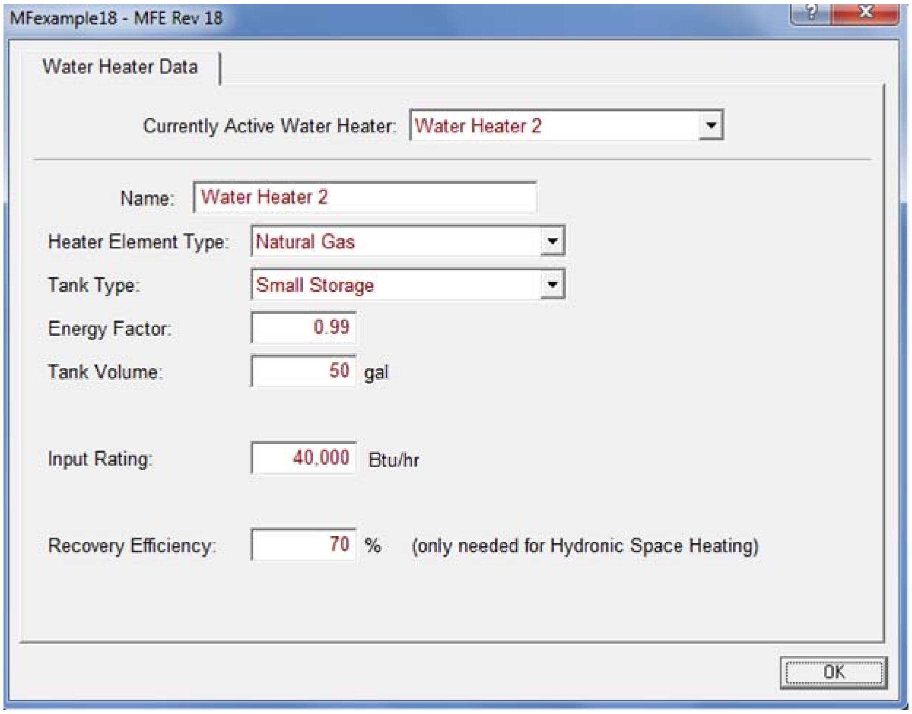


FIGURE 13. WATER HEATER SYSTEM INPUT SCREEN (CBECC-RES)

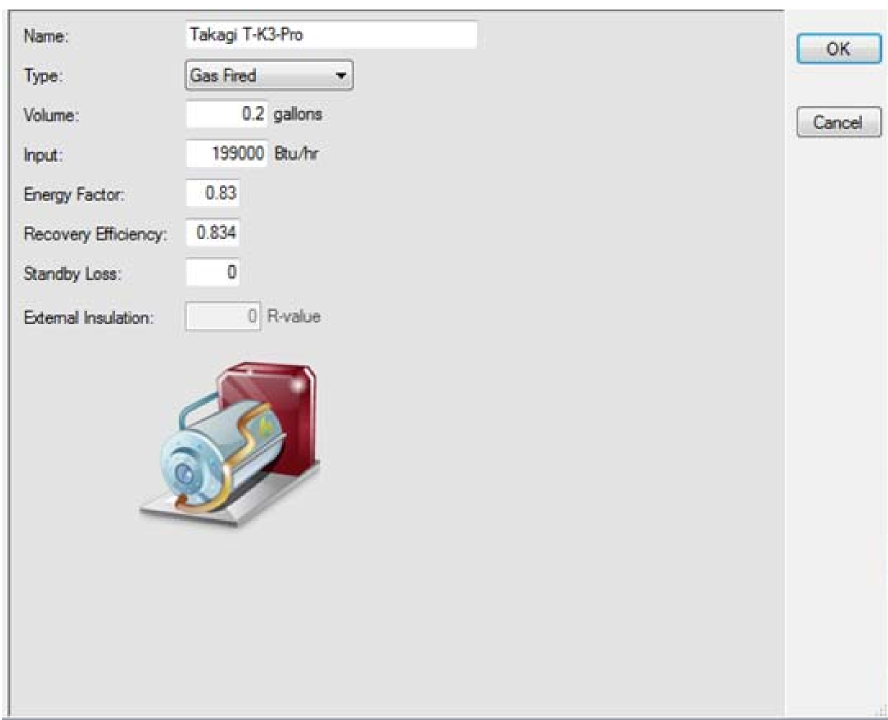


FIGURE 14. WATER HEATER SYSTEM INPUT SCREEN (ENERGYPRO 6)[xi]

Guiding customers through SCE program applications from within the BEM tool is the most direct way to engage customers before they submit the energy model, and to ensure that SCE program review is as efficient and cost-effective as possible. SCE should define the requirements of BEM tool demands for program compliance to make sure that any new tool has the appropriate capabilities. Initial checklist items SCE should consider:

- Input variable ranges (SEER values from 8.0-16.0)
- Program specific default assumptions (Roof type for commercial buildings assumed to be flat asphalt roof with effective R-value of X.)
- BEM reports (hourly load calculations, GHG reduction estimates, PV generation forecast)
- Configurable calculations (Percent above code, DEER peak demand)

Specific BEM Project Recommendations

The following (Table 1) is a comprehensive list of recommendations based on specific needs from SCE's portfolio of programs. It identifies the section of this document where the recommendation's justification is located, as well as the platform component that needs to be addressed. SCE stakeholders and non-SCE stakeholders can gauge and prioritize these recommendations to develop new BEM projects that are in alignment with the findings of this roadmap.

TABLE 1. POLICY, COMMUNICATION AND BEM SOFTWARE NEEDS IDENTIFIED BY SCE PROGRAM MANAGERS

DOCUMENT LOCATION	DOCUMENT SECTION HEADING	RECOMMENDATION	PLATFORM COMPONENT OR POLICY	SCE STAKEHOLDERS	PUBLIC STAKEHOLDERS
Policy Needs	Code Compliance Vs. Above Code Performance	SCE should advocate and support development of an ASHRAE Appendix G style approach to model actual project baselines for programs.	Rulesets, GUI	Res and Non Res Retrofit Programs	ASHRAE
	CPUC Guidance on BEM Investments	SCE should seek direct guidance from the CPUC on how program funds can be used to develop BEM tools.	Policy	Corporate Strategy	CPUC
	Program Rules Consistency	SCE should integrate program specific rules and data input ranges into BEM tools natively; or the information can be written in a format that is accessible to program participants and energy consultants developing the energy models so they are clear on the rules, guidelines, and procedures for the programs.	Rulesets, GUI	Program Managers (PMs)	CPUC, IOUs
	Leverage Industry Efforts	SCE should continue to support energy simulation advances by providing experienced feedback and real-world data towards the improvement and calibration of simulation assumptions and results.	Inputs and Outputs	ET, Technical Advisors	DOE, Software Vendors
	BEM Tool Transparency	SCE's programs should consider moving towards, primarily or exclusively, using non-proprietary, open source tools such as EnergyPlus-based tools.	Policy	Corporate Strategy, ET	DOE, Software Vendors
	Legacy Versions	TRC recommends that new construction programs use the most current version of approved tools, and existing construction programs use one version generation previous (than the	Policy	Corporate Strategy, PMs	CEC

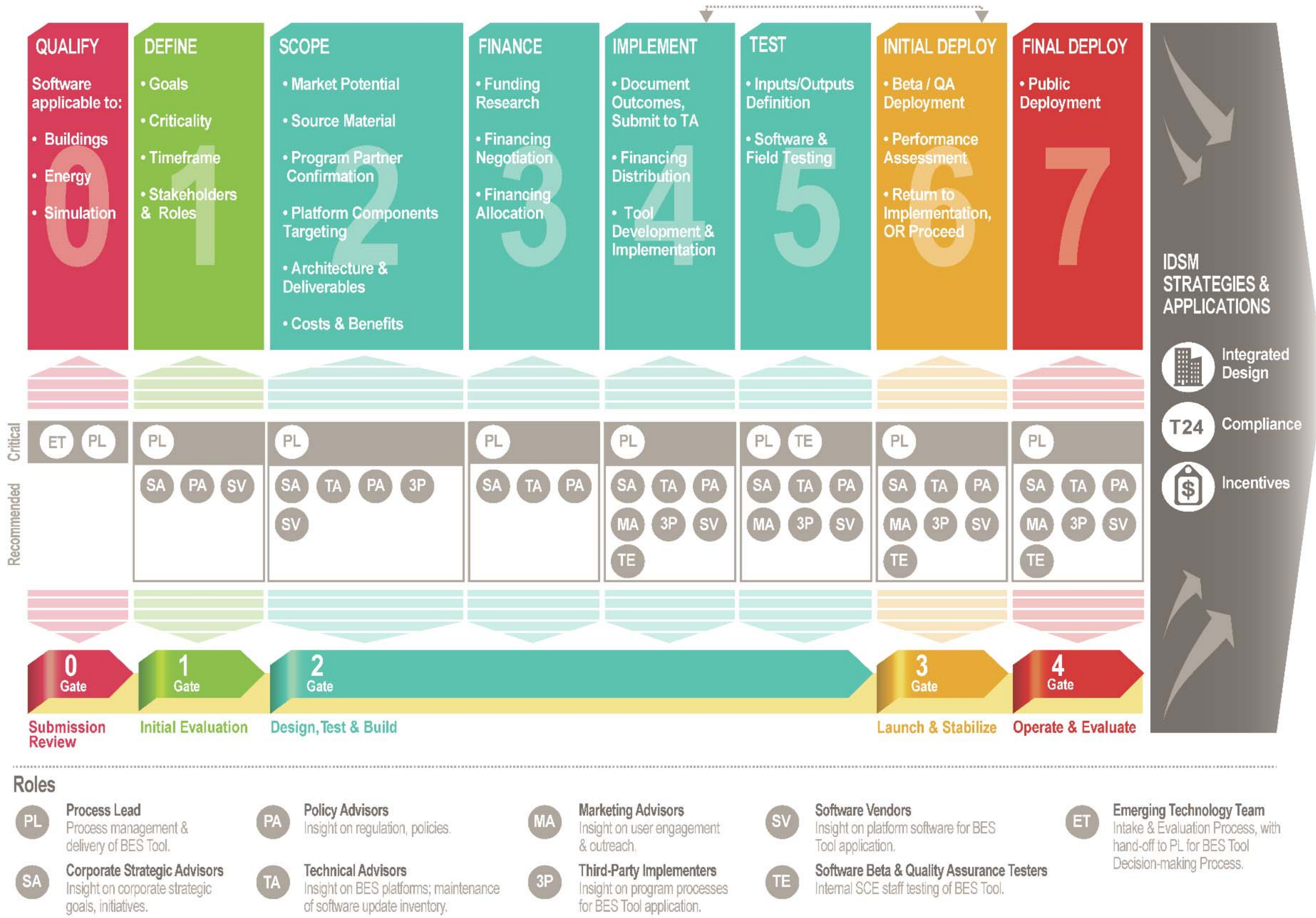
Document Location	Document Section Heading	Recommendation	Platform Component or Policy	SCE Stakeholders	Public Stakeholders
		most current version) of the approved BEM tool for each program.			
	Align Energy Efficiency and Demand Response	SCE could consider investing in a CBECC-Com calculation module to estimate DR potential as a generator.	Rulesets, GUI, Input, Output	DR, PLS	CEC, DR Aggregators
	SCE Specific Program Criteria Needs	SCE should explore opportunities for incentivizing projects on different metrics than percent above code. For example, using a whole-building EUI that addresses non-regulated loads, even for new construction programs where the goal is to incentivize above code projects.	Rulesets, GUI, Output	RNC, NRNC	CPUC, CEC
Communication Needs	Align BEM Results with Actual Project Impact	SCE should consider developing rulesets that enable users to complete a compliance simulation and actual design conditions simulation simultaneously.	Rulesets, GUI, Output	Program Managers (PMs)	CEC, Software Vendors
	Code Change Communication	SCE should integrate trigger sheet prompts and code change fact sheet synopsis for various building systems (e.g., HVAC, DHW, insulation, HERS credits) into compliance rulesets and CBECC-Res and –Com GUIs.	Rulesets, GUI	Program Managers (PMs)	CEC, Software Vendors
	Documentation and Validation of Custom Tools	SCE should document and provide validation data for the custom BEM tools at the time of upload to the CTA.	Policy	DSM Engineering	CEC, CPUC, IOUs
	Documentation and Validation of Custom Tools	SCE can develop an internal custom tool database to improve tracking of the custom measures database and work paper updates.	Policy	DSM Engineering	CEC, CPUC
	Communicate BEM Tool Input Requirements	SCE has an opportunity to communicate BEM tool requirements more clearly by maintaining an updated approved tools list for each program on	Policy	Corporate Strategy	n/a

Document Location	Document Section Heading	Recommendation	Platform Component or Policy	SCE Stakeholders	Public Stakeholders
		each program's website (or each program's area on SCE.com).			
Software Development Needs	Project Cost Effectiveness and Parametric Analysis	SCE should develop (or advocate that CEC should develop) a GUI to support parametric analysis capabilities in CBECC-Res and –Com.	Rulesets, Engine	Program Managers (PMs)	CEC, Software Vendors
	Project Cost Effectiveness and Parametric Analysis	SCE should promote parametric analysis as the standard approach to energy simulation for programs to provide customers with more project options, and to potentially reduce the penalty of free ridership.	Policy	Program Managers (PMs)	IOUs, CPUC
	CBECC Missing Functionality	SCE should identify bugs and recommend updates to CBECC engines to address program needs.	Engine	Program Managers (PMs)	CEC, IOUs
	BEM Engine Needs	Thermal energy storage	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Phase change materials (PCM)	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Natural ventilation (passive ventilation)	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Variable refrigerant flow (VRF)	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Heat recovery for showers	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Daylighting (Dynamic Radiance)	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Advanced lighting control systems (ALCS)	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	BEM Engine Needs	Dedicated outside air	Engine	DSM Engineering, ET	CEC, CPUC, IOUs
	Building Type Case Needs	Sports fields	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	Building Type Case Needs	Supermarkets	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	Building Type Case Needs	Data centers	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs

Document Location	Document Section Heading	Recommendation	Platform Component or Policy	SCE Stakeholders	Public Stakeholders
	Building Type Case Needs	Jails	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	Building Type Case Needs	Hospitals	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	BEM Assumptions, Schedules and Outputs	Equipment degradation factors	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	BEM Assumptions, Schedules and Outputs	Greenhouse gas (GHG) estimate	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	BEM Assumptions, Schedules and Outputs	Water energy calculator	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	BEM Assumptions, Schedules and Outputs	Controls and commissioning	Rulesets	Program Managers (PMs)	CEC, CPUC, IOUs
	Building Simulation Registry Issues	SCE should advocate for development and completion of the BEM registry for commercial projects.	Policy	Program Managers (PMs)	CEC, CPUC, IOUs
	SCE Firewall	SCE should work with SCE IT to remove the firewall limitations on performing CBECC-Res and CBECC-Com simulations, while users are behind the SCE firewall.	SCE IT	SCE IT	n/a
	Processing Speed and Design Time	SCE should advocate for CBECC-Com users to be able to revise a building architecture and re-run a simulation in a reasonable amount of time.	Policy	Program Managers (PMs)	CEC, CPUC, IOUs
	Develop BEM Tools to Serve SCE Programs	SCE should develop program-specific model outputs (e.g., DEER peak demand results) and reports (including program-specific incentive calculations and savings claims).	Rulesets, GUI	Program Managers (PMs)	CEC, CPUC, IOUs
	Align BEM Tools with ZNE goals	SCE should work with the BEM Tool developers (DOE, CEC, etc.) to develop rulesets, modeling procedures, and output formats that support whole building	Policy, Rulesets, GUI, Output	Program Managers (PMs), RNC, NRNC, PLS, EV, DSM Engineering, ET	CEC, CPUC, IOUs

Document Location	Document Section Heading	Recommendation	Platform Component or Policy	SCE Stakeholders	Public Stakeholders
		energy modeling that analyzes energy efficiency, demand response, energy storage, and renewable generation all under one BEM tool stack. Part of the challenge are current CPUC rules that separate renewable generation, electric vehicles and energy storage from energy efficiency programs. The technical challenge is to get the BEM tools to perform the necessary analysis.			
	Simplify and Streamline Quality Control	SCE should develop building unique model evaluation steps (and protocols) for each program or building type to speed up review and also to ensure consistent assumptions across program projects.	Rulesets	Program Managers (PMs)	CEC, Software Vendors
	Simplify and Streamline Quality Control	SCE should develop simulation software built-in mechanisms to automatically review inputs based on expected ranges (e.g., boiler thermal efficiency range 80-96% is “normal”).	Rulesets	Program Managers (PMs)	CEC, Software Vendors

APPENDIX A – BEM TOOLS DECISION MAKING FRAMEWORK



APPENDIX B – SPECIFIC BEM IMPROVEMENT NEEDS

BEM ENGINE

Thermal energy storage: This is the collection of technologies incentivized by the permanent load shift (PLS) program. Currently, usage of thermal energy storage is limited by the understanding of its operation in the real world, as the schedules of operation are not yet standardized and the performance of the cooling with respect to occupant comfort models is not fully understood. SCE can support development of this technology by collecting and utilizing laboratory and field performance data to estimate thermal comfort of occupants using existing BEM tools such as EnergyPlus. Of particular interest to SCE in expanding thermal energy storage is better modeling of performance of Phase Change Materials (PCM). In buildings, PCM provide better thermal energy storage than conventional ice storage systems. In buildings, PCM functions much like large cold compresses or heat packs that humans use to reduce swelling or release tension.

Natural ventilation: This can be a challenge as identified by SCE's Codes & Standards program, "In the ideal situation it would be really nice if for every compliance run there was a full CFD calculation, especially for natural ventilation. There's also no way to run a comfort model in [residential applications], for natural ventilation or evaporative cooling. But, I'm not sure the trade off in accuracy is worth the additional effort to incorporate it."

Variable refrigerant flow (VRF): According to the DSM Engineering team, "[A user cannot model] VRF, which is a problem inherent to CBECC-Com. In Energy Plus you can model VRF with heat recovery; in eQuest you can model VRF but not heat recovery. One of the challenges with modeling VRF is that you can't model behavior [because] the models continue to think that the heat recovery is free, but that is not the case." During building operation, when the airflow is unbalanced and the heat transfer between zones is unbalanced, the system has to work harder, but the models do not model unbalanced situations accurately. SCE can aide the development of better VRF modeling guidelines by providing project data and BEM export data for projects implementing VRF systems. When BEM engine developers have access to datasets with VRF performance, the BEM engine can model these unbalanced scenarios more accurately.

Heat recovery for showers: Captures otherwise wasted heat entrained in greywater, pre-heating the cold water supply to the shower. These systems are already in operation throughout the industry but cannot be modeled because BEM tools need more project examples to justify savings claims. The DOE estimates that the simple payback for heat recovery systems is between 2.5-7 years[xii]. SCE can continue to support the development of a heat recovery simulation algorithm by providing project data to simulation engine developers.

Daylighting (dynamic radiance): Helps to understand and simulate the interactive effects of daylighting. Currently, SCE typically has to use a separate tool to simulate daylighting, and then feed performance parameters back into the whole building BEM model. Some DOE-2-based tools can simulate simple sidelit daylighting controls, but SCE is not confident in the models accuracy when the building includes skylights because of the interactive impact of shades, lighting, and HVAC.

Advanced lighting control systems (ALCS): Involves the use of multiple layers of manual and automatic lighting controls. As the Title 24 code requires more automatic lighting controls, calculation of baseline and energy savings from lighting efficiency projects has become more difficult. SCE should support efforts to develop an ALCS calculator tool to encourage lighting efficiency in programs.

Dedicated outside air: This will need further real-world research and monitoring before BEM tools can accurately model heat recovery ventilation (HRV) and energy (enthalpy) recovery ventilation (ERV). In addition to thermal comfort model limitations, HRV and ERV performance depends on outside air conditions and the heat exchanger configuration (enthalpy wheel, fixed plate, heat pipe, run-around coil, and thermosiphon)[xiii].

BUILDING TYPES

Sports fields: These have not been included in SCE incentive programs because the occupancy schedule and hours of use are not well understood. SCE needs to advocate for PUC rules regarding schedules for sports complexes. The technologies in place at sports fields are not limiting; the schedule of operation and the interactive effects need further study.

Supermarkets: Present unique modeling struggles because refrigerated cases operating within air conditioned space do not have reliable project data. The refrigerated cases support the air conditioning in the space through radiation, while also adding additional load to the air conditioning systems through the heat rejection of the refrigerated case equipment (pumps, motors, and lights). The complexity of modeling refrigerated cases in air conditioned spaces is exacerbated by sprinklers used to keep food fresh. The added liquid adds evaporation into the heat balance of the space. SCE can pilot research into the operation of heating and cooling systems in supermarkets.

Data centers: Hold a unique place in Title 24. Given the immense value and secrecy of data centers, regulations create a special case for them. SCE has a great opportunity to engage data center operators by developing a more accurate data center baseline. Modeling data centers requires accurate documentation of schedules of operation of the cooling systems employed in the space, but this building type does not require technical advancements to model correctly.

Jails: Present a unique challenge about occupancy schedules. With changing tenancy over time as well as non-standard building use schedules, jails require policy review and alignment to develop rules of building simulation.

Hospitals: Hospitals have the most projects outside of compliance with the energy standards (according to Savings by Design). Because hospitals are governed by the Occupational Safety and Health Administration instead of Title 24, there is no baseline for hospitals. SCE is using a document to create rules for hospitals (developed by PG&E) to establish baseline. In order to incentivize energy efficiency in hospitals, Savings by Design surveyed multiple hospitals to create the baseline. This is an example of the activity SCE should continue to support for other unique building types identified in this document.

BEM ASSUMPTIONS, SCHEDULES AND OUTPUTS

Equipment degradation factors: Equipment degradation factors will help SCE customers accurately model the performance of existing systems. Title 24 provides guidance about existing equipment efficiency based on the installation year. The "vintage table" default values document one performance factor for all legacy equipment installed during a certain time period. (e.g., Water heaters installed before 1990 are assumed to have an energy factor of 0.525.) SCE should consider refining these default assumptions for various equipment based on the conditions of the equipment (visual inspection or diagnostic testing).

Greenhouse gas (GHG) estimate: This tool runs cost-effectiveness and feasibility calculations on reach codes, and then translates impacts into "cars taken off the road" equivalents. The tool addresses local government GHG reduction goals. SCE should invest resources to incorporate this reporting mechanism directly into CBECC-Com and CBECC-Res. Allowing users to report GHG equivalents will assist local governments and cap and trade programs in realizing their goals.

Water energy calculator: A water energy calculator computes the embedded energy in water (the amount of energy used to pump, treat, and transport the water to the end-use building). With California's drought conditions, water reduction programs are becoming more prevalent, and SCE can generate energy savings through water reduction. Similar to the GHG tool, embedded water energy calculation should be incorporated directly in CBECC-Res and Com providing users with information about energy savings through low-flow fixtures and low-water-use appliances.

Controls and commissioning: These projects (including refrigerant charge adjustment) wish to claim savings by adjusting the use schedules using advanced control methods. Schedule adjustments require review and certification of validity in order to be implemented in projects that want to operate more efficiently than code.

APPENDIX C – BEM TOOLS AND DEVELOPMENT HISTORY

The algorithms used to calculate building energy began development in 1925 when Nessi and Nisolle used response factor methods (RFM's) to calculate transient heat flow[xiv]. In the 1960s ASHRAE engineers began implementing energy simulation algorithms into computer engines. From the 1960s through today, Building Energy Modeling tools have been developed by various entities in an attempt to continue to refine and perfect the simulation results.

After the 1990s, more BEM tools were developed and many more specialized tools were built to address unique needs such as air flow measurement (CFD) and daylighting analysis. However, during the 21st century, these specialized tools and other advanced features began to become incorporated into more mainstream BEM tools. Today, there are literally hundreds of BEM tool options for professionals to use in the building industry.

EnergyPlus is rapidly emerging as the tool of choice for several jurisdictions, including the California Energy Commission, due to the fact that EnergyPlus is open source, and using the open architecture allows multiple modules to be added over time to expand capabilities and develop derivatives.

Some examples of BEM tools/engines used prominently in CA are:

- **EnergyPlus**: The open source BEM engine developed and maintained by the US Department of Energy (DOE) to perform whole building simulation. EnergyPlus is a simulation tool that receives regular investment and development under the oversight of DOE. EnergyPlus has existed in some nature since 1996, but its development can be traced back even farther because EnergyPlus is an amalgamation of BLAST and DOE2.1e.
- **DOE2.2 (eQuest):** A proprietary engine developed by J Hirsch and Associates to perform whole building simulation based on a variant of the DOE-2 energy simulation engine. eQuest is the simulation tool used to develop DEER.
- **Trace 700:** A proprietary engine developed by TRANE to perform HVAC energy utilization and lifecycle cost. Trace 700 performs simulation on HVAC systems only and does not perform whole building analysis. Trace 700 is not a whole building simulation and does not compete with EnergyPlus or eQuest for that distinction.
- **IES-VE:** A proprietary platform developed by Integrated Environmental Solutions to perform whole building simulation based on the ApacheSim engine. IES-VE is a modular tool that allows users to change calculation modules to suit different simulation needs. IES-VE has a Title 24 module available for projects to use to build a performance path simulation for compliance with Title 24.
- **TRNSYS:** A proprietary engine developed by Thermal Energy System Specialists to perform whole building simulation. TRANSYS is a research level tool that is designed to allow for customization and algorithm definition. TRANSYS developed a module built into EnergyPlus for more mass market use.

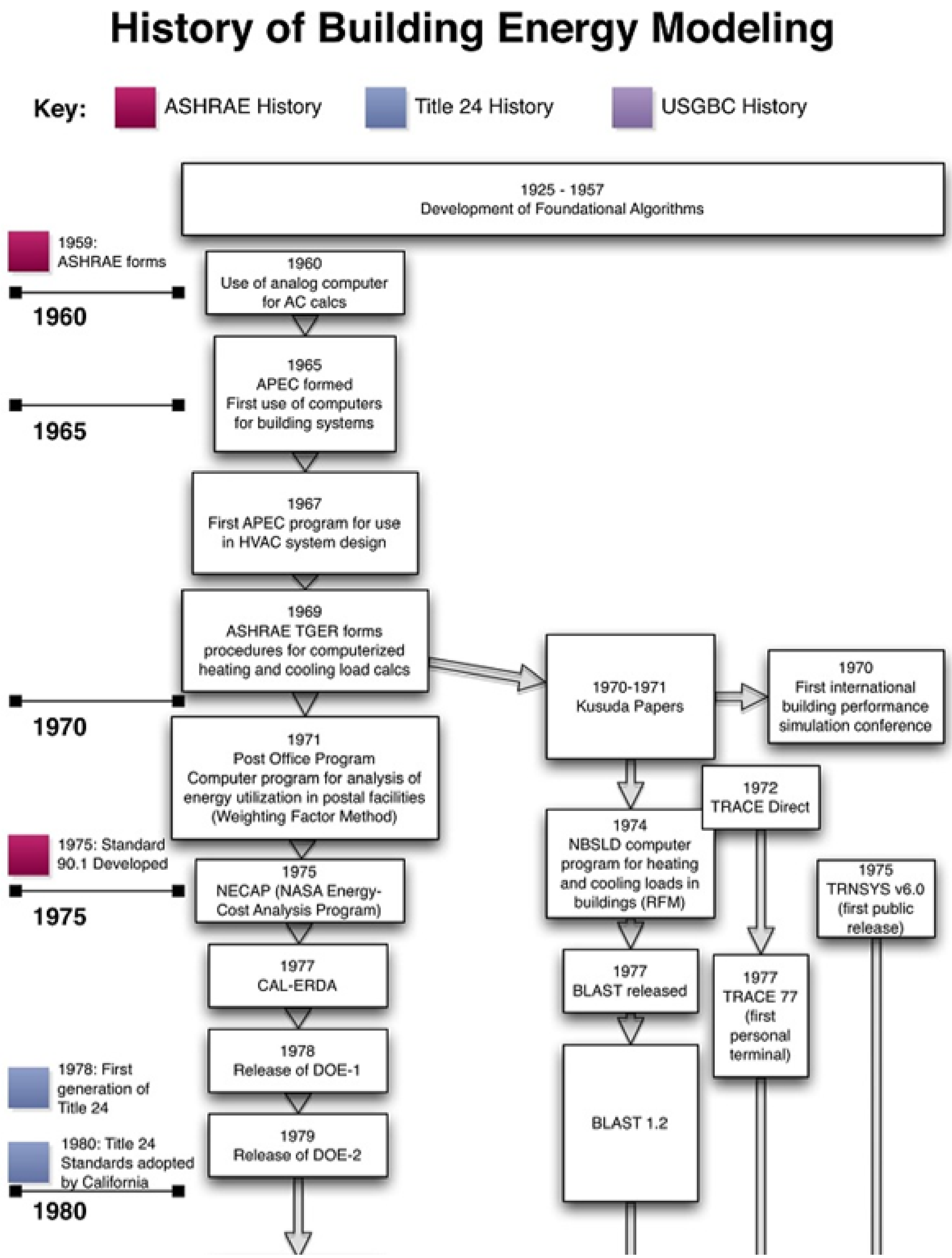
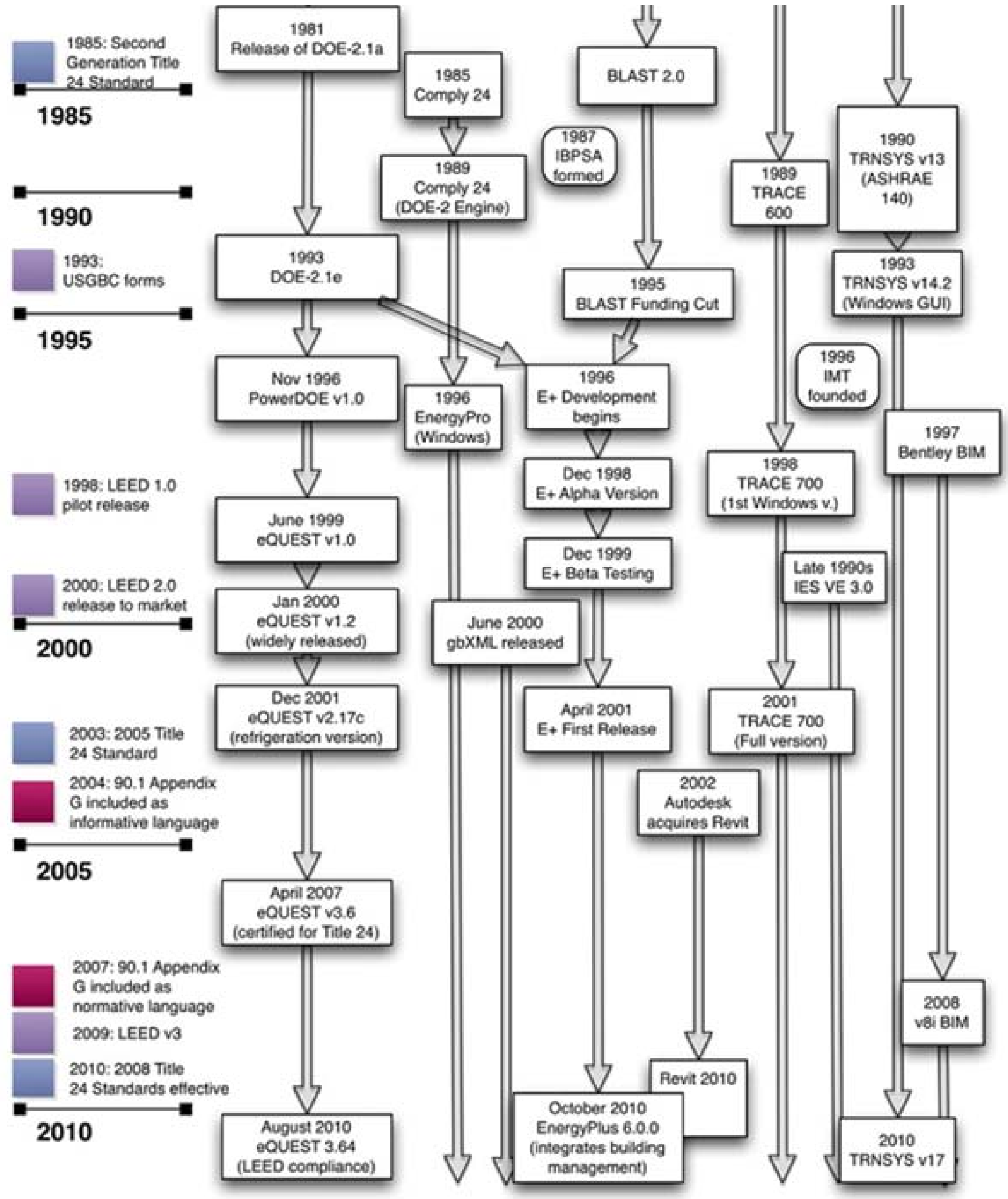


FIGURE 15. HISTORY OF BUILDING ENERGY MODELING (1 OF 2)



*A portion of this flow chart was adapted from: Haberl, J. & Cho, S. (2004). *Literature review of uncertainty of analysis methods*. Texas Engineering Experiment Station, Texas A&M University, College Station, Texas.

FIGURE 16. HISTORY OF BUILDING ENERGY MODELING (2 OF 2)

APPENDIX D – SCE PROGRAM MANAGER INTERVIEW SCRIPT

TRC will interview SCE program managers to gather feedback about BEM tools current use cases, limitations, and program-specific experience using BEM tools and future programmatic needs. TRC will use this interview to develop a survey to solicit feedback from a larger group of BEM tool stakeholders. TRC will use the interview results to inform the structure of the survey. TRC will use the interview and survey results to guide two focus group discussions. One focus group will include BEM industry experts and the other focus group will include SCE management and planning staff.

INTERVIEW INTRODUCTION

- On behalf of SCE, TRC is conducting a BEM tool research study to develop a long-term BEM improvement roadmap. The objectives are to establish BEM needs priority and develop decision making framework for long-term planning.
- We are speaking with SCE program managers to gather program-specific knowledge about BEM tool capabilities, limitations and future BEM improvement needs.

BACKGROUND AND ROLE

- What is your name and title?
- Please briefly describe your role within SCE.
- What is your role (or your group's role) in making decisions about building energy modeling (BEM) tools?
- How many SCE staff use BEM tools in support of your program? How many consultants?

BEM TOOLS USED

- Can you provide a list of BEM tools you use?
- Can you please identify a list of measures that projects apply for most often?
- What application(s) do you use BEM tools for most often? Least often?
- Does your utility-administered program require calculations from BEM software tools? Is BEM tool-use optional?
- Which is more important to your program: usability (GUI), reliability, and accuracy (engine) or cost? Why?
- Which BEM related capabilities help your program(s) most?
- Does your program track or calculate estimated GHG reductions through BEM tools?

FOR CODE COMPLIANCE SOFTWARE USERS

- Do you believe BEM tool margin above code calculation is an accurate basis by which to calculate incentives?

Missing Features, Disputed Calculations

- Which BEM related inabilities hinder your program(s) most?
- Are there any BEM tools that you would prefer to use in your program but cannot due to regulatory restrictions? If so, what tools?
- Are there any BEM tools that you continue to use despite known limitations because of CPUC rules or CEC software choices?
- Are there any measures that you wish to include in your program but cannot? Why?
- For any measures listed, please describe the limitations of BEM tools if any.

Limitations or Concerns With Tools

- Which BEM tools do you feel most confident about the accuracy of the calculations?
- Which BEM tools do you feel least confident about?
- How would you describe how BEM tools help to translate project applications into real energy savings?
- Are some BEM tools more user-friendly?
- Do particular BEM tools provide more useful outputs (pdf report, csv, etc.)?
- What BEM tools do you absolutely avoid using? Can you please describe why you avoid using these tools?
- What BEM tools do you prefer to avoid using? Can you please describe why you prefer to avoid using these tools?

Procedures for Selecting BEM Tools

- What BEM tools do you prefer to use? For which efficiency measures?
- Has your program adopted new BEM tools during your tenure as program manager? If so, for what purpose?
- How does your group make decisions to adopt BEM tools for your program?

Workarounds or Engaging With Developers

- Does your program recommend changes to BEM tools developers (eQuest, EnergyPlus, EnergyPro, etc.)?
- What are some examples of recommended changes to BEM tools?
- Can you list any BEM tool developers that you have engaged to identify workarounds to current BEM tool limitations?
- Do you instead prefer to develop internal SCE program work around solutions?
- Based on your staff's most common operations, do participants request to use other BEM tools not expressly approved by your program?

Notes and Comments

- What changes do you feel are necessary to make BEM tools more suitable to your workflow?

- What feedback/impressions do your customers typically have concerning your program's BEM-related processes?
- Do you have any other feedback about BEM tools or recommendations new needed features?

GLOSSARY

Analytics: A collection of software as a service (SAAS) providers that identify patterns in utility data, providing customers with recommendations for utility-use reductions through energy efficiency or demand response. Analytics allows firms to conduct audits on properties without visiting the site. Through patterns in utility data, analytics firms can identify whether a building can be operated more efficiently and whether the property can reduce its peak demand.

BEM Tool: For the purpose of this study, BEM Tool is defined as a physics-based simulation that, at a minimum, calculates:

- Thermal loads (based on climate, envelope characteristics, occupancy and other internal loads, and ventilation rates) at hourly (or finer) time steps
- Impacts of all common major building systems and equipment (e.g., HVAC (equipment and distribution system), lighting, service water heating, refrigeration, cooking, plug loads, and controls)
- Interactions among building systems (sometimes called secondary impacts)
- Energy-use by fuel type

Codes and Standards Enhancement (CASE): The mechanism by which C&S program proposes updates to Title 24 and Title 20 for review and adoption by the California Energy Commission (CEC). The CASE process proscribes a methodology for analyzing energy savings potential and the incremental cost of the proposed measure.

Codes and Standards (C&S) Program: A statewide program that among other activities, provides studies to update energy codes including Title 24 and Title 20 in California. Title 24 part 6 is the building energy code and is typically updated on a three-year cycle. Title 24 part 11 is the 'green' code and is also typically updated on a three-year cycle. Title 20 is the state appliance standards and is updated on a continuous improvement model. C&S Program

Compliance Software is a collection of BEM software elements that includes a software engine to complete a Title 24 performance path simulation model. The compliance software imposes rules for simulation processing (e.g., default schedules of operation) through a compliance ruleset.)

Demand Response (DR): Describes the activity of a customer who decides to reduce power-use when the cost of electricity is above a certain threshold. SCE operates a range of demand response programs, because of the differences between power demand and energy use, the implementation of these programs differs drastically from energy efficiency programs.

Demand Side Management (DSM): The modification of customer-side demand for energy by using any combination of strategies: energy efficiency (EE), demand response (DR), distributed generation (DG), and energy storage (ES).

Distributed Generation (DG): Comprises all localized generation capabilities including solar PV, wind turbines, and small scale hydroelectric power. Distributed generation most often refers to rooftop solar PV. Distributed generation does not include renewable generation plants that sell power to SCE, and does not include power plants that only operate during peak demand periods (e.g., "peaker" plants).

DSM Engineering: The team within SCE that supports all demand side management (DSM) programs with engineering support, custom calculation review, energy simulation advice. and regulatory engagement for SCE's program activities. (Note: At the time of finalizing this document, SCE has changed the name of this team to be Engineering Services among other changes. However, to maintain consistency of the document narrative, we continue to use the term DSM Engineering in this document to reflect the views and opinions during the course of the project.)

Energy Use Intensity (EUI): A metric commonly used to define an index of the building energy-use based on the building square footage and is calculated by dividing the energy-use in question with the area affected by that energy-use. In case of whole building energy-use, the EUI equals the total building energy-use divided by the conditioned floor area of the building. Similar to how the miles per gallon metric can compare fuel efficiency between a pickup truck and a sedan, the EUI is a metric to show the relative efficiency of different buildings.

Green House Gases (GHG): Gases that absorb and emit thermal radiation in the atmosphere. GHG primarily refers to carbon dioxide (CO_2) but also includes methane (CH_4) water, vapor, and nitrous oxide (N_2O).

Home Energy Rating System (HERS) Program: A set of rules regarding diagnostic testing and acceptance of HVAC equipment. HERS also refers to an asset rating scale of buildings (from 0 to 250) which shows the building's efficiency relative to a reference home built to Title 24 prescriptive standards.

Interactive Effects: Refers to the impacts of various building systems on other building systems. One key example is lighting's interactive effect on heating and cooling loads. When inefficient lights are used, the space is warmed by the lights thereby reducing the need for heating. When inefficient lights are replaced, heating and cooling loads are impacted.

Integrated Demand Side Management (IDSM): Includes all activities an enduser can implement to operate a building most efficiently, for the lowest cost, using the most sustainable energy generation available. IDSM activities encompass energy efficiency, demand response, and distributed generation.

Lighting Power Density (LPD): The measure of lighting power (in Watts) used per floor area (square feet) of the space.

Parametric Analysis: A method to compare the results from changes to various parameters of building simulation. For example, parametric analysis allows the user to run an identical building simulation while changing window performance to compare the relative impact of various window types.

Software Engine: The collection of algorithms used to approximate thermodynamics, illumination, ventilation, and other energy-related calculations within buildings and to capture the energy performance of various systems and equipment.

Time Dependent Valuation (TDV): Describes a methodology of accounting for the value of energy-use dependent on the type of fuel used, hour of use, and location of use (climate zone). TDV is the accounting standard for Title 24 and all compliance building simulation.

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