CALIFORNIA
TECHNICAL FORUM

Cal TF Technical Position Paper No. 10: Recommendations for Improving Building Energy Modeling in California

I. Overview

Building energy modeling (BEM) serves a variety of purposes in California, from assessing Title 24 Energy Code compliance to estimating energy savings for deemed and custom measures. It also supports statewide load forecasting and integrated demand side management efforts. More recently BEM has been incorporated into grid-level optimization, distributed energy resources, and decarbonization initiatives. Over the years, however, there has been a general divergence of resources supporting the various modeling efforts such that a substantial level of redundant modeling work is done by those practitioners who need to satisfy multiple objectives. Given the variety of energy-related initiatives being undertaken in the state (including decarbonization, zero-net-energy buildings, and elevated energy efficiency goals), the California Technical Forum (Cal TF) considers the current, divergent modeling ecosystem as being ripe for review and reform. This technical position paper (TPP) outlines the various use cases and outlines a roadmap to harmonize those use cases, with an emphasis on aligning software and modeling rulesets and establishing processes that facilitate model sharing among the many users to reduce or eliminate redundant development efforts.

II. Background

Building energy modeling (BEM) has been used in California for a variety of purposes over the past several decades. The California Building Energy Efficiency Standards (Title 24) are formulated using BEM, and compliance for new buildings is often demonstrated using BEM. Also, the deemed energy efficiency measures approved for investor-owned utilities (IOUs) in California derive their default savings and demand impact estimates from prototypical BEM analyses. BEM is also used for a variety of custom project analyses as well as new construction programs such as Savings By Design (SBD). Finally, BEM is used for energy and load forecasting at the state level. More recently, communities have begun using the more advanced capabilities of new-generation simulation engines and dynamic BEM to support geographic energy impacts associated with buildings, distributed energy resource (DER), and energy efficiency.

III. Process to Develop Recommendations

The Cal TF held a one-day modeling charrette in San Francisco on May 30, 2019. The purpose of the charrette was several-fold:

1. Establish a common understanding of current use cases, simulation models, rulesets, and identifying broad areas of agreement in California.
2. Gain insights into the unique characteristics of each use case, including rulesets, data inputs and outputs, prototypes, and relationship to other identified use cases.
3. Identify new and emerging use cases for BEM that would inform the path forward from a software perspective, as well as use case management.
4. Identify the roles and responsibilities of the various market actors across the realm of building modeling.
5. Improve coordination by discussing how California stakeholders can more effectively track existing efforts to improve modeling while also reducing costs.
6. Identify future and emerging use cases for modeling, and develop processes to anticipate and plan for those use cases
7. Rank and prioritize recommendations for a roadmap to a future state that will focus resources going forward.

The morning session of the charrette provided a historical perspective of modeling in California and laid out the current landscape of building energy modeling. Notably, viewpoints expressed by the California Public Utilities Commission (CPUC) Staff and California Energy Commission (CEC) Staff:

- CPUC Staff expressed an interest and openness toward looking at other building simulation tools beyond DOE-2. Part of this exploration includes an understanding of why such a change would be needed, what the roadmap toward that transition would look like, and what cost and resources would be needed to get there. They also expressed an interest in understanding what would be needed to gain comfort that alternate tools would produce accurate results.
- CEC Staff noted that government resources should be more efficient with respect to modeling tools and methods. While there may be a role for regulators to develop rulesets, every effort should be made to use existing tools, rely on established industry standards, and collaborate with others to support test standards. CEC also noted that funds have been used extensively over time to model most or all buildings in California; these models should be kept in a central repository where they can be reused as needed. Finally, CEC notes that models have historically been used to derive singular point values (e.g., energy savings, demand reduction), whereas in practice most inputs and outputs follow probability distributions. Policies in the State should reflect this.

Steve Kromer provided a brief history of modeling in California and discussed prior efforts to improve modeling. In the last decade, several workshops and symposia have been conducted predominantly to serve as knowledge exchanges; few if any action steps or forward processes have resulted from these efforts. Key events discussed included:

- Rocky Mountain Institute (RMI) modeling workshop (2011)
- CPUC Energy Modeling Tools Workshop (2015)
- Southern California Edison (SCE) Code Compliance Software Symposium (2017, 2018)

Additionally, the Cal TF TPP #3 was briefly discussed; this TPP addressed the merits of using EnergyPlus versus DOE-2 simulation software for building energy use analysis in California.[1]

Doug Mahone provided a comprehensive presentation of the various use cases along with limitations and constraints that those use cases impose on modelers. Key use cases include:

- Energy code compliance
- Energy efficient building design
- Utility new construction programs
- Evaluation of utility whole-building new construction programs
- Estimation of measure impacts using normalized before/after metering (NMEC)
- Estimation of deemed energy savings for measures
- Estimation of savings for custom measures, projects, or measure bundles

The afternoon sessions of the charrette focused primarily on audience feedback on relevant modeling topics. One key exercise collected ideas and concerns from participants for each of three major topics:

Goals and Metrics: How progress of implementing changes and opportunities that would arise from the charrette should be tracked and how success of such changes will be measured.

Desired Future State: The future vision for BEM in California.

Future Uses, Opportunities, Emerging Needs: Types of new use cases that would be served by BEM.

For each topic, issues and concerns were identified and an informal vote was taken on each item to facilitate prioritization of efforts going forward. Key findings are addressed below; a complete list of all issues for the three categories can be found in Attachment C.

The information and recommendations in this TPP are based on the input gathered during the May 2019 charrette. The remainder of this TPP is organized as follows: Section IV summarizes the current modeling landscape and Section V presents the identified goals/metrics, desired future state, and future opportunities for BEM in California. Section VI explains how the Cal TF efforts are aligned with other initiatives. Section VII outlines a path forward for short-, medium-, and long-term perspectives. Section VIII enumerates next steps.

Several attachments provide supplemental information: Attachment A lists the modeling charrette attendees, and attachments B and C provide details and outcomes from modeling charrette break-out group exercises. More details on BEM use cases can be found in Attachment D.

[1] Beitel, A. et. al. 2016. "Cal TF Technical Position Paper No. 3: Case for Using EnergyPlus as "Default" Modeling Engine for the "Electronic TRM" Project." January 28.

IV. Current Modeling Landscape

A. Current State

While California has enjoyed a rich history of BEM, the variety of use cases that have evolved over time has led to situations where multiple models must be developed for a single building, with each model specifically developed to address the particular needs of an individual use case. Different core simulation engines are used for specific use cases, particularly in the regulatory arena, and highly-individualized rulesets have also been developed to support those use cases. As a result, practitioners who need to satisfy multiple objectives often need to create multiple, nearly-redundant models. Perhaps an extreme example of this can be represented by a recent University of California campus project, which comprised multiple buildings each of which needed to have five models developed to serve five use cases:

1. Title 24 compliance
2. Savings By Design
3. Code minus 20% new construction
4. Leadership in Energy and Environmental Design (LEED)
5. Performance contract savings achievement

B. Current Challenges

While there are a number of software engines and user interfaces available, the major use cases that currently exist rely on three discordant software engines. The CEC relies primarily on EnergyPlus for commercial energy code compliance and the California Simulation Engine (CSE) for residential energy code compliance. The CPUC relies on DOE-2.3 and DOE-2.2r for deemed measure savings development. The immediate challenge raised with this discordance is that models built to serve code compliance under either EnergyPlus or CSE cannot be run under the DOE-2 environments due to the structural differences in the software code libraries.

A related but separate issue centers around rulesets, which vary by use case and are generally not interchangeable. Title 24 models must be run against a specific CBECC-Com or CBECC-Res ruleset, which affixes certain non-site-specific operating criteria to the model structure (e.g., operating hours, occupancy levels). Feedback from parties during the charrette suggest that up to 80% of ruleset contents can be identical across most rulesets. Establishing and maintaining a common “base” ruleset could reduce redundant development costs for use-case specific rulesets.

Prototype development and maintenance was also identified as an area where redundant development costs are incurred. In California, at least three different prototype libraries have been used for commercial building modeling over the past two years for regulatory purposes:

- CBECC-Com – For 2019, 15 commercial building prototypes are available for Title 24 building analysis.[2]
- MASControl3 – This DOE-2-based software application uses 24 building prototypes to evaluate a variety of deemed energy efficiency measures as part of the Database for Energy Efficient Resources (DEER).[3]
- IOU Load Shapes – In the most recent load shapes study for the CEC ADM Associates developed 27 commercial prototypes, expanding on the 12 CEC commercial building types. This expanded prototype library was also calibrated using the 2006 CEUS study results, AMI data from the IOUs, and DEER2011 end use profiles.[4]

These prototype libraries are separately derived and maintained, and the parties that develop and use them do not share findings and rulesets with the other parties. It was also generally observed that the prototypes do not have well-documented inputs, making it difficult to ascertain whether the given prototype accurately reflects the building type it is intended to model.

In California, many buildings have been modeled in furtherance of code compliance, energy efficiency projects, and other objectives. However, no centralized model repository exists in the State, either public or otherwise. One of the opportunities raised by charrette participants suggested that having such a centralized library would facilitate modeling of subject buildings over time. For example, a Title 24 model developed for a given building could be retained in a publicly accessible repository; when future energy efficiency projects would need to be modeled for that building, the stored model could be "checked out", used to evaluate energy efficiency options, and when any selected energy efficiency measures are selected, implemented and verified, the model would be "check in" with the upgrades included. This would present practitioners with significant opportunities to evaluate client buildings more efficiently.

V. Improving the California Modeling Ecosystem

A. Goals/Metrics

The key metrics identified by the charrette participants are outline below:

Ensure Models, Prototypes, Rulesets and Processes are Successfully Integrated. Ensuring that all of the models, prototypes, rulesets and simulation processes work seamlessly together. This was an overarching metric with a message: whatever solutions arise out of this effort to align and harmonize modeling statewide needs to function properly. As part of this goal, certain key elements are necessary:

- Develop a roadmap to support this goal, which will necessarily identify one or more responsible parties for each element:
    - Regulators (CEC and CPUC)
    - Utilities (IOU and POU)

[2] http://bees.archenergy.com/resources.html
[3] http://deeresources.com/files/DEER2020/download/DEER2020_Prototype_Changes.xlsx
[4] https://ww2.energy.ca.gov/publications/displayOneReport_cms.php?pubNum=CEC-500-2019-046

Industry (developers and practitioners)
Cal TF

- Establish a single Reference Library of Building Prototypes. This library should be publicly available, useful across the spectrum of use cases (subject to tailored rulesets) and should contain fully documented inputs. Along with this library, clearly-defined ownership should be established to ensure that models will be updated as needed.

Minimize Redundancies. There should be a driven effort to eliminate duplicate expenditures of resources within the modeling community. A regulatory example cited by one participant identifies how the CEC, through its staff and consultants, must update prototype models to reflect baseline changes in Title 24 code, only to have CPUC, through its consultants, develop updated prototype models to reflect the same changes in the DEER prototype models.

Develop Interoperable Rulesets. As part of the effort to consolidate and reduce duplicate efforts, development of interoperable rulesets would be beneficial. As previously discussed, up to 80% of rules are common across rulesets, and eliminating the duplicate ruleset maintenance for that 80% could provide substantial resource savings.

B. Desired Future State for California Building Energy Use Modeling

The charrette participants generally agreed that, whatever form the future state of modeling takes, it should be based on open-source software with good documentation. The software should be transparent and support whatever level of peer review parties would deem appropriate. Ideally the software should be developed with public funding; this would reduce the risk of any “black-box” proprietary components being incorporated whose codebase cannot be verified or tested. Key elements of a desired future state include:

Coordinate with National Entities. Participants also agreed that coordination with National entities is important to a successful future state. Coordination with the International Code Council (ICC), which maintains the International Energy Conservation Code (IECC), as well as with ASHRAE and others, not only helps ensure a stable future state for modeling in California, but it can also cement State leadership in the national building modeling arena.

Standardize Outputs. Standardized model outputs, reports and metrics with common units of normalization would be beneficial. Today’s models generate a variety of outputs that serve the particular use case under consideration. It may be possible to establish a single set of standardized outputs that serve most, if not all, use cases while providing a common view for all users.

Include Uncertainties. Models in the future state should generate energy savings/consumption estimates with uncertainties attached. While it may seem axiomatic that any model only provides an estimate of energy impacts, there is no easy way to assess the range of uncertainty that is associated with the model. In a future state where probabilities and distributions may be assigned to inputs in lieu of the point estimates used today, the outputs should calculate and present the resulting uncertainty that those distributions create.

Any "Qualified" Building Simulation Tool Could be Used for Any Use Case. Finally, there was interest expressed by parties that any qualified software platform could be used for any use case. Participants understand that some test method must be used to qualify the software, to ensure that the model outputs are within the realm of reasonableness.

C. Future Uses of and Opportunities for Modeling

Several significant emerging opportunities were identified under this topic. The opportunities were quite varied in nature. The four highest-ranked opportunities described below.

Zero Net Energy and Decarbonization. Modeling of zero net energy (ZNE) buildings was the top-ranked opportunity. Charrette participants included building decarbonization in this category due to the related objectives that both opportunities present. Key to success with this opportunity is the modeling of behind-the-meter generation (e.g., solar PV), energy storage, and emerging technologies. Also key to this opportunity is the incorporation of electric space heating baselines as part of the Title 24 building code going forward.

Non-Energy Benefits. The determination and monetization of non-energy benefits (NEBs) also ranked high on participants lists of opportunities. While NEBs may not seem intuitively integral to building energy modeling, such modeling can help quantify greenhouse gas attributes by developing hourly energy profiles that can be matched to power plant dispatch profiles. In some cases, health benefits can be determined through analyses of building air change rates and indoor air temperature profiles.

Persistent Models: Developing a process that allows a BEM to follow the life of the building is seen as a breakthrough opportunity. Here the original model for the building persists over time; it can be reused and repurposed to address and model future building renovations and energy efficiency retrofits. The model could be continuously calibrated over time using AMI data, real-time weather data, and as such the model could track effects such as energy drift over time due to equipment performance deterioration. A user dashboard could be developed that would tie this capability to available building automation.

Case Study: Grid-level Building Energy Modeling

The Los Angeles Department of Water and Power (LADWP) and Southern California Gas Company teamed up with National Renewable Energy Labs (NREL) to develop modeling tools that would support grid-level analyses of energy consumption and energy efficiency in support of AB2021 energy efficiency goals and potential, as well as support comprehensive DSM planning for Los Angeles. The tool that NREL developed builds out 75,000 residential, commercial and industrial building models that reflect the range of building types within Los Angeles. Models are calibrated using meter-level energy consumption. While the tool is still being completed, it represents a good example of a new use case that merges "big data" and utility Advanced Metering Infrastructure with scalable building modeling to address energy efficiency and distributed energy resources geographically. The benefits espoused by the presenters is that the approach is transparent with well-documented references, and the output has a high degree of granularity. A key takeaway from this session is that this type of approach to large-scale modeling can be done for large and small territories alike; it may be possible to use this approach at the state level with sufficient access to customer and meter data along with sufficient computing resources.

Behavioral Effects Modeling. Finally, there was great interest in exploring the incorporation of behavioral effects into the BEM. Current building models do not use stochastic determinants for basic inputs such as building occupancy, equipment schedules, temperature setpoints, and activities. In reality, all of these are subject to wide degrees of variability, and they can be further affected by energy efficiency measures that fundamentally affect how end-uses are operated by building occupants.

VI. Alignment with Other Modeling Efforts

SCE has been hosting a series of software symposia over the past two years. The focus of these symposia has been on code compliance, with some discussions of measure analysis, renewables and GHG. The SCE upcoming symposium, renamed CalBEM 2019 and scheduled for November 2019, takes a more expansive approach toward modeling and will utilize a highly interactive "working group" agenda which will focus on the following topics:

- Educating Users: Development of Key Resources and Guidelines
- Advancing Simulation Capabilities and Metrics
- Creating a Streamlined Process for Building Simulation

The approach being developed for CalBEM 2019 will likely be continued beyond the actual symposium, with the development of working groups that will continue to advance the topical work into 2020.

As part of its approved Business Plan, on behalf of all four IOUs, SCE will continue to coordinate the statewide efforts to rationalize modeling in California. However, actually addressing the myriad issues that need to be addressed to achieve the goals and future state will be a costly and substantial effort. Cal TF expects to address some of the California modeling challenges and needs that relate to its core work in 2020 and beyond.

VII. Path Forward

Based on feedback from the charrette participants, there is a desire for a roadmap to harmonize and align modeling use cases and efforts in California. This roadmap should address key issues presented within this TPP, identify which stakeholders are responsible for each element of the roadmap, and will include regulators, IOUs and POUs, practitioners, model users, program administrators and implementers, and evaluators. The roadmap should categorize the elements of the path forward as short term (1-2 years), medium term (2-3 years), and long term (3-5+ years).

Short-term Roadmap Elements

Establish a single reference library of building prototypes	– The prototype library should be centralized and publicly accessible – All prototypes should be well-documented and transparent to facilitate validation and maintenance – Entities should be designated to maintain and update existing prototypes – A process should be developed to allow for creation of new prototypes for inclusion in the library
Identify a path forward for regulators and practitioners that reduces redundant modeling efforts.	– A transition process should be established for CPUC deemed measure analyses to be conducted using EnergyPlus. This could allow CPUC and CEC to cooperatively develop common building prototypes that serve the specific needs of each regulator. – A centralized model repository should be developed for the numerous building models to support multiple use cases. Such a library could accelerate future modeling of existing buildings (e.g., for retrofits or renovations) and could also support emerging use cases (such as modeling-based continuous commissioning) that would utilize updated models in conjunction with AMI data. – Establish a public web-based forum to notify stakeholders about modeling initiatives in California so stakeholders can track efforts. – Document differences between the common commercial building prototypes (differences in rulesets) – Create and populate a single statewide repository of well-documented common EnergyPlus commercial building prototypes that can be used for modeling deemed and custom measures and in the new construction programs – Investigate the creation of a set of well-documented EnergyPlus residential prototypes that could be used as a basis for deemed, custom, and code-compliance. – Identify and create a documentation library for all current deemed modeled measures: ▪ For all modeled measures (primarily DEER measures), identify missing documentation for the eTRM (requires assistance from EAR Consultants) ▪ Create documentation standard for modeled measures to ensure all modeled measures for deemed are well-documented and reproducible.

Medium-term Roadmap Elements

Develop interoperable rulesets that can be applied across multiple use cases with a minimum level of customization.	– These rulesets should be well-documented and transparent – They should be stored in a central repository – Entities should be designated to maintain the core rulesets – The rulesets should support interoperability with multiple applications
Use modeling to replace the current "single-point" approach to measure savings with savings ranges that may be correlated with key inputs.	– Current models provide a single "point estimate" of energy consumption, even though the myriad inputs into the model have inherent uncertainty – Providing a "range estimate" of savings would more accurately describe the usefulness of the model outputs – Example of an energy use output: 924,000 kWh, lower bound = 887,000 kWh, upper bound = 961,000 kWh, C.I. 90%, two-tailed normal distribution.

Long-term Roadmap Elements

Explore the nascent arena of dynamic model development (such as the LADWP grid-based modeling project).	– These models would use probability distributions for inputs and outputs, which would reflect a range of building parameters and consequent energy consumptions consistent with real world operations. – Part of these distributions could reflect behavioral effects that are often associated with energy efficiency measures, energy messaging, and actionable data that may be provided to occupants. – Machine learning methods could be explored as a potential means of optimizing model development through incorporation of "big data."

VIII. Next Steps

Cal TF Staff is collaborating with SCE and its consultants in the development of the CalBEM 2019 symposium. The outcome of CalBEM 2019 symposium may be incorporated into the roadmap discussed above, which would result in a single, cohesive roadmap for the State. The development of this roadmap, which would define needs, tasks, objectives, and responsibilities, will be completed after the conclusion of the CalBEM symposium.

In addition, Cal TF Staff will convene a modeling subcommittee in Q1 2020 to refine the recommendations above and finalize this TPP by Q2 2020.

Date Issued	October 17, 2019 (Draft)
Prepared by:	Roger Baker
Approved by:	
Prior Versions	

Attachment A:
Cal TF Modeling Charrette Attendees

Table 1. In-person Attendees

Last Name	First Name	Company
Al-Shaikh	Ayad	Cal TF staff
Athalye	Rahul	NORESCO
Baker	Roger	Cal TF staff
Barnes	Jennifer	Cal TF staff
Beeler	George	AIM, Cal TF member
Beitel	Annette	Cal TF staff
Boyce	Bryan	Energy Solutions
Brook	Martha	California Energy Commission
Buckley	Liam	IES Ltd.
Bulger	Neil	Red Car Analytics
Chhabra	Mohit	NRDC
Contoyannis	Dimitri	Model Efficiency
Costa	Marc	The Energy Coalition
Coulter	Dallen	Southern California Edison
Criswell	Scott	SAC Software Solutions, LLC
Dela Cruz	Imma	SF Environment
Ehrlich	Charles	PG&E CIT
Endurthy	Akhilesh Reddy	Solaris-Technical, LLC.
Fergadiotti	Andres	Southern California Edison
Fette	Nicholas	Solaris Technical
Froess	Larry	Sacramento - California Energy Commission
Haselhorst	Susan	Energy & Resource Solutions, Inc. (ERS)
Jenkins	Rebecca	SCG
Kromer	Steve	SKEE
Kruis	Neal	Big Ladder
Lakhanpal	Manisha	CPUC, Energy Division
Liu	Henry	PG&E
Long	Steven	Lockheed Martin
Mahone	Douglas	TRC (retired), Cal TF member
Maxwell	Jonathan	Energy & Resource Solutions, Inc. (ERS)
Melloch	Tim	Cal TF staff
Mendon	Vrushali	Resource Refocus LLC
Modera	Mark	UC Davis
Neumann	Ingrid	California Energy Commission
Pande	Abhijeet	TRC
Parker	Andrew	NREL
Punjabi	Sonia	PG&E
Ramirez	Bob	DNV GL
Reynoso	Ed	SDG&E, Cal TF member
Richard	Kerri-Ann	Energy & Resource Solutions, Inc. (ERS)
Ridgley	Robert	California Energy Commission

Last Name	First Name	Company
Rogers	Christopher	CLEAResult, Cal TF member
Roth	Amir	US Department of Energy
Saiyan	Armen	LADWP, Cal TF member
Saxena	Mudit	Vistar Energy Consulting
Seto	Jeffrey	Alternative Energy Systems Consulting, Inc. (AESC)
Shahinfard	Sepideh	Cadmus, Cal TF member
Singh	Alok	Southern California Edison
Torres-Garcia	Tomas	Cal TF staff
Tsan	Bach	Southern California Edison
Vu	Martin	RMS Energy Consulting, LLC, Cal TF member
Wilcox	Bruce	
Wilson	IBPSA-USA	IBPSA-USA

Online Attendees

Last Name	First Name	Company
Burrows	Tim	Sustainable Returns
Collins	Greg	
Cooper	Benjamin	
Escala	Aida	California Energy Commission
Fisher	Anne	California Energy Commission
Glazer	Jason	GARD Analytics, Inc.
Hanna	James	Energy Solutions
Janusch	Nicholas	California Energy Commission
Kotewa	Lawrence	Elevate Energy
Kwong	Melanie	LADWP
Lor	Thomas	Southern California Edison
Maddox	Doug	Maddox Energy Consulting
Mateo	Tiffany	California Energy Commission
Mendon	Vrushali	Resource Refocus LLC
Paek	Chan	SCG
Shallenberger	David	Synergy Companies
Sun	Luke	LADWP
Tso	Bing	SBW Consulting
Valenzuela	Keith	Consultant to SDG&E
VanSise	Randy	Onsite Energy Corp
Vicent	Will	Southern California Edison
Wall	Elise	2050 Partners, Inc.

Attachment B:
Cal TF Modeling Charrette Ice Breaker Exercise

The beginning of the charrette included an informal "Ice Breaker" session, which was designed to elicit participants' feedback regarding expectations for the charrette. Each participant was asked to anonymously complete two written statements:

1. I have the following objectives for today's meeting/If I could change one thing, it would be…
2. I have the following concerns about the [charrette]…

Responses were collected, participants were parsed into groups and, within each group, participants took turns reading out the anonymous responses. This exercise helped establish the general expectations from participants for the rest of the charrette.

Primary objectives from participants included learning about how modeling is used throughout California, understanding the future of modeling, and addressing the issue of standardization across use cases while increasing transparency.

Participant concerns centered on whether there would be useful outcomes from the charrette, and that the policy regime in California would not effect changes that would come out of this effort.

Below is a summary of the ice breaker exercise responses, and the actual responses themselves.

I. Overview

At the start of the Cal TF Modeling Charrette, participants were asked to anonymously complete a short form to respond to the following questions:

- I have the following objectives for today's meeting/If I could change on thing, it would be…
- I have the following concerns about the meeting

All responses were collected. Respondents then broke into small groups where they took turns randomly selecting a completed form and reading it to their group. The groups briefly discussed each response in turn.

The responses are summarized in the sections below. Table 2 at the end of the document lists all of the anonymous responses.

II. Participant Objectives

Participants comments indicate that participants had a wide range of expectations from the charrette.

Many participants viewed the charrette as an educational opportunity on topics ranging from modeling-specific to a broader industry view. Participants were interested in learning about specific details or techniques for conducting modeling, including the calculation methods for GHGs, custom calculations, and metering data. Others expressed more general needs around modeling software and approved tools.

> *Assumptions & basic framework of various building EE simulation software.*

> *I would like a clear understanding on which energy modeling tools should be used in which applications so that it avoids confusion in the marketplace on which tools are "approved" for energy savings estimates*

Other participants attended to gain insight into the broader modeling industry and the issues facing practitioners.

> *Understand the full breadth and depth of the modeling issues*

> *To learn the landscape of current coordination efforts around integrating whole-building modeling for small-medium commercial energy assistance programs implemented by local govt.*

Many participants were specifically interested in the future of modeling in California.

> *To learn the future direction of modeling*

> *Understanding if there's any chance that CA will make any decisions/changes that result in meaningful improvements in the modeling process*

Some participants expressed a desire to learn about the Cal TF. Specifically, they wanted to understand the Cal TF's mission, vision, and goals, and understand their relationship and role in advising the CPUC.

> *I am interested in learning more about Cal TF's role in advising the CPUC and what their current vision is for using energy modeling to support utility programs*

Many participants expressed a desire for building energy modeling in California to be more standardized and transparent.

> *Want to see CA transition to using open-source software for shared calculations (eg. deemed savings, code updates) and a certification system for project level software*
>
> *Ensure that CA is moving towards transparent, rigorous, and accurate modeling practices for savings estimation*
>
> *It would be ideal to have standardized modeling tools, processes, and deliverables for the different uses of modeling tools*
>
> *Better documentation in tools replacing DEER, a bit more academic (publish studies with dates)*
>
> *Standardize rulesets for modeling*

The need for resources to support and inform the modeling community in California was identified by one participant. Another expressed a need for a process to create and adopt energy efficiency measures more expeditiously.

> *Maybe need an online journal, blog, or forum to help track developments for the sake of new entrants to the community (like myself)*
>
> *Create a process for creating, vetting and adopting energy efficiency measures faster*

III.Participant Concerns

A consistently expressed concern was that no change would occur/result from this effort.

> *Same old thing…lots of talk very little action*
>
> *These meeting often result in rehashing the same issues, and arguing about simulation engines*
>
> *Too difficult to arrive at consensus for where to go from here*

Some participants expressed concerns about the outcome of the charrette.

> *Leaving without concrete, actionable objectives*
>
> *It will only be a battle of protecting organizational interests*
>
> *Concerned that some are interested in the status quo to the extent that they will torpedo progress. Concerned that some will torpedo progress if they are not allowed to define the new state to their liking*
>
> *The Commission and other stakeholders will not be able [to] relax their own requirements so that BEMs can be useful for all the necessary rulesets (2) No BEM developers will step up and deal with the various ruleset requirements*

Many participants were concerned that there would not be effective decision making during the charrette or to enact the recommended changes within the policy environment in California.

Decisions made too slowly end up being less effective and regulatory needs may be moving faster. With time will come different challenges unforeseen today

Too difficult to arrive at consensus for where to go from here

Who will be the final arbitrator of which energy modeling tool will be the tool of choice when competing tools produce different results with different assumptions and functionalities?

Even though the group reaches consensus here, how will it be translated into state policy changes?

There were concerns about the way the event was organized, the parties represented and Cal TF's role as organizer.

There should be more collaboration in preparation for these events. How can we properly assign responsibility in the respective areas, accuracy, education, simplify

Cal TF does not represent BEM users or organizations -> IBPSA-USA

Biased whitepaper

Appearance of conflicts of interest

That this forum is too insular. Modeling is used by LEED, design community, etc. I think we need feedback from these communities to better solve the issues

Topics & coverage too broad to result in meaningful change (though likely will increase overall understanding by many participants)

It does not represent enough practicing modelers

Some participants expressed concerns specific to modeling rather than the charrette.

Transparency in the inputs in the modeling tools

Mandating Energy Plus Only

Remain software agnostic & focus on the needs, applications & requirements

Models are too complex to compare efficiently and rigorously

Moving the current building prototypes to the new software and maintenance

How will energy models be prioritized in comparison to other energy savings estimation methods such as engineering formulas and calculations and data logging info?

Conflate custom & deemed requirements

Table 2. Ice Breaker Responses

Identifier	I have the following objectives for today's charrette:	I have the following concerns about the charrette:
1	• History of modeling tools in CA in regard to deemed programs • Forum's perspectives on the future of modeling • Future of DEER • Integration of modeling with various programs such as NMEC	• Transparency in the inputs in the modeling tools • Possibility of one tool for all projects • Time/effort required to modify the existing approaches
2	• Learn, track and listen to how BEM software is used • Ensure alignment with the industry and other statewide efforts	There should be more collaboration in preparation for these events. How can we properly assign responsibility in the respective areas, accuracy, education, simplify
3	To gain a better "big picture" understanding of energy modeling and current issues facing practitioners	None!
4	• Understand Cal TF • Simplify BEM for Savings By Design	• Mandating Energy Plus Only • Cal TF does not represent BEM users or organizations -> IBPSA-USA • Biased whitepaper
5	Learn about and contribute to the understanding of the use of modeling tools in Energy Efficiency	Appearance of conflicts of interest 1 immutable thing about CA EE: "The definition of energy efficiency: a product or service that a. is more expensive, b. uses less energy, and c. provides equipment service as the baseline"
6	A greater appreciation of the power of good, well built energy models in predicting energy performance & load shapes. Let's recognize that modeling and statistical analysis using AMI data are both needed to achieve our goals!	Too much inertia w/ existing ways of working with old DOE-2 based modeling methods.
7	• To learn the landscape of current coordination efforts around integrating whole-building modeling for small-medium commercial energy assistance programs implemented by local govt. • To answer: What is the feasible scope for local govt implementation to support an energy services market, providing standard data formats efficiently to provide access to small-medium to robust energy mgmt. services	[left blank]
8	Understand the full breadth and depth of the modeling issues	That this forum is too insular. Modeling is used by LEED, design community, etc. I think we need feedback from these communities to better solve the issues
9	Learn what the CA ecosystem re: BEM • Who is doing what?	Same old thing…lots of talk very little action

Identifier	I have the following objectives for today's charrette:	I have the following concerns about the charrette:
	• How can we work together to standardize inputs/outputs	
10	Things to change: (1) Better documentation in tools replacing DEER, a bit more academic (publish studies with dates) (2) Maybe need an online journal, blog, or forum to help track developments for the sake of new entrants to the community (like myself)	I may not have much to contribute in regard to experience with building modeling. I'm worried that I won't know to whom to send my future questions after today.
11	Answer questions & provide input re: existing/past CBECC & eQuest/DEER tools/rulesets	Topics & coverage too broad to result in meaningful change (though likely will increase overall understanding by many participants)
12	• Make it easier to use and understand • Standardize rulesets for modeling and have an easy/traceable documents to follow through. Open to all platforms	Too much to cover, too little time.
13	1. Gain insight of full needs 2. Make path to tools usable for all (academics…lay user) 3. Lower barriers to leverage models	1. Changes will happen 2. Changes will simplify process/improve quality
14	• I am interested in learning more about Cal TF's role in advising the CPUC and what their current vision is for using energy modeling to support utility programs • Ideally, we can select one or more issues to prioritize, and then begin working on a plan to solve them	• These meeting often result in rehashing the same issues, and arguing about simulation engines
15	I would like to know about the GHG calculations for each of these tools? What are the load shape sources? Which one of these tools can be modified to do custom calculations and metering data.	[left blank]
16	Identify what's broken & not working	Remain software agnostic & focus on the needs, applications & requirements
17	Assumptions & basic framework of various building EE simulation software. Learn more about existing data repositories or collections of existing simulation results	[left blank]
18	• Address the issue of forward vs. inverse modeling (i.e. measured data vs. ground up simulation) • Address how to compare model results • Address model calibration	• Too difficult to arrive at consensus for where to go from here • Models are too complex to compare efficiently and rigorously
19	Understanding if there's any chance that CA will make any decisions/changes that result in meaningful improvements in the modeling process	It does not represent enough practicing modelers
20	I would like a clear understanding on which energy modeling tools should be used in which	1. How will energy models be prioritized in comparison to other energy savings

Identifier	I have the following objectives for today's charrette:	I have the following concerns about the charrette:
	applications so that it avoids confusion in the marketplace on which tools are "approved" for energy savings estimates	estimation methods such as engineering formulas and calculations and data logging info? 2. Who will be the final arbitrator of which energy modeling tool will be the tool of choice when competing tools produce different results with different assumptions and functionalities?
21	Learn about all of the modeling software possibilities and pros & cons	Moving the current building prototypes to the new software and maintenance
22	Understanding BES requirements/landscape for evaluation of deemed/custom measures moving forward	Transition from current DOE-2 tools to ET
23	(change one thing) Continuity between systems/models	[left blank]

24	• Learn about Cal TF, their mission/mandate, their goals
	• Understanding the California modeling landscape:
	  ○ Roles
	  ○ Players
		• Standardization of prototypes

25	• Better understanding of energy modeling • Software to help make better decisions on EE	• Focus on problems not solutions
26	• Addressing concerns about consistency without limiting software options • Explore ways to harmonized CA and national efforts	• Leaving without concrete, actionable objectives • It will only be a battle of protecting organizational interests
27	• (overall/general) Begin the process of building consensus on how best to use energy models and modeling results to support CA's clean energy policy goals • (specific/short-term) CPUC and CEC share resources for energy modeling + results databasing	• (specific) spending too much time on problem I.D. and not enough time on finding solutions
28	• Listen, observe & learn what's in store for modeling EE world	• Industry could move too fast for reg. process to keep pace

29	• Not for the charrette, but in general:
	  ○ Want to see CA transition to using open-source software for shared calculations (eg. deemed savings, code updates) and a certification system for project level software
	  ○ Want to see CA align better with ASHRAE
		• Concerned that some are interested in the status quo to the extent that they will torpedo progress. Concerned that some will torpedo progress if they are not allowed to define the new state to their liking

30	• Come up with an implementable/actionable plan and follow through on the development of an energy efficiency tool/platform for all of CA	• Dependence on multiple tools that all provide different results • Complex tools that are not user friendly

Identifier	I have the following objectives for today's charrette:	I have the following concerns about the charrette:
31	Learn about modeling history – why things are the way they are today.	Even though the group reaches consensus here, how will it be translated into state policy changes? Even though CA is large – what ability does this group have to change national issues?
32	Understand how Cal TF modeling protocols align with those to be used for programs, codes, and designers	If there will be any concrete takeaways that can move longstanding simulation questions towards resolution
33	1. Encourage CEC & CPUC to make BEM used for code compliance useful for A/E best practice design 2. Change from % better than T24 to energy/sq. ft. compared to ZNE 3. Make reduction of GHG goal of EE not $ saved 4. EE programs should aim for most cost effective way to reduce GHG 5. Calculate GHG of NG from the source including fracking, pipeline leaks, well leaks, etc. over its 20 year life not 100 yrs.	That the above will not be accomplished
34	Find out what people are thinking about modeling	[left blank]
35	Change one thing about modeling in CA o (User interface) having one approved modeling standard o Library, training videos and/or website repository	[left blank]
36	• Understand the issues facing different participants • Ensure that CA is moving towards transparent, rigorous, and accurate modeling practices for savings estimation	• Too "model-choice" focused. Ignores socioeconomic factors that impact models • May over-complicate the issue. Modeling rigor & best practices are as more important than model choice
37	• Scheme for assuring consistent and representative savings values across the state for a typical measure for deemed savings o How will we determine population characteristics • Narrow where we need statewide models – why lighting, for example	• Conflate custom & deemed requirements
38	Agree that one or more BEMs will have full flexibility to implement all rulesets	(1) The Commission and other stakeholders will not be able [to] relax their own requirements so that BEMs can be useful for all the necessary rulesets (2) No BEM developers will step up and deal with the various ruleset requirements
39	It would be ideal to have standardized modeling tools, processes, and deliverables for the different uses of modeling tools	Modeling in CA is very established and will be very difficult to standardize and change

Identifier	I have the following objectives for today's charrette:	I have the following concerns about the charrette:
40	Understand landscape of modeling. Simplified approach	Get caught in minutia of modeling details
41	(or change in CA environment) Create a process for creating, vetting and adopting energy efficiency measures faster	Decisions made too slowly end up being less effective and regulatory needs may be moving faster. With time will come different challenges unforeseen today
42	Meet people. Share ideas. Help others. Connect & learn	It might get too detailed (on mechanics of modeling)
43	Basic: Understand alternative proposals for using one or multiple different models Advanced: Consider ramifications of modeling replacement or expansion of options on evaluation	Decisions on change are already made and I'm still catching up
44	To learn the future direction of modeling	[left blank]

Attachment C:
Cal TF Modeling Charrette Exercise #2 Results

I. Overview

The objective of this session is to develop an "inventory" of issues and concerns related to certain key items, as well as possible solutions to those issues and concerns, that will aid in the forward progress of modeling in California.

Each facilitator manned one of three "stations" positioned in the auditorium; attendees were free to visit any or all of the stations and provide input related to that station's topic. The role of the facilitator was to document issues as they are presented, ask clarifying questions as needed to ensure an understanding of the issue, and managing the categorization and enumeration of similar concerns to minimize redundancy.

Each station was assigned one of three "topics":

- *Goals/Metrics – How will success be measured as it pertains to aligning modeling needs in California?*
- *Desired Future State for CA Modeling Ecosystem – How should the ecosystem look in 5,10,20 years? What issues would prevent California from achieving this future state?*
- *What are the future uses of, opportunities for, and emerging needs associated with modeling in California? What issues and challenges arise from these new uses, and how can they be addressed?*

After collecting all issues, each facilitator presented the list of issues to the participants, and then the auditorium audience collectively prioritized the issues based on a show of hands. Each participant was asked to limit votes to no more than five items per topic list. Items with higher total votes were perceived by the audience to be more deserving of resource focus.

II. Results

Goals/Metrics

Votes	Issue

23	Data format and Data Aligned (where possible) and Multiple Tools Approved for Multiple Use Cases; Ratepayer-funded building prototypes are retained centrally and reviewed/used over time.
	• Alignment and standardization completed pursuant to a Roadmap
	• Who Does What
	    ○ Commissions
	    ○ Cal TF
	    ○ Industry

23	Reference Library of Prototypes • With documented inputs
19	Eliminate Duplicate Effort

Votes	Issue
7	Tools that can Do: • Different Rulesets • Different Use Cases
4	Soft Convergence between Tools [Outputs close, do not need to be identical]
4	Only One (1) Model per Building [in CA]
2	Modeling [is done] Only When Necessary
1	Reference Library of Prototypes • Public Database
1	Automated Updates [to models] as Parameters Change
1	Useable by non-engineers
1	Modeling Activity is Cost-Effective

III. Cal TF Staff Summary – Actionable Items

The highest priority action items relate to standardizing and aligning data formats and rulesets across multiple use cases, reducing duplicative effort (and cost), fostering inter-agency (CEC and CPUC) coordination, developing a master library of well-documented and (where possible calibrated) building prototypes. The work should be conducted pursuant to a roadmap and should involve input from all key actors: the regulatory agencies, Cal TF, program administrators, implementers, and other industry stakeholders.

Desired Future State

Votes	Issue
20	Open Source & With Good Documentation • Publicly Funded
16	Coordination w/National [Entities] • IECC/ASHRAE
14	Standardized Model Outputs/Reports/Metrics • Ideally # per-area/unit
12	Estimates Have Uncertainty Attached
10	Any Software Can Be Used For Any Analysis Type • Must Pass Some Test for Approval
6	More Robust Operational/Schedule-Driven Datasets
5	Have Industry-Accepted Level of Detail Definitions
4	Tools are Interoperable
3	Stable Baseline (like [ASHRAE] 90.1 App.G Addendum BM) • Mainly for new construction
3	Make Sure Models are Based on Ground Truth
2	ANSI-like Process to Get Review & Acceptance
1	Standards are Written in Code Instead of English
0	Good Information on Existing Component • Faults, maintenance level, etc.
0	BEM is Still a Useful and Relevant Tool • Not replaced by cheap solar and batteries
0	So user-friendly that non-engineers can use BEM

Votes	Issue
N/A	Consolidated Set of Prototypes • Maybe input files, maybe raw inputs • Updated w/AMI data • In a single repository

Future Uses, Opportunities, Emerging Needs

Votes	Issue
20	Zero Net Energy • Generation, storage, emerging tech • Electric heating baseline (2019 code)

13	Non-Energy Benefits
	• Monetize NEB
	  ○ Health impacts
	  ○ GHG
	  ○ Productivity
	• Impact Cost-effectiveness

12	Model to Follow Life of Building
	• Input/output standard
	  ○ Future remodel
	  ○ Calibrate and track usage, drift, night usage
	    ▪ Tie to building automation, continuous commissioning
	    ▪ Dashboard

10	Behavioral Effects • How to Include, manage ○ OHM-connect, existing program in CA • How to keep track, verify • Can connect = personal assistant (Siri, etc) • Use modeling to connect to community – make easy
9	Microgrids/Safety/Resiliency • Wildfire impact mitigation • Model at scale • Storage/islanding
7	Scaling – Planning for Community Level • City planning, traffic • BIM • Connect to lifestyle • Large impact potential for community, larger GHG impacts

Attachment D:
Cal TF Modeling Charrette BEM Use Cases

Handout #1: Modeling Categorization Matrix

Author: Doug Mahone

The intent of this matrix is to identify and explain the different purposes for whole-building energy modeling, and how these inform the processes and capabilities of the various building energy modeling (BEM) tools and their applications. It does *not* identify *all* the differences, but rather focuses attention on the major ones so that non-experts can readily grasp the distinctions between applications.

It is useful to think of these as different **use cases**, and of the different approaches to modeling required for each use case as **rulesets** that the modeler must apply.

Use Case (Purpose of Model)	BEM Tool Used	Base Case for Comparison	Weather Data	Operating Conditions & Occupancy	Other Constraints	Limitations on Measures	Caveats
Energy Code Compliance – demonstrate that building meets code under standardized conditions.	Special purpose tool specified and certified by CEC (CBECC-Res, CBECC-Com, EnergyPro, etc.)	As-designed building, but standardized & minimally code compliant. Compared to as-designed building.	Standard weather year for climate zone. Does not include extremes needed to size systems.	Standard schedules, operating conditions, occupancy specified by Title 24.	All non-compliance aspects of model must be identical in both base case and as-designed case models.	Can only analyze options that qualify for code compliance; doesn't do renewables, DR, chilled beams, etc.	**BEM will not predict actual energy use or cost**. Thus, model has limited utility as a design tool. Not usable outside CA.
Energy Efficient Building Design Tool – explore trade-offs and evaluate cost effectiveness of options.	Designers' choice – based on familiarity, and ability to model options of importance to designers.	Designers' choice – starting point for design and evaluation of options.	Designers' choice – weather year (average, extreme), climate zone or local (if data available).	Designers' choice - as-anticipated, worst case, best case, etc.	Designers' choice – May use actual rates/structure, may include renewables and storage, may explore fuel switching, etc.	Limited only by capabilities of modeling software, designers' assumptions; tools need parametric capabilities.	Model may not meet other needs (e.g. code compliance or programs.) May provide decent estimates of cost effectiveness, but only if cost estimates for measures are accurate.

Use Case (Purpose of Model)	BEM Tool Used	Base Case for Comparison	Weather Data	Operating Conditions & Occupancy	Other Constraints	Limitations on Measures	Caveats
Utility New Construction Programs – demonstrate that building meets program requirements.	Specified by program, based on program needs; may be a special version of code compliance software, or of commonly used design tools.	Specified by program – typically energy code baseline. Program may require specific baseline conditions.	Specified by program – standard energy code weather for climate zone, to get "typical" energy savings.	Specified by program –use anticipated occupancy/operation rather than standardized.	Specified by program - may limit choices of efficiency measures or fuel switching.	Similar to code compliance but emphasizes innovative or new measures encouraged by programs.	Use of BEM specified by program, which does not necessarily meet other needs for modeling (e.g. code compliance, design options, LEED, etc.).
Evaluation of Utility Whole Building New Construction Programs – accurately estimate real-world savings performance of as-built participant buildings.	Chosen by evaluators – may be same tool used by the program participants, or other choice believed to be better for evaluation.	Chosen by evaluators – typically same baseline as used by program (code) but may use field measurements to confirm as-built assumptions.	Chosen by evaluators – typically use standard weather data for final savings estimates.	Evaluators may adjust occupancy and/or operations to match actuals. May adjust equipment operating parameters based on field measurements vs. assumed.	Evaluators may try to calibrate model to actual building energy use before estimating actual energy savings due to program.	Can only use measures recognized by program and CPUC, but some new measures may strain capabilities of BEM. Can be difficult to tease out savings by measure.	Choice of BEM specified by evaluators; may not suit other uses for BEM.
Estimate Efficiency Measure Savings Using Before/After Metering Data – use models to normalize metered data, and to control for non-measure variables. Rules for how to do this are still being developed.	Chosen by program (and by evaluators) based on available data and on model capabilities.	Building energy use before program treatment, compared to energy use after program treatment.	Must account for weather differences between the before and after timeframes. Final savings estimates typically based on standardized weather.	Need accurate data on actuals, and must account for any significant differences before & after.	May need to calibrate both before and after models to the metered energy use; for small projects, simplified methods may be used.	Program/CPUC may constrain allowable measures. BEM must be capable of handling all measures, including old measures in the before building.	Collecting sufficient information on non-measure parameters (such as changes to occupancy patterns and use) before *and* after measure treatment is often difficult and incomplete; can lead to unknown errors in savings estimates.

Use Case (Purpose of Model)	BEM Tool Used	Base Case for Comparison	Weather Data	Operating Conditions & Occupancy	Other Constraints	Limitations on Measures	Caveats
Estimate DEEMED Savings for New, Weather-Dependent Measures – same uses as above.	DOE-2.2/eQuest and MASControl. Full scale simulations needed to account for measure performance under varying weather conditions, building types, building vintages. WP developers generally can't develop new and innovative measures given existing DEER suite of modeling tools.	Base case: DEER assumptions. Captures interactive effects between the measure and other building energy systems through external application of "interactive effects" factors contained in the DEER database.	Must use DEER climate zones and weather data.	WP developers must use DEER assumptions.	DEER fixes allowable, building types, vintages, climate zones.	Existing DEER suite of modeling tools does not allow development of new/innovative measures.	If existing data is not available to meet measure calculation needs, additional research may be required to characterize expected measure performance.
Estimate savings for custom measures or bundles – use models to estimate savings for a specific set of measures in a specific building.	Implementer's choice from program-accepted list of tools; tool choice based on measure type and number of measures, up to and including whole-building energy modeling tools such as eQUEST and EnergyPlus.	Appropriate baseline selected based on program rules; may include standard practice (code), industry standard practice (ISP), dual baseline (for accelerated replacement), and others.	Typically, model is calibrated reporting period weather conditions (AMY or equivalent), then normalized using standard CZ weather data.	Actual conditions are modeled where possible. Otherwise, assumptions may be used based on standard/typical values. If neither is available, model defaults may be used.	Custom modeling applications allow for a wide range of modeling methodologies and it is important to ensure that methodologies and measure treatments are consistent across implementers.	Custom encompasses likely the widest variety of measures, but measure eligibility is constrained by program and CPUC rules.	Due to the endless combination of inputs available in custom models, it is important to ensure that the inputs and modeling approaches used best represent actual conditions.