Action Plan

2016
CBECC-Com Development Prioritization and Gap Analysis Report

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1 EXECUTIVE SUMMARY

This report recommends a series of actions that could be taken to rapidly advance the capabilities of California compliance software such that it could be used to analyze more features employed in low-energy and ZNE buildings. A gap analysis and survey of stakeholders was performed to identify the most urgent needs and to prioritize future development activities. The top priorities included:

1. Add capabilities for modeling renewables, specifically photovoltaic (PV) systems
2. Add capabilities for modeling advanced HVAC systems, including mixed mode systems that can utilize natural ventilation and free cooling
3. Add capabilities for providing customization of operational assumptions (setpoints, schedules, etc.).

An action plan was developed to support adding this functionality and rolling it out in a 5-6 year timeframe. The key actions include:

- Action 1 – Propose the Prioritization of the Measure Development
- Action 2 – Achieve Consensus on the Prioritization
- Action 3 – Define the Timeline and Budgets of the Development Plan
- Action 4 – Provide Transparency on the Development Plan
- Action 5 – Execute the Short Term Plan by Adding Top Priority Measures
- Action 6 – Plan for Ongoing Evaluation of the Development Plan
- Action 7 – Provide Education

2 INTRODUCTION

The state of California has set a goal of zero net energy (ZNE) for all newly constructed commercial buildings by 2030. Achieving this goal will require significant advancements to the energy code and buildings will need to employ advanced design strategies, both active and passive, in order to comply with a ZNE code. The compliance software tools will need to offer new functionality to allow design projects to analyze these advanced strategies and demonstrate that projects meet the ZNE goals.

California's Building Energy Code Compliance Commercial software (CBECC-Com) is the state's certified software for demonstrating compliance with the performance path of Title 24, Part 6 as defined in the Nonresidential Alternative Calculation Method (NACM) Reference Manual. CBECC-Com's development began during the 2013 code development cycle in order to achieve three primary goals:

1. Give the California Energy Commission (CEC) greater control over the implementation of the NACM by developing a software-based "ruleset" that they could review with full transparency prior to approval.
2. Transition the performance approach for code compliance to the open source EnergyPlus simulation engine in order to leverage its advanced modeling capabilities, and ongoing development support from the U.S. Department of Energy (DOE).
3. Expand the market for compliance software by allowing third-party software vendors to integrate the compliance analysis capabilities of CBECC-Com into their tools without needing to invest significant resources.

The first and third goals have been accomplished. The CEC has provided input and oversight over the ruleset development since the outset of the CBECC-Com development. With CEC as the gatekeeper of the ruleset, they are also able to rapidly fix any errors identified during testing or by the general public. In addition to the long-standing, market-leading commercial Title 24 compliance software (EnergyPro), two new third-party software vendors have integrated CBECC-Com into their tools (IES Virtual Environment, Simergy) providing users more opportunities to perform Title 24 analysis using software interfaces with which they are familiar. Additional vendors have expressed interest in integrating with CBECC-Com in the future.

The integration with DOE's EnergyPlus simulation engine is an ongoing process. The primary focus of integration to date has been to develop functionality and energy measures for conventional designs that meet or exceed minimum compliance. Additional development must occur for CBECC-Com to be able to model the breadth of design strategies available in EnergyPlus that may be employed in high performance and ZNE buildings. This report examines an action plan to rapidly add functionality with a prioritization defined by a broad range of stakeholders.

3 THE GAP ANALYSIS

This project commenced with a rigorous analysis of design strategies used in conventional and low-energy buildings with a primary focus on comparing the full range of modeling capabilities of both EnergyPlus and CBECC-Com with respect to these strategies. The goal of this initial step was to identify gaps between modeling features supported by EnergyPlus that are not currently available in CBECC-Com. The Gap Analysis process is illustrated below in Figure 1.

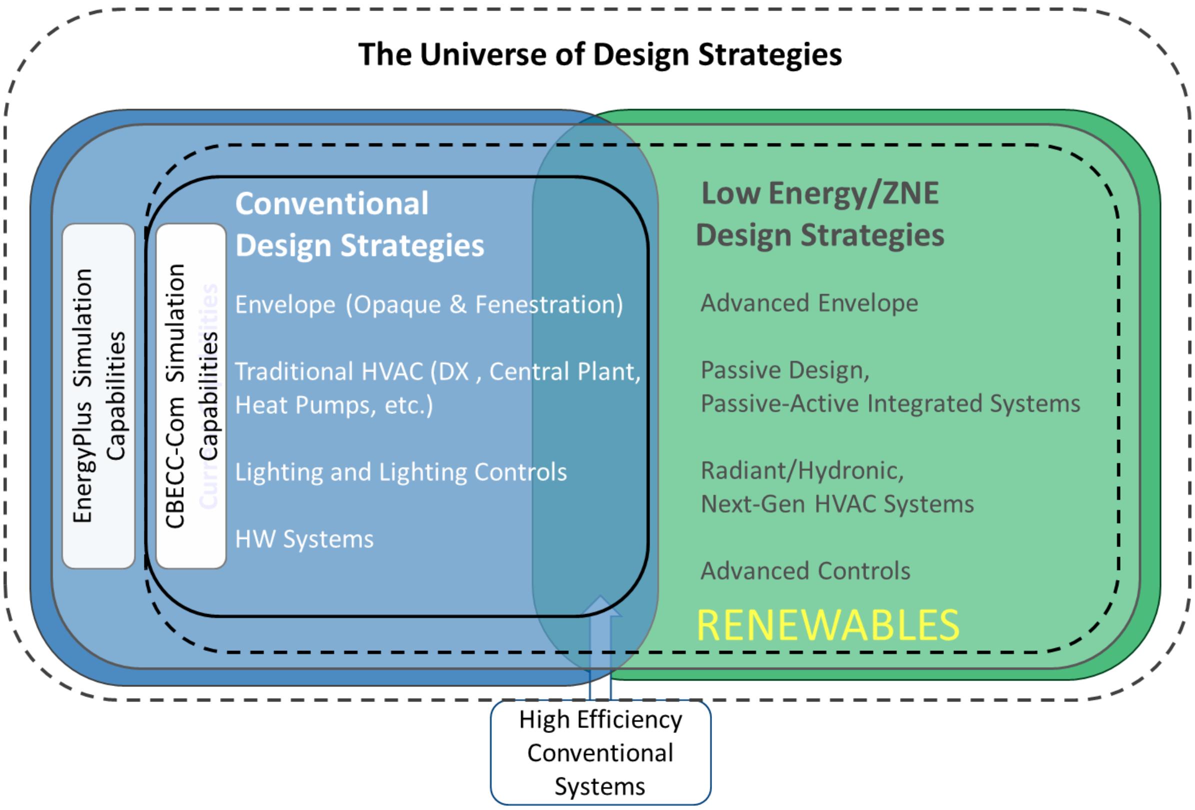


Figure 1 – The Gap Analysis Process, Illustrated

Identifying the Features

One outcome of the Gap Analysis was to develop a Software Functionality Matrix that clearly lists all of the energy measures available in CBECC-Com and compares them to the complete list of measures available in the software's simulation engine (EnergyPlus). To identify the capabilities of EnergyPlus, a detailed review of the software's reference materials was performed including the Input/Output Reference, the suite of example files that are part of the EnergyPlus installation, and the full set of EnergyPlus release notes. This information was distilled down from a set of highly technical energy modeling terminology to a clear list of analysis features that could be understood by building design or energy efficiency professionals. A similar process was followed to delineate the features supported by CBECC-Com. As the prime contractor working with the CEC on CBECC-Com's development, our team has a detailed knowledge of its capabilities and was able to produce the list of features. The feature list was cross-referenced against the CBECC-Com release notes and the user manual to ensure completeness. An excerpt from the Software Functionality Matrix is shown below in Figure 2 and the full matrix is included in Appendix A. A full report of the Gap Analysis process is also included in Appendix B.

Modeling Functionality	CBECC-Com	EnergyPlus	Notes
Fenestration	2	13	Totals For Section
Construction Assemblies			
Simple Method (U-Factor, SHGC, VT)	x	x	
Window Glazing		x	
Windows Gas		x	
Window Frame and Divider		x	
Storm Window		x	Storm windows are scheduled to be added in the winter to increase the U-Factor and decrease infiltration
Advanced Assemblies			
Window Operability		x	Open windows when outdoor enthalpy is preferred to indoor
Thermochromic Glazing		x	As the glazing is heated by the sun less light is allowed to pass through
Electrochromic Glazing		x	As the electricity is passed through the glazing less light is allowed to pass through
Internal Fenestration		x	Daylighting controls can be used in interior spaces
Double Skin Facades		x	Natural ventilation, operable windows, internal fenestration
Shading			
External (overhang, fin, louver)	x	x	CBECC provides transmissivity scheduled control
Light Shelves - Exterior and Interior		x	Light is refected off the shelves onto the ceiling to illuminate the space without electric lighting
Mechanical Blinds		x	A schedule is created to decrease the amount of light entering the space
Air Systems	13	34	Totals For Section
Displacement Ventilation			
Temperature Stratification		x	The occupied space is conditioned while the air above the occupants is indirectly conditioned
Ventilation effectiveness (Ev)		x	With a higher ventilation effectiveness, the amount of outdoor supply air can be reduced
Underfloor Supply		x	Ventilation air supplied from below the floor to displace the warm air above it
Low Supply Grill		x	Ventilation air supplied from a low point in the space to displace the warm air above it
Demand Control Ventilation			
Occupancy Schedule	x	x	
CO2 Simulation		x	Vary the ventilation rate based on the CO2 concentration in the space
Package Variable Air Volume	x	x	
Variable Air Volume	x	x	
Single Zone Air Conditioner	x	x	
Single Zone Heat Pump	x	x	
Single Zone Variable Air Volume Air Conditioner	x	x	
Single Zone Variable Air Volume Heat Pump	x	x	
Heat Ventilation	x	x	
Exhaust			
General	x	x	
Laboratory	x	x	
Commercial Kitchen	x	x	
Parking Garage	x	x	
Exhaust Heat Recovery		x	The warm air leaving the space through the exhaust exchanges heat with the incoming air
Ground Source Heat Pump			
Heat Sink / Source - Pond		x	The heat pump moves heat to and from a pond which has a temperature closer to the supply air than the outdoor air
Heat Sink / Source - Surface		x	The heat pump moves heat to and from ground surface which has a temperature closer to the supply air than the outdoc
Heat Sink / Source - Horizontal		x	The heat pump moves heat to and from a horizontal loop which has a temperature closer to the supply air than the outd
Heat Sink / Source - Vertical		x	The heat pump moves heat to and from a vertical loop which has a temperature closer to the supply air than the outdoor
Variable Refrigerant Flow			
VRF without heat recovery		x	VRF reduces energy by moving heat with refrigerant instead of air and runs at a rate to match the load instead of cyclin
VRF with heat recovery		x	VRF with heat recovery can heat one space from the cooling process of another space
Chilled Beams		x	Chilled beams reduce energy by moving heat with water instead of air
Radiant Surface			
heating		x	The supply temperature for radiant heating is lower than baseboard heating, and the radiant temperature of the room is i
cooling		x	Cooling with a radiant surface saves the fan energy of a fan coil, but must have reliable controls to avoid condensation o
Heat Recovery			
Runaround		x	
Flatplate		x	
Heat Tube		x	
Desiccant Wheel		x	
Desiccant Wheel for Dehumidification		x	
DOAS	x	x	
Component Order and Grouping		x	Changing the order of the components the fuild moves through to optimise preheating and other functions desired by the

Figure 2 - Gap Analysis Software Functionality Matrix (Excerpt)

4 THE ACTION PLAN

After identifying the gaps in software functionality, the next phase of the project focused on performing a needs assessment to understand the priorities of a broad range of stakeholders. A survey was developed to gather feedback in a manner that allowed the results to effectively rank the list of measures from most important to least important.

The list of stakeholders included: IOU program managers, reach code program representatives, ET program managers, CABEC representatives, low energy building designers, national laboratory technical managers, CASE authors and compliance software users (CBECC-Com or third-party interfaces to CBECC-Com). This diverse group provided feedback to identify a range of needs:

- Are there measures commonly used today for conventional buildings that can't be properly modeled in CBECC-Com?
- What features are most common in low-energy and ZNE building designs and are most urgently needed for projects seeking compliance today?
- Are there missing features that are limiting the software's use for reach codes, or beyond-code incentive programs?
- Are there additional features that would allow the software to be more effectively used in the code development (CASE) process?

Based on the survey feedback, a preliminary ranking of the measures was determined. Refer to Appendix B for the full details of the survey development process and results. The remainder of this report proposes a series of actions, based on the stakeholders' feedback, which could be taken to rapidly advance the compliance software tools to allow for their use in the analysis of ZNE buildings.

Action 1 – Propose the Prioritization of the Measure Development

A preliminary prioritization has been completed based on the gap analysis survey. Refer to Figure 3 below for the list. The top priorities identified to allow for modeling low-energy and ZNE buildings were:

1. Add capabilities for modeling renewables, specifically photovoltaic (PV) systems
2. Add capabilities for modeling advanced HVAC systems, including mixed mode systems that can utilize natural ventilation and free cooling
3. Add capabilities for providing customization of operational assumptions (setpoints, schedules, etc.).

It should be noted that while these measures will certainly help to analyze ZNE buildings, many of them will require updates to the Title 24 Standards and/or the NACM Reference Manual. Renewable systems do not currently provide credit for compliance. The use of natural ventilation is strictly regulated by mandatory requirements. Operational assumptions are fixed as per the NACM. In addition to developing software functionality, these measures will also require re-examining aspects of Title 24. This effort is addressed in more detail in "Action 2" below.

While these measures may need some further analysis for their application in code compliance, they all are very relevant in the context of integrated design and used for beyond-code programs so their addition would be useful immediately.

CBECC-Com Feature Prioritization

Key	
(yellow)	Requires Modification to T24 Requirements
(grey)	Time Frame to Implement
(box)	Projected Implementation Date
x	Actual Implementation Date

Priority	Category	Topic	Count	Details	Funded By	Approved By CEC
1.00	Renewable	Photovoltaics	1	Photovoltaic		
2.00	HVAC	VRF - Heat Recovery	2	VRF without heat recovery	Private Co.	No
2.01				VRF with heat recovery	Private Co.	No
3.00	HVAC	Demand Control Ventilation	1	CO2 Simulation		
4.00	HVAC	Air Heat Recovery	6	Exhaust Heat Recovery		
4.01				Flatplate		
4.02				Heat Tube		
4.03				Desiccant Wheel		
4.04				Runaround		
4.05				Desiccant Wheel for Dehumidification		
5.00	Renewable	Solar Hot Water	1	Solar Hot Water		
6.00	HVAC	Custom HVAC Setpoints	1	Custom Setpoint Schedules		
7.00	Loads	User Defined Loads + Schedules	3	Plug - Custom Loads		
7.01				Plug - Custom Schedules		
7.02				Occupancy - Custom Schedules		
8.00	HVAC	Radiant Surfaces	2	cooling		
8.01				heating		
9.00	HVAC	Natural Ventilation	10	Window Operability		
9.01				Air Flow Network		
9.02				Hybrid Ventilation		
9.03				Earthtube		
9.04				Double Skin Facades		
9.05				Thermal Chimney		
9.06				Cool Tower		
9.07				Trombe Walls		
10.00	Controls	Plant Staging	2	Load Based		
10.01				Seasonal / Custom Schedule		
11.00	HVAC	Custom Curves	2	High Efficiency Defaults		
11.01				Custom Curves		
12.00	HVAC	Chilled Beams	1	Chilled Beams		
13.00	Controls	Thermal Comfort	1	Thermal Comfort Setpoints		
14.00	HVAC	Displacement Ventilation	4	Ventilation effectiveness (Ev)		
14.01				Temperature Stratification		
14.02				Underfloor Supply		
14.03				Low Supply Grill		
15.00	HVAC	Heat Pump Water Heater	1	Hot Water Heat Pump		
16.00	HVAC	Ground Source Heat Pump	5	Ground Temperature (shallow / deep)		
16.01				Heat Sink / Source - Vertical		
16.02				Heat Sink / Source - Horizontal		
16.03				Heat Sink / Source - Surface		
16.04				Heat Sink / Source - Pond		
17.00	HVAC	Thermal Energy Storage	1	Thermal Storage (Ice / Chilled Water)		
18.00	Envelope	Fenestration and Opaque	3	Mechanical Blinds		
18.01				Custom Infiltration Rates		
18.02				Effective Leakage Area		
19.00	Daylighting	Tubular Daylighting Devices	2	Tubular Daylighting Device		
19.01				Light Well		
20.00	Renewable	Battery Storage	1	Battery		
21.00	Daylighting	Light Shelves	2	Light Shelves - Exterior and Interior		
21.01				Interior Surface Reflectance		
22.00	HVAC	Boiler Heat DHW Storage	2	Boiler Heated Storage Tanks		
22.01				Domestic Hot Water Storage		
23.00	HVAC	Water Heat Recovery	2	Water to Water		
23.01				Desuperheater		
24.00	HVAC	Refrigeration Heat Recovery	8	Heat Recovery		
24.01				Case - Closed Vertical		
24.02				Case - Open Horizontal		
24.03				Walk-in refrigeration		
24.04				Case - Open Vertical		
24.05				Case - Closed Horizontal		
24.06				Refrigeration Components		
24.07				Remote Condenser		
25.00	HVAC	Waste Heat Boilers	1	Waste Heat		
26.00	Renewable	Wind Turbine	1	Wind Turbine		
27.00	Envelope	Switchable Glass / Smart Glass	2	Thermochromic Glazing		
27.01				Electrochromic Glazing		
28.00	Envelope	Movable Insulation	1	Movable Insulation		
29.00	Envelope	Green Roof	2	Green Roof		
29.01				Roof Irrigation		

Figure 3 - CBECC-Com Feature Prioritization

Action 2 – Achieve Consensus on the Prioritization

As noted, the prioritization list was based on surveys from a broad group of stakeholders and therefore it is a good preliminary plan. However, a consensus must be reached before moving forward with development. At the time of writing this report, there are several similar efforts underway to identify gaps to achieving ZNE and attempt to prioritize the development of tools to fill those gaps. These efforts are being led by multiple parties within the IOUs. Additionally, the CEC Building Standards Office has its own internal list of priorities. The CEC and the CBECC-Com development team also receive feature requests from software users on an ongoing basis. A logical next step would be to consolidate these efforts and develop a "definitive" priority list. It is recommended that a workshop or series of coordination meetings be held to review priorities and seek consensus.

It must also be noted that depending on the type of features to be developed, there may be varying levels of review required to get the functionality approved by the CEC for use in compliance analysis. Features that are fairly common or conventional tend not to be controversial and therefore the review is geared towards making sure that the feature has been implemented correctly as per the NACM. However, for new, innovative, or uncommon systems that make aggressive energy savings claims (by manufacturers, designers, etc.), more scrutiny will likely be given during the review because the use of such a technology will have a significant impact on a building's compliance margin. In these cases, a public workshop or other review of detailed analysis substantiating the energy savings claims may need to occur prior to approval of the new functionality. For any new feature that requires significant changes (or entirely new language) to the NACM rules or the Standards, such a level of analysis, review, and scrutiny will be a certainty since they will likely be tied into the Rulemaking process. During the consensus-building discussions, it would be helpful to identify the level of documentation and review that would be required for each feature on the list.

Action 3 – Define the Timeline and Budgets of the Development Plan

This action plan recommends an aggressive timeline to implement the new functionality. It is suggested that a significant portion of the development should occur over the next 5-6 years, roughly aligning with the next two code development cycles (2019 and 2022 code cycles). There are two primary reasons for this timeline:

1. There is an immediate need for more advanced design strategies to be available in the compliance tools because they are commonly used in projects being designed and constructed in California. This notion has been supported across all of the stakeholder groups surveyed during the gap analysis and needs assessment phase.
2. The Codes and Standards Enhancement (CASE) process used to develop the code is limited in its ability to assess cutting edge design strategies that may become future code requirements. Given that most of the attention of the CASE team is currently focused on residential buildings until 2020, now would be an ideal time to supplement the features of the non-residential software such that when future code cycles commence, the software will be able to be analyze "future-looking" design strategies, rather than those that are just considered "common practice."

The current development process is unlikely to be able to meet this timeline. The primary constraint is that nearly all of the software development to date has been funded and managed by a single entity, the California Energy Commission. The CEC has numerous priorities, of which CBECC-Com development is only one; therefore their budget is a limitation to the amount of new development that could be done.

It is recommended that additional funding sources be identified to contribute to the development. As an Open Source project, CBECC-Com could readily benefit by contributions from other entities. Potential contributors include the California IOUs who could fund features that are most important to specific program areas, or manufacturers who wish to accelerate the adoption of their technologies. In order to facilitate the identification of new funding sources, it is recommended that budget estimates be prepared for each new feature on the priority list so that funders understand the level of effort involved.

Action 4 – Provide Transparency on the Development Plan

It is recommended that the development plan and prioritization be made publicly available. By providing transparency to the plan, several objectives may be accomplished:

- Users of the software will have a complete understanding of the capabilities. Questions or concerns about the capabilities and the plan to address any gaps will be readily available and eliminate any uncertainty. There will be a clear plan and not information flowing through various channels or a "rumor mill."
- Software vendors will have a clear understanding of the development plan such that they can plan to update their tools to incorporate new features in a timely fashion without any uncertainty about the schedule.
- Stakeholder groups will have a clear understanding about where features stand on the prioritization list and this may help to bring funding partners to the project. For example, if a product manufacturer sees that their technology is low on the prioritization list, they may seek to fund development to bring it into the software sooner. This has occurred in the past – a manufacturers' group has provided funding to develop capabilities for modeling an advanced HVAC technology (development is complete, final report for CEC review is under internal review by the manufacturers' group).

It is recommended that the Software Capabilities Matrix be made available immediately. This can be readily posted on the CBECC-Com project website (bees.archenergy.com) and links can be provided at other locations as deemed important (e.g. energycodeace.com, CEC website, EDR website, etc.). It is also recommended that the final prioritization matrix be made available once a consensus has been reached.

Another topic to address is a means to temporarily fill the gaps prior to completing the development of new features. If a project team is incorporating a technology that is not currently supported by the compliance software, what should they do? It is recommended that appropriate modeling approximations (i.e. "workarounds") be developed, published, and reviewed/approved by the CEC such that there is a transparent, acceptable, and well documented manner to demonstrate compliance when using these technologies on a project.

Action 5 – Execute the Short Term Plan by Adding Top Priority Measures

The feature development process is fairly complex and requires research, development, and testing for each new feature. A detailed summary of the development process and how measures are added into the compliance software is included in Appendix C.

It is important to state as a preface that while EnergyPlus supports a wide range of energy efficiency measures, integrating them with CBECC-Com is not a simple matter of recreating the E+ inputs within CBECC-Com and providing a direct connection. One of the underlying principles of CBECC-Com is that the software inputs are meant to be correlated to the terminology, units, and level of detail that is specified in the T24 Standards, or commonly available to design practitioners. EnergyPlus, on the other hand, has significantly more detail associated with the inputs and requires more expertise or input minutia to be defined that is not commonly available to designers or T24 energy analysts. Another reason for not exposing all of the EnergyPlus inputs and “knobs to turn” is that it becomes very difficult to review and enforce the Standards if users of compliance software are specifying the designs in technical energy modeling terminology that is not easily correlated with information on the design drawings.

A guiding principle for the development will be to take a thoughtful approach to how users should interact with the software:

- What is the right level of detail required to specify a design element?
- How much customization of the inputs should be allowed?
- What inputs should be controlled (or defaulted) by the NACM?

Where appropriate, it is recommended that the development team coordinate with subject matter experts or other stakeholders to ensure that the assumptions are well informed, and there is a level of buy-in to all proposed methodologies to be developed.

As previously recommended, the Software Capabilities Matrix and Prioritization Plan should be updated as new features are added to the software.

Action 6 – Plan for Ongoing Evaluation of the Development Plan

The development plan and prioritization should be maintained and reassessed on an ongoing basis. Regular maintenance should occur to ensure that publicly facing data such as the Software Capabilities Matrix is always up to date. This could be done by ensuring that its update is included as part of each release of the compliance software, and after each release of EnergyPlus.

Reassessing the priority list will ensure that the priorities remain relevant over time. Changes in priorities may be due to advancements in technologies, changes in design and construction practices, or due to research needs. It is recommended that the priority list be reviewed annually or, at a minimum, at the start of each new code cycle. An annual review would be best to ensure that milestones are being met, and if not, there would be an opportunity to adjust timelines and modify priorities based on new timelines. A review at the start of the code cycle would ensure that measures that are prioritized for research, analysis, and possible inclusion in updates to the Standards are given high priority in the development plan.

Action 7 – Provide Education

The design and analysis of ZNE buildings is extremely challenging. Even with software tools that have all the features to perform the analysis, it still requires subject matter expertise that is beyond the capabilities of many practitioners. There is a perception among some energy analysts that the tools should be easy to pick up and use, but as designs change from optimizing components of conventional systems to designing truly integrated active/passive systems, more knowledge of building physics and energy modeling will be needed to achieve the ZNE targets.

It is recommended that ongoing training or other educational activities be designed and promoted to raise the bar of energy analysts’ skillset. Energy analysis must move beyond simply entering design data into software to truly understanding how buildings function and what strategies are most appropriate to help a particular building achieve ZNE. Activities may include in-person or online software training, and building physics education with an emphasis on integrated design strategies. Additionally, design guides could be developed to communicate “best-practices” for designing high performance or ZNE buildings. On-demand educational materials would allow for the greatest accessibility.

5 CONCLUSION

The first action item, proposing a prioritization of the list of features to be developed, has been completed and is presented in this report. It is recommended that the next action, seeking a consensus, be pursued as soon as possible such that the remaining activities can be started shortly thereafter. Elements of subsequent actions could be commenced in parallel to the consensus seeking activity, namely beginning to provide transparency to the gap analysis, defining concrete timelines and estimated budgets, and planning for ongoing education activities. The actions identified in this plan will rapidly advance compliance software to allow for its use in analyzing low-energy and ZNE buildings, and prepare practitioners to apply these tools to meet ZNE-based energy code requirements.

APPENDIX A - SOFTWARE FUNCTIONALITY MATRIX

Modeling Functionality	Available In CBECC-Com	Available In EnergyPlus	Notes
Opaque Envelope	4	11	Totals For Section
Construction Assemblies			
CEC Material List	x	x	CBECC does not support user defined reflectance
Layer by Layer Method - General Surfaces	x	x	
Layer by Layer Method - Below Grade Floors		x	Below grade layers can be added to reduce heat loss or increase heat storage
F-factor - Below Grade Floors	x	x	
Custom Materials		x	Advanced materials can be modeled more accuratly without the need to combine approved materials
Internal Wall and Ceiling Properties		x	CBECC does not support user defined reflectance
Advanced Assemblies			
Movable Insulation		x	Insulation can be moved away from the assembly when higher heat transfer is preferable
Green Roof		x	Simulates vegitation and soil on roof
Roof Irrigation		x	Models the amount of water avaliable for evaporation on the roof
Trombe Walls		x	The trombe wall stores direct solar radiation during the day and releases it at night.
Construction Quality (Infiltration)	x	x	CBECC provides a fixed infiltration for all buildings (ACM Requirement)
Fenestration	2	13	Totals For Section
Construction Assemblies			
Simple Method (U-Factor, SHGC, VT)	x	x	
Window Glazing		x	
Windows Gas		x	
Window Frame and Divider		x	
Storm Window		x	Storm windows are scheduled to be added in the winter to increase the U-Factor and decrease infiltration
Advanced Assemblies			
Window Operability		x	Open windows when outdoor enthalpy is preferred to indoor
Thermochromic Glazing		x	As the glazing is heated by the sun less light is allowed to pass through
Electrochromic Glazing		x	As the electricity is passed through the glazing less light is allowed to pass through
Internal Fenestration		x	Daylighting controls can be used in interior spaces
Double Skin Facades		x	Natural ventilation, operable windows, internal fenestration
Shading			
External (overhang, fin, louver)	x	x	CBECC provides transmissivity scheduled control
Light Shelves - Exterior and Interior		x	Light is refected off the shelves onto the ceiling to illuminate the space without electric lighting
Mechanical Blinds		x	A schedule is created to decrease the amount of light entering the space
Site	3	8	Totals For Section
Ground			
Temperature (surfaces)	x	x	
Slab Preprocessor		x	Accurate ground temperature model. Important for small buildings
Ground Temperature (shallow / deep)		x	This is for horizontal and vertical ground source heat pump fields.
Reflectance		x	
Water Main Temperature	x	x	
Building			
Shading by Terrain		x	The terrain around the building can provide shading
Orientation	x	x	
Shading by Adjacent Structures		x	The structures around the building can provide shading
Air Systems	13	34	Totals For Section
Displacement Ventilation			
Temperature Stratification		x	The occupied space is conditioned while the air above the occupants is indirectly conditioned
Ventilation effectiveness (Ev)		x	With a higher ventilation effectiveness, the amount of outdoor supply air can be reduced
Underfloor Supply		x	Ventilation air supplied from below the floor to displace the warm air above it
Low Supply Grill		x	Ventilation air supplied from a low point in the space to displace the warm air above it
Demand Control Ventilation			
Occupancy Schedule	x	x	
CO2 Simulation		x	Vary the ventilation rate based on the CO2 concentration in the space
Package Variable Air Volume	x	x	
Variable Air Volume	x	x	
Single Zone Air Conditioner	x	x	
Single Zone Heat Pump	x	x	
Single Zone Variable Air Volume Air Conditioner	x	x	
Single Zone Variable Air Volume Heat Pump	x	x	
Heat Ventilation	x	x	
Exhaust			
General	x	x	
Laboratory	x	x	
Commercial Kitchen	x	x	
Parking Garage	x	x	

Modeling Functionality	Available In CBECC-Com	Available In EnergyPlus	Notes
Exhaust Heat Recovery		x	The warm air leaving the space through the exhaust exchanges heat with the incoming air
Ground Source Heat Pump			
Heat Sink / Source - Pond		x	The heat pump moves heat to and from a pond which has a temperature closer to the supply air than the outdoor air
Heat Sink / Source - Surface		x	The heat pump moves heat to and from ground surface which has a temperature closer to the supply air than the outdoor air
Heat Sink / Source - Horizontal		x	The heat pump moves heat to and from a horizontal loop which has a temperature closer to the supply air than the outdoor air
Heat Sink / Source - Vertical		x	The heat pump moves heat to and from a vertical loop which has a temperature closer to the supply air than the outdoor air
Variable Refrigerant Flow			
VRF without heat recovery		x	VRF reduces energy by moving heat with refrigerant instead of air and runs at a rate to match the load instead of cycling on and off
VRF with heat recovery		x	VRF with heat recovery can heat one space from the cooling process of another space
Chilled Beams		x	Chilled beams reduce energy by moving heat with water instead of air
Radiant Surface			
heating		x	The supply temperature for radiant heating is lower than baseboard heating, and the radiant temperature of the room is increased allowing for a lower air temperature to maintain comfort
cooling		x	Cooling with a radiant surface saves the fan energy of a fan coil, but must have reliable controls to avoid condensation on the cooling surface
Heat Recovery			
Runaround		x	
Flatplate		x	
Heat Tube		x	
Desiccant Wheel		x	
Desiccant Wheel for Dehumidification		x	
DOAS	x	x	
Component Order and Grouping		x	Changing the order of the components the fuild moves through to optimise preheating and other functions desired by the modeler. Building systems from components Ex. Trnsys.
Air Components	11	13	Totals For Section
Cooling Coils			
Chilled Water	x	x	
Direct Expansion	x	x	
Water Cooled Condenser		x	Using water to cool the condenser lowers the temperature from dry bulb to wet bulb
Evaporative Cooling	x	x	
Heating Coils			
Four Pipe Fan Coil	x	x	
Baseboard Heating	x	x	
Hot Water	x	x	
Heat Pump	x	x	
Furnace	x	x	
Water Source Heat Pump	x	x	
Fans			
Constant Volume	x	x	
Multispeed		x	More accurate model of multispeed fans
Variable Volume	x	x	
Plant Systems	4	14	Totals For Section
Micro Combined Heat and Power		x	Small system that generates electricity and useable heat
CoGen		x	System the generates electricity and useable heat
TriGen		x	System that generates electricity, usable heat, and cooling
QuadGen		x	System that generates electricity, usable heat, cooling, and dehumidification
Plant Configuration			
Primary Only Loop	x	x	
Primary Secondary Loop	x	x	
Bypass		x	
No Bypass	x	x	
Custom		x	Allowing the modeler to group plant objects to test different configurations
Plant Staging			
Load Based		x	Multiple plant components can be prioritised to maximise efficiency for a given load
Seasonal		x	Multiple plant components can be prioritised to maximise efficiency for each season
Custom Schedule		x	Multiple plant components can be prioritised to maximise efficiency
Boiler Heated Storage Tanks		x	hot water can be stored from the time it is generated until the time it is used, to collect waste heat or for load shifting
Space Heating and Hot Water	x	x	
Plant Components	20	43	Totals For Section
Electric Chiller			
Screw	x	x	
Reciprocating	x	x	

Modeling Functionality	Available In CBECC-Com	Available In EnergyPlus	Notes
Centrifugal	x	x	
Scroll	x	x	
Gas Engine Chiller			
Screw		x	Chillers are powered by a gas engine instead of electricity
Reciprocating		x	Chillers are powered by a gas engine instead of electricity
Centrifugal		x	Chillers are powered by a gas engine instead of electricity
Turbine Driven Chiller			
Centrifugal		x	Chillers are powered by a turbine instead of electricity
Absorption Chiller			
Indirect Single Effect	x	x	Steam or hot water enters the chiller to provide cooling
Indirect Double Effect		x	Steam or hot water enters the chiller to provide cooling with two condensers and generators to increase efficiency
Indirect Triple Effect		x	Steam or hot water enters the chiller to provide cooling with three condensers and generators to increase efficiency
Direct Single Effect		x	The fuel is burned in the chiller to provide cooling
Direct Double Effect		x	The fuel is burned in the chiller to provide cooling with two condensers and generators to increase efficiency
Direct Triple Effect		x	The fuel is burned in the chiller to provide cooling with three condensers and generators to increase efficiency
Hot Water Boilers			
Gas	x	x	
Oil	x	x	
Electric	x	x	
Waste Heat		x	Hot water is generated in a boiler by collecting heat from a waste source
Steam Boilers			
Gas	x	x	
Oil	x	x	
Electric	x	x	
Cooling Towers			
Open Single Speed	x	x	
Open Variable Speed	x	x	
Closed Single Speed		x	Best used in humid climates and small scales
Closed Variable Speed		x	More efficient than a Closed Single Speed
Heat Recovery			
Water to Water		x	Heat is transfered from water with a higher temperature and used to preheat cooler water
Desuperheater		x	High temperature energy is recovered from a superheated fluid
Fuel Cell		x	Electricity can be generated on site by moving a fuel across a proton exchange membrane
Internal Combustion Engine		x	Electricity can be generated on site by burning fuel in an internal combustion engine
Combustion Turbine		x	Electricity can be generated on site by burning fuel in a combustion turbine
Micro Turbine			
Primary Only Loop		x	
Primary Secondary Loop		x	
Bypass		x	
Pumps			
Constant Speed	x	x	
Variable Speed	x	x	
Gas Water Heater			
Storage	x	x	
Instant	x	x	
Electric Water Heater			
Storage	x	x	
Instant	x	x	
Oil Water Heater		x	
Hot Water Heat Pump		x	Electricity is saved by pumping heat into a hot water tank instead of generating heat with an electric resistance coil
Recirculating Hot Water	x	x	
Domestic Hot Water Storage		x	
Load Shifting	1	5	Totals For Section
Thermal Storage		x	Cooling a mass at off peak times and then absorbing heat through the day from the space
Phase Change Material		x	Cooling an internal mass below it's freezing point at off peak times and then absorbing heat through the day from the space
Battery		x	Storing electricity at off peak times and discharging the battery at peak hours
Internal Mass	x	x	
Custom Setpoint Schedules		x	Reducing heat flow through the envelope by moving the setpoint nearer to the outdoor temperature than standard setpoints
Renewable Energy	0	3	Totals For Section
Photovoltaic		x	Collecting solar energy and converting it to electricity
Solar Tracking PV			Increasing the effeciancy of a PV panel by pointing it towards the sun throughout the day

Modeling Functionality	Available In CBECC-Com	Available In EnergyPlus	Notes
Solar Hot Water		x	Collecting solar energy to heat water
Wind Turbine		x	Collecting wind energy and converting it to electricity
Refrigeration	0	9	Totals For Section
Refrigeration Case			Refrigeration is not modeled explicitly in CBECC
Case - Closed Vertical		x	
Case - Closed Horizontal		x	
Case - Open Vertical		x	
Case - Open Horizontal		x	
Walk-in refrigeration		x	
Carbon Dioxide Refrigerant		x	Using a refrigerant with a lower global warming potential in the system
Heat Recovery		x	Using heat removed from the refrigeration case in other parts of the building where needed
Refrigeration Components		x	Create refrigeration systems from individual components
Remote Condenser		x	
Internal Loads	10	19	Totals For Section
Lighting Systems	x	x	
Daylighting			
Split-flux	x	x	
DElight		x	More accurate daylight model
External Daylighting Analysis		x	More accurate daylight model with the results imported from an external program
Daylight Schedule from external simulation		x	
Daylit Zones	x	x	
Illumination Setpoint	x	x	
Reference Point	x	x	
Tubular Daylighting Device		x	Bringing daylight into a space through a tube to reduce the need for electric lighting
Interior Surface Reflectance		x	Bringing daylight into a space by reflecting the light off a shelf and onto the ceiling to reduce the need for electric lighting
Light Well		x	Bringing daylight into a space through a skylight above the ceiling of a space to reduce the need for electric lighting
Occupancy			
Occupancy - Custom Schedules		x	More accuratly model the number of people in the space to account for internal heat generated and ventilation requirements
Occupancy - Custom Loads	x	x	
Plug Loads			
Plug - Custom Schedules		x	More accuratly model when devices are operating in the space to account for internal heat generated
Plug - Custom Loads		x	More accuratly model how much power devices draw in a space to account for internal heat generated
Gas Equipment			
Custom Schedules	x	x	
Custom Load	x	x	
Elevators	x	x	
Escalator	x	x	
Natural Ventilation	0	7	Totals For Section
Custom Infiltration Rates		x	Reduce or increase the amount of outdoor air entering the space to balance occupant comfort and energy use
Effective Leakage Area		x	Use the effective leakage area to calculate the infiltrated based on wind speed
Air Flow Network		x	Use to calculate the air flow between spaces to model how outdoor air can heat or cool the entire building
Earthtube		x	Air flows underground to be preheated or precooled before entering the building
Cool Tower		x	Precools air entering the building by creating a passive downdraft in the tower with evaporative cooling
Thermal Chimney		x	Removes air from a building by creating a boyant flow in the chimney heated with solar energy
Hybrid Ventilation		x	Mechanical ventilation only turns on when natural ventilation is not meeting the demand in the space
Simplified Inputs			Natural Ventilation model available with minimal user input
Occupant Interactions			Occupant comfort directly correlated to outdoor temperature
Controls	11	18	Totals For Section
Custom Controls		x	Use EnergyPlus EMS to pre-calculate new schedules
Occupancy Based		x	Setting building loads based on the current occupants in the space
Thermal Comfort Setpoints		x	Controlling the HVAC equipment to provide a comfort setpoint as opposed to a temperature setpoint
Night Cycle	x	x	
Reheat Control			
Single Maximum	x	x	
Dual Maximum	x	x	
Air First	x	x	
Temperature First	x	x	
Preheat Control		x	
SAT Control	x	x	

Modeling Functionality	Available In CBECC-Com	Available In EnergyPlus	Notes
Multiple HVAC Systems			CBECC-Com is limited to 1 heating/cooling system and 1 ventilation system
Optimal Start Time	x	x	Choice of single control zone or zone with maximum start time
Economizers			
Fixed temperature	x	x	
Differential temperature	x	x	
Fixed enthalpy	x	x	
Differential enthalpy	x	x	
Electronic Enthalpy		x	
Fixed Dew Point and Dry Bulb		x	
Differential Dry Bulb and Enthalpy		x	
Input / Output	1	3	Totals For Section
Autosizing		x	More accurate modeling by not oversized equipment
Preliminary Design Function	x	x	In simplified geometry
Custom Reporting		x	Provide outputs useful for the modeler to to know when more energy savings can be found
Performance Curves	1	3	Totals For Section
Standard Default	x	x	
High Efficiency Defaults		x	Providing performance curves for high efficiency equipment to allow for more credit to be realized
Custom Curves		x	Using performance curves specific for the equipment being installed for more accurate simulation

CBECC-Com ZNE Gap Analysis Report

Introduction

The Problem

The state of California has set a goal of zero net energy (ZNE) for all new commercial buildings by 2030. This is a significant change from the current requirements for buildings following the performance path, and will require energy simulation and compliance software to offer new functionality to meet these ZNE goals. California's Building Energy Code Compliance Commercial software (CBECC-Com) is the state's certified software for performance path compliance, and utilizes the Department of Energy's (DOE) simulation engine, Energy Plus. The primary goal of CBECC-Com is to reduce user and compliance error when following the performance path. This is achieved by automating the development of the standard design model, mandatory requirement checks, and reporting. CBECC-Com currently offers software functionality and energy measures that typically support conventional design strategies and buildings that meet minimum compliance. For this report, an energy measure can be qualified as any mechanical, control, or use characteristic of a building that consumes or influences energy. The objective of this analysis is to determine the additional functionality required for compliance simulations to achieve ZNE, and then to prioritize the implementation of additional functionality based on needs of the building energy analysis community. To do this a gap analysis was performed to identify the divisions between where we are now and where we need to be when comparing the existing capabilities of code compliance software to the full capabilities of available energy modeling software.

Importance

The California Energy Commission (CEC) is planning to decrease energy consumption for commercial buildings incrementally each code cycle, with ZNE as the ultimate goal. To meet this energy reduction at each code cycle, CBECC-Com will need to move from only supporting typical energy measures to supporting the more advanced measures often seen in the design of low energy and ZNE buildings.

This analysis is important because for each new version of CBECC-Com there is a limited amount of new functionality that can be added and tested based on complexity, budget and schedule. Therefore, it is critical that any new functionality be either immediately used by the energy analysis community or available to test for future use. There are currently 110 energy measures available in Energy Plus that can be added to CBECC-Com (see the Action Plan's Appendix A). The objective is to prioritize new measures based on input from experts in the building energy analysis community.

Proposed Solution

The proposed solution was to first develop a complete list of energy measures available in version 8.3 of the Energy Plus simulation engine. From the complete list, a list of measures not yet available in CBECC-Com was developed into a survey. The survey was distributed digitally to key stakeholders, where the importance rating for each energy measure has helped prioritize the implementation of future CBECC-Com measures.

Methods

Studying the Problem

To begin studying the problem all relevant Energy Plus v8.3 documentation and example models were reviewed to understand all features available in the simulation engine. An extensive review of CBECC-Com's documentation, example files and interface was also conducted. Research was then started on the survey's rating method to be sure that inputs would be clear for surveyors, directly translatable to numeric results, and that the survey would offer a way to include additional information. A test survey was sent out internally to gain insight on the number of technical questions that can be included in a survey while still receiving meaningful results. The initial list of stakeholders went through three review stages to expand and focus the list to insure the survey would elicit low energy specific inputs.

Gap Analysis Procedure

The software functionality matrix was developed from a list of all relevant energy measures available in Energy Plus and CBECC-Com. Fifteen general topics were developed to help determine how well each part of a building is supported by CBECC-Com and which parts of a building have addition features available in Energy Plus. The general topics were: Opaque Envelope, Fenestration, Site, Air Systems, Air Components, Plant Systems, Plant Components, Load Shifting, Renewable Energy, Refrigeration, Internal Loads, Natural Ventilation, Controls, Performance Curves, and Autosizing / Detailed Simulation Results. Each general topic has a list of subtopics. Typically a subtopic is a definable measure, but in some cases the subtopic is broken down further to show the different options available. CBECC-Com's available measures were then used as a filter to obtain a list of future measures. Additionally, within the Software Functionality Matrix there are additional notes that explain what the measure is and how it would benefit or be used in a low energy / ZNE building (Table 1, see the Action Plan's Appendix A).

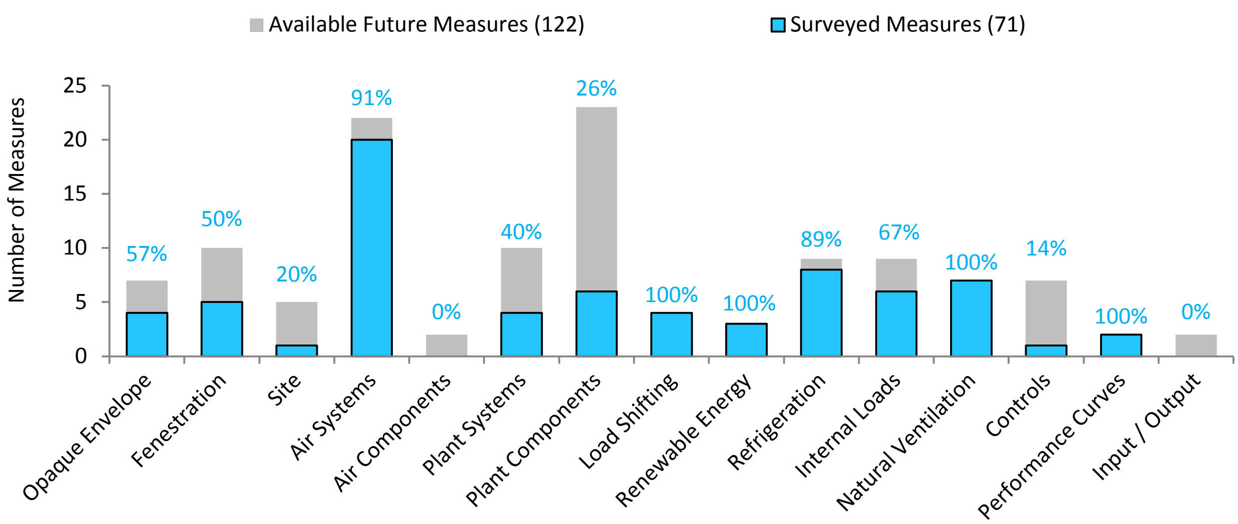
Table 1: Excerpt from Software Functionality Matrix

Modeling Functionality	Survey	Future	CBECC	Energy Plus	Notes
Natural Ventilation					
Custom Infiltration Rates			x	x	Manage outdoor air entering a space to balance comfort and energy use
Effective Leakage Area	x	x		x	Used to calculate the infiltrated based on wind speed
Air Flow Network	x	x		x	Used to model air flow between spaces and heating / cooling with outdoor air
Earth Tube	x	x		x	Air flows underground to be preheated / precooled before entering building
Cool Tower	x	x		x	Precools air entering the building by using downdraft and evaporative cooling
Thermal Chimney	x	x		x	Removes air from a building with buoyant flow created by solar energy
Hybrid Ventilation	x	x		x	Mechanical ventilation turns on when natural ventilation is not meeting loads
Refrigeration					
Refrigeration Case					Refrigeration is not modeled explicitly in CBECC
Closed Vertical	x	x		x	
Closed Horizontal	x	x		x	
Open Vertical	x	x		x	
Open Horizontal	x	x		x	
Walk-in refrigeration	x	x		x	
Carbon Dioxide Refrigerant		x		x	Using a refrigerant with a lower global warming potential in the system
Heat Recovery	x	x		x	Using heat removed from the refrigeration case in other parts of the building
Refrigeration Components	x	x		x	Create refrigeration systems from individual components
Remote Condenser	x	x		x	

Developing the Survey

The Software Functionality Matrix specified 200 energy measures available through Energy Plus, 90 energy measures currently supported by CBECC-Com, and 110 future CBECC-Com measures. To limit the number of future measures to a surveyable list, measures were grouped into basic building energy topics (HVAC, Envelope, Renewables, Loads / Daylighting, and Controls) and then filtered based on three criteria; the ability to group energy measures together into a single survey question, if the measure is currently supported by the energy code / NRACM, and if a measure is typical for low energy or California buildings (Gap Analysis Report Appendix A). Using this process the initial list of 110 future CBECC-Com measures was reduced to 65 (Figure 1).

Figure 1: Percentage of Measures Included in Survey Based on Available Future Measures



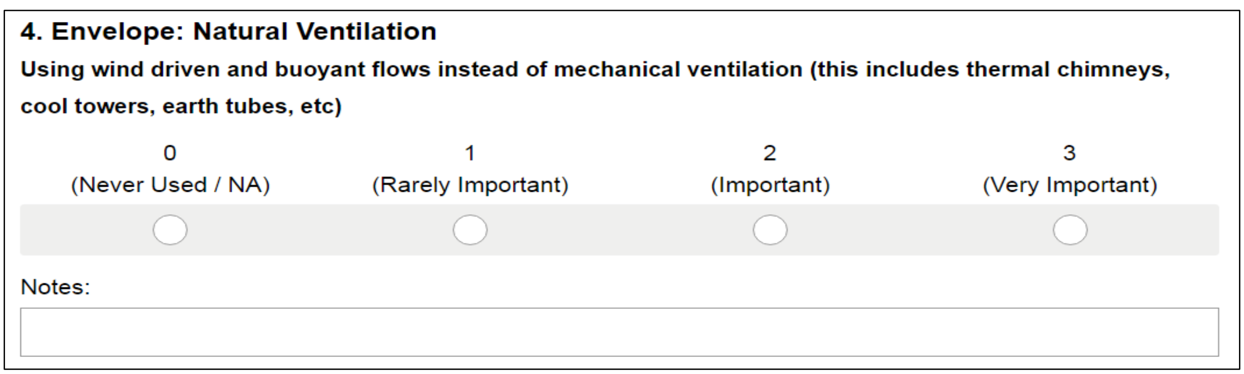
The general topic of Refrigeration is a clear example of the process used to further reduce the list of 71 measures (Table 1). In the Refrigeration category there are 9 detailed measures under the general category, but the only true low energy measure would be Heat Recovery from Refrigeration Equipment. If this one measure is deemed important for low energy buildings then the other 8 measures in the refrigeration list should be implemented to make the Heat Recovery from Refrigeration Equipment possible. This “thin slicing” process allowed the survey to cover 71 unique energy measures with 29 survey questions (Table 2).

Table 2: Reducing Measures from 71 to 29

HVAC 13	Envelope 7	Renewable 4	Loads + Daylighting 3	Controls 2
Demand Control Ventilation	Natural Ventilation	Photovoltaics	User Defined Loads + Sch.	Thermal Comfort
Ground Source Heat Pump	Thermochromic Glazing	Solar Hot Water	Light Shelves	Plant Staging
VRF - Heat Recovery	Mechanical Blinds	Battery Storage	Tubular Daylighting Devices	
Chilled Beams	Movable Insulation	Wind Turbine		
Radiant Surfaces	Green Roof			
Boiler Heat DHW Storage	Thermal Energy Storage			
Waste Heat Boilers	Displacement Ventilation			
Air Heat Recovery				
Water Heat Recovery				
Refrigerator Heat Recovery				
Heat Pump Water Heater				
Custom HVAC Set Points				
Custom Curves				

For the layout of the survey, each question has a general topic heading, the measure's title, a brief explanation of the measure, the rating scale, and an option for additional notes (Figure 2). The rating system of the survey was 0 to 3, where 0 = Never Used / NA, 1 = Rarely Important (25% of the time), 2 = Important (50% of the time), 3 = Very Important (75% of the time or more). The percentages of 0% to 75% represented the frequency a measure is typically used in a low energy building. Surveyors were given the following three instructions at the top of the survey to help qualify their responses: (1) rate the importance of each low energy measure, (2) all climate zones and building types can be considered, and (3) energy measures not on this list are currently supported by CBECC-Com.

Figure 2: Survey Question Example


4. Envelope: Natural Ventilation

Using wind driven and buoyant flows instead of mechanical ventilation (this includes thermal chimneys, cool towers, earth tubes, etc)

0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)

Notes:

Stakeholders and Interviews

A list of key stakeholders was generated (9 groups) with the knowledge that about 50% of the stakeholders would respond. There were 85 stakeholders on the initial list (Table 3). Stakeholders were contacted, the project background was explained, and a link to the survey was included in the email.

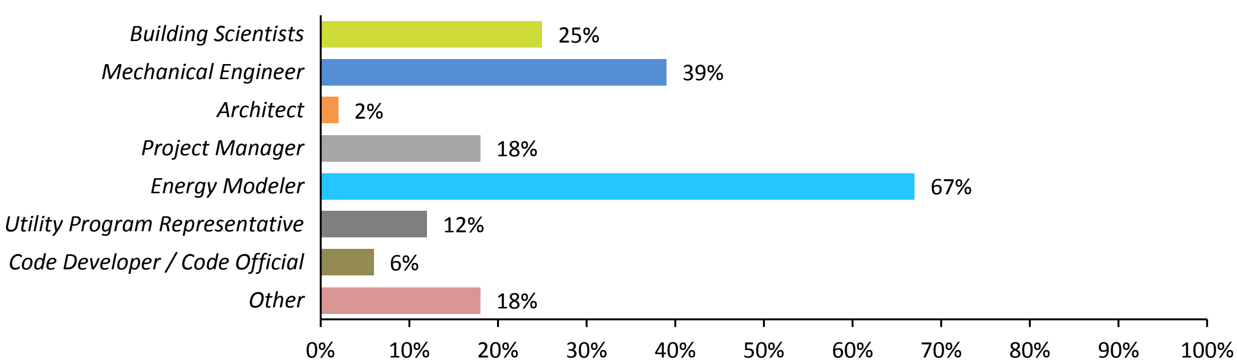
Table 3: Stakeholder Groups

Count	Stakeholder Groups
8	IOU Program Managers (Savings By Design)
2	Reach Code Representatives
5	ET Program / Project Managers
2	CABEC Representatives
25	Designers Involved in Low Energy and ZNE Projects
3	National Laboratories
3	CASE Authors
3	CEC Technical Staff
34	CBECC-Com Issue "Power Users"
85	Total

Results

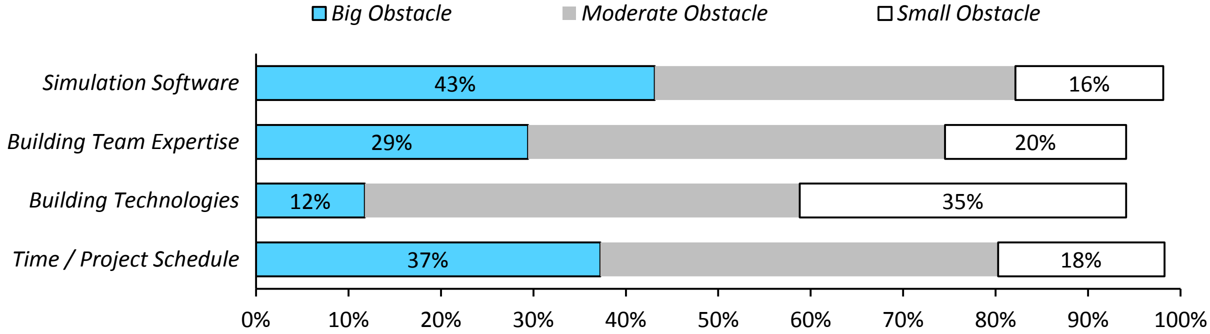
The intent of the survey was to gain insight on the order of importance of low energy measures, and to prioritize the implementation of new features so that CBECC-Com will keep pace with code requirements, the energy analysis community, and move toward ZNE simulation capability. Survey results were analyzed for 52 stakeholders with an average of 10 additional comments per question (Gap Analysis Report Appendix B). Questions with the most additional comments were ZNE Obstacles, Natural Ventilation, Thermocromic Glazing, Mechanical Blinds, Thermal Energy Storage, Demand Control Ventilation, Air Heat Recovery, Custom HVAC Setpoints, Custom Curves, User Defined Loads / Schedules, and Battery Storage. The professional background question in the survey allowed stakeholders to select all building energy titles that apply to them (Figure 3). The intent of the survey was to analyze a wide range of building energy professionals with a focus on energy modelers. Out of the 52 stakeholders surveyed 67% (35) considered themselves an energy modeler and 46% (24) considered themselves both an energy modeler and another professional title.

Figure 3: Survey Background



Each stakeholder was asked what they felt were the biggest obstacles for low energy and ZNE buildings (Figure 4). Software capabilities were voted the most significant obstacle for low energy buildings. It should be noted that this question had the highest number of comments from stakeholders (22) referencing other significant obstacles (see complete results in the Gap Analysis Report Appendix B).

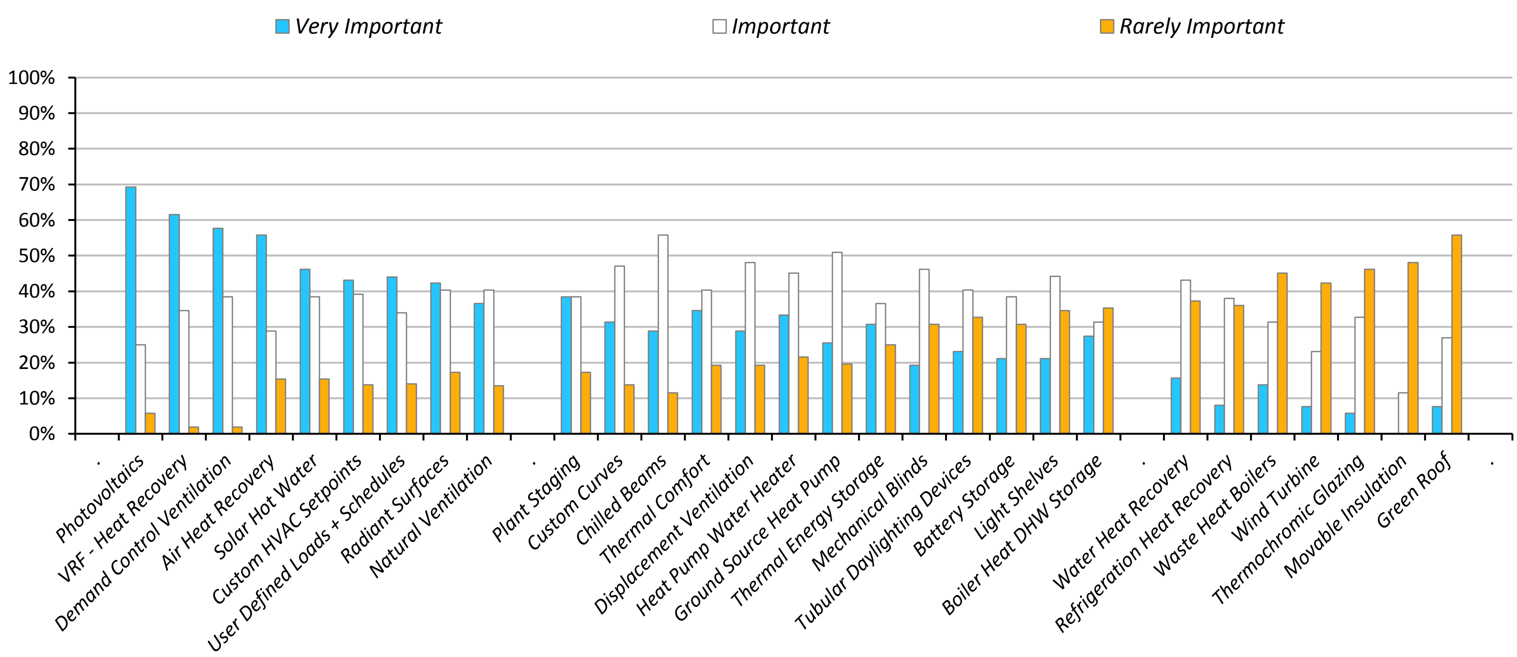
Figure 4: Low Energy Building Obstacles



The survey covered 29 unique energy measures with each measure being rated as Very Important, Important, Rarely Important, and Never Used / NA. Never Used / NA was removed from the results because it accounted for only 7% of the votes, and based on notes provided was used as a "No Opinion / No Experience", rather than a vote that the measure was not important.

The results of the survey were analyzed with the following weighted rating scale: Very Important was given a value of "+2", Important was given a value of "+1", and Rarely Important was given a value of "-2". The weighted rating gave the measures a scale from "+80" to "-44". The complete list of rated measures was then split into three groups based on the predominance of importance (Figure 5).

Figure 5: Prioritization of Surveyed Energy Measures



There were measures that were expected to be valued as “Very Important” (Photovoltaics, Air Heat Recovery, Natural Ventilation), and there were measures that were not expected to be valued as “Rarely Important” (Water Heat Recovery, Thermochromic Glazing, and Green Roof), however, where each measure fit in the overall list and in relation to adjacent measures was very clear.

Conclusion

Important Findings

The process of developing the survey and the results of the survey showed that three basic goals were achieved; targeting the correct audience, asking low energy and ZNE relevant questions, and covering a large number of measures in a compact survey. Most importantly the analysis justified that CBECC-Com should be adding specific energy measures by specific dates to keep up with energy code development and the needs of the energy analysis community in California. Details of these results are in the following section.

Patterns and Principles

The list of energy measures available in Energy Plus, filtered by existing energy measures available in CBECC-Com, gave a clear list of future measures for CBECC-Com. Reducing the complete list of measures to 29 questions, where each question embodied two to three energy measures, was a valuable process because of the limited time people have to give detailed feedback in surveys. The survey questions also did not stretch too far beyond California’s current use, as shown by the low percentage of “Never Used / NA” ratings. This implies that the survey accurately represented the list of 65 measures by not including measures that were too advanced or only used in typical buildings. Therefore, it can be concluded that the surveyed measures were indicative of what would be required in a low energy or ZNE building.

There were two personal background questions in the survey. The first gave clear guidance as to the expected audience, and justifies that the survey was able to focus on a wide range of building energy experts with energy modeling as a focus. The results of the second background question emphasized the importance of simulation software when pursuing low energy and ZNE buildings. This justifies the prediction that there are many obstacles to low energy and ZNE buildings, but simulation software is the biggest obstacle and the first step in any low energy projects.

When weighting and prioritizing the results, three measures were visually out of place after the preliminary sort: Demand Control Ventilation, Chilled Beams and Green Roofs. Each of these had a higher numeric rating (by 1-2 places) than they did in the visual rating. Moving these three measures was justified based on the positive connotation of “Very Important” and the negative connotation of “Rarely Important”. A rating alternative would be to amplify the weight of each vote from +2, 1, and -2, to +3, 1, and -3. This could potentially capture numeric and visual predominance more accurately.

Using the Results

The results of this analysis were used to develop the CBECC-Com Functionality Roadmap. The roadmap has expanded the 29 survey questions to the 72 energy measures covered and organized the measures into implementation phases to ultimately benefit the energy analysis community now and as energy codes move toward ZNE. The overall conclusion of the results show that there are quite a few energy measures that are important to be added to CBECC-Com now, but to get to ZNE it is likely that all of the energy measures in the roadmap will be important. Prioritizing and implementing new measures will allow the energy analysis community to meet new requirements as the code moves toward ZNE.

Gap Analysis Report Appendix A – Measures Excluded from Survey

Topic	Measure	Notes
HVAC: Absorption Chiller	Indirect Double Effect	Absorption Indirect Single Effect is currently supported
HVAC: Absorption Chiller	Indirect Triple Effect	Absorption Indirect Single Effect is currently supported
HVAC: Absorption Chiller	Direct Single Effect	Absorption Indirect Single Effect is currently supported
HVAC: Absorption Chiller	Direct Double Effect	Absorption Indirect Single Effect is currently supported
HVAC: Absorption Chiller	Direct Triple Effect	Absorption Indirect Single Effect is currently supported
Controls: Economizers	Electronic Enthalpy	Future Survey
Controls: Economizers	Fixed Dew Point and Dry Bulb	Future Survey
Controls: Economizers	Differential Dry Bulb and Enthalpy	Future Survey
Controls: EMS	Custom Controls	Future Survey
Controls: EMS	Occupancy Based	Future Survey
Controls: Preheat	Preheat Control	Future Survey
Daylighting: External Compliance	External Daylighting Analysis	Future Survey
Daylighting: Internal Fenestration	Internal Fenestration	Future Survey
Daylighting: Simulation Engine	DElight	Future Survey
Daylighting: Upload Results	Daylight Schedule from external simulation	Future Survey
HVAC: Air System Configurations	Component Order and Grouping	Future Survey
HVAC: Cooling Coils	Water Cooled Condenser	Future Survey
HVAC: Cooling Towers	Closed Single Speed	Future Survey
HVAC: Cooling Towers	Closed Variable Speed	Future Survey
HVAC: Input / Output	Autosizing	Future Survey
HVAC: Input / Output	Custom Reporting	Future Survey
HVAC: Micro Turbine	Primary Only Loop	Future Survey
HVAC: Micro Turbine	Primary Secondary Loop	Future Survey
HVAC: Micro Turbine	Bypass	Future Survey
HVAC: Plant Configuration	Bypass	Future Survey
HVAC: Plant Configuration	Custom	Future Survey
Envelope: Fenestration	Windows Gas	NFRC tools can calculate fenestration UFactors
Envelope: Fenestration	Window Frame and Divider	NFRC tools can calculate fenestration UFactors
Envelope: Fenestration	Storm Window	NFRC tools can calculate fenestration UFactors
Envelope: Fenestration	Window Glazing	NFRC tools can calculate fenestration UFactors
Daylighting: External Reflectance	Reflectance	Not supported by T24
Daylighting: Internal Surfaces	Internal Wall and Ceiling Properties	Not supported by T24
Envelope: Below Grade	Layer by Layer Method - Below Grade Floors	Not supported by T24
Envelope: Opaque	Custom Materials	Not supported by T24
HVAC: Water Heater	Oil Water Heater	Not supported by T24
Loads: Site	Shading by Terrain	Not supported by T24
Loads: Site	Shading by Adjacent Structures	Not supported by T24
HVAC: Fans	Multispeed	Not supported well by EnergyPlus
HVAC: Engines	Internal Combustion Engine	Not typical for low energy buildings
HVAC: Turbines	Combustion Turbine	Not typical for low energy buildings
Envelope: Below Grade	Slab Preprocessor	Not typical in California
HVAC: Refrigeration	Carbon Dioxide Refrigerant	This is a green house gas mitigation measure
HVAC: Cogeneration	CoGen	Typically for District / Central Plant Buildings
HVAC: Cogeneration	TriGen	Typically for District / Central Plant Buildings
HVAC: Cogeneration	QuadGen	Typically for District / Central Plant Buildings
HVAC: Gas Engine Chiller	Screw	Typically for District / Central Plant Buildings
HVAC: Gas Engine Chiller	Reciprocating	Typically for District / Central Plant Buildings
HVAC: Gas Engine Chiller	Centrifugal	Typically for District / Central Plant Buildings
HVAC: Turbine Driven Chiller	Centrifugal	Typically for District / Central Plant Buildings
HVAC: Cogeneration	Micro Combined Heat and Power	Typically Residential Scale

Gap Analysis Report Appendix B – Complete Survey Results and Notes

1. Your Name: (This is optional, but will help us track results)	
Answer Options	**Response Count**
	46
answered question	**46**
skipped question	**7**

2. Which title best describes you (check all that apply)		
Answer Options	**Response Percent**	**Response Count**
Building Scientist	25.5%	13
Mechanical Engineer	39.2%	20
Architect	2.0%	1
Project Manager	17.6%	9
Energy Modeler	66.7%	34
Utility Program Representative	11.8%	6
Code Developer / Code Official	5.9%	3
Other (please specify)	17.6%	9
	answered question	**51**
	skipped question	**2**

Comments:

Energy Analyst and Design Consultant
Sustainability Consultant
Trained as an architect with focus on building energy efficiency. Architectural energy analyst and consultant. Expert on Title 24 energy code compliance.
Environmental Design Consultant
Provide training and resources for Energy Code Ace
Inventor
Energy Engineer
Commissioning Professional
Energy Engineer

3. What are the biggest obstacles for Low Energy / ZNE buildings?					
Answer Options	**Big Obstacle**	**Moderate Obstacle**	**Small Obstacle**	**Rating Average**	**Response Count**
Simulation Software	22	21	8	1.00	51
Building Team Technical Expertise	15	23	10	1.00	48
Building Technologies	6	24	18	1.00	48
Time / Project Schedule Constraints	19	23	9	1.00	51
Other (please specify)					22
				answered question	**51**
				skipped question	**2**

Comments:

Lack of clear understanding of what ZNE means, and whether (and how) it can work without on-site renewable power generation (e.g., a clear system of carbon credits, etc.)
Cost
Client willingness for early stage analysis and design for low energy
Shrinking incentives due to higher baselines
Budget, Unreasonable Expectations (also budget)
low energy cost
#1 Human Behavior - buildings don't use energy, people do, and our initial findings with built ZNE buildings suggest that occupants tend to increase their hours of operation which energy appliances when they know they have additional "goodies". Education is the key. Making (building) science concepts understandable and unintimidating to the
Access to readily available resources pertaining to ways of getting to net zero and their impacts on cost and ROI.
Validation, case studies, & calibrated models.
The utility loading order (EE and DR having priority over renewable resources and distributed generation) serves as an obstacle to allowing the utility incentive programs to
Energy codes are also an obstacle when looking at the difference between the proposed and baseline model. When the proposed has low eneryg use the baseline will as well and savings are not apparent.
Apparent long "payback"
Additional expense
Biggest Obstacle: First cost and/or high payback period (real or perceived). Another big obstacle: Lack of owner/developer drive or desire for low energy/ZNE design in the first
Project budget, site constraints
Close-minded people, codes requiring installation of heating systems, short-sighted cost evaluation, etc.
Project Budget - major obstacle
Cost
Project cost is a big obstacle
Mindset that if something is more efficient first cost must be greater, and not valueing life cycle costs

Construction Cost
Budget - Big obstacle; Occupant Behavior (Post occupancy) - Big obstacle

4. Envelope: Natural VentilationUsing wind driven and buoyant flows instead of mechanical ventilation (this includes thermal chimneys, cool towers, earth tubes, etc)						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	5	7	21	19	1.00	52
						17
					answered question	**52**
					skipped question	**1**

Comments:
Not considered much now, but could be in the future.
Am seeing more and more natural ventilation projects near the coast
T-24 regulations make true natrual
Especially in CA, many attempt to get credit for this in Savings By Design but end up abandoning the idea because there is no incentive for it.
Not essential to a ZNE building but can be a good design element, depending on the building architecture. Have recommended but never modeled because of limitations - feel this is something you need CFD to do well.
This would be and is a useful feature in actual buildings, but it would take careful thinking to know how to define the critical components of a natural ventilation system and how to model them for energy code compliance.
Important for what? For achieving ZNE? For adding to simulation software? Something that I promote or use frequently or infrequently? This question needs clarification, as do the rest of the questions.
This is not a frequently applied system, but is very important on the projects that utilize natural ventilation.
When natural ventilation is beneficial.
At least considered on many projects (especially in Southern California) but not often implemented
Protocols should address mixed-mode operation as well as Nat-vent only applications, with mixed-mode being the priority for development.
Suggest revising category labels: 0= "Never Used / NA" 1="Rarely used / Low Priority" 2="Moderate Modeling Gap / Medium Priority" 3="Major Modeling Gap / High Priority" it may make more sense for the instructions to be above #4 instead of at the very beginning.
need ASHRAE 55 thermal comfort in CBECC / E+
Likely requires full back up ventilation for times when outdoor air conditions (air quality, temp, etc.) are not right. Need appropriate signals to occupants to open windows, or have them open automatically. For full effectiveness, must consider control ramifications regarding the HVAC equipment (shut down forced air, etc.), and implement solutions.
Important for Calfornia (mild climates, in general) but probably not as much in harsher climates
The importance/viability is highly dependent on climate zone.

5. Envelope: Thermochromic WindowsLight and heat entering the building is reduced at high outdoor air temperatures						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	8	24	17	3	1.00	52
						13
					answered question	**52**
					skipped question	**1**

Comments:
Not considered much now, but could be in the future.
We can already simulate this using weighted SHGC and a schedule based on daylight/insolation analysis
Still very cost prohibitive on most projects.
Too expensive to apply to most buidings.
This question should include all chomics - thermo, electro, photo. In simulation these are environmentally-dependent building properties. There are more and more of these innovations arriving on the market (thermochromic paints, photochromic windows, etc.), and the key to including these in simulation is addressing them in their entirety.
When solar radiation is significant.
We do see an increasing number of teams starting to consider this technology.
CEC and Title 24 prescriptive has alrady acknowledged these - why not the performance method?
Hearing more about this on current near net zero projects
Depends on orientation, shading and location (climate)
External shading and appropriate geometry/orientation would be more effective
This was used at RSF, seems like it might be a good idea. As with any measure, would like to see modeling results.
There are other ways to do this, like mechanical shading

6. Envelope: Mechanical BlindsShading fenestration based on a proposed schedule (shading can be located on the exterior, interior or within the window panes)						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	2	16	24	10	1.00	52
						12
					answered question	**52**
					skipped question	**1**

Comments:
Could be important for modeling if appropriate eligibility rules and modeling algorithms to capture this were well defined.
We can already model this using daylight/insolation analysis and apply this in CBEC-COM
Proposed all almost all buildings. Important for occupant satisfaction (glare control) so almost always included.
Building self shading is also important that the code does not account for.
Not just schedule, schedule and solar radiation typically. Should include "probability" for manual blinds
When solar radiation is significant
We rarely see this expensive technology deployed on projects in our territory, though a number of high-profile ZNE projects nationwide feature them.
include lightshelves?
Depends on orientation, shading and location (climate)
Have seen this used, but often not well integrated with controls, so is likely not to be effective for energy conservation if left to occupant control.
Important if you have east/west glazing. Exterior is much better.
Caveat to importance rating: If the shading is mechanical or manual (non-fixed), occupant behavior is a potential barrier to achieving full benefits.

7. Envelope: Movable InsulationTypically this is interior insulation that is placed against fenestration during unoccupied hours (also called "Night Shutters")						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	21	25	6	0	1.00	52 9
					answered question	**52**
					skipped question	**1**

Comments:
An artifact from the 1970s ..
Can already simulate this roughly
I have never seen this.
Similar to insulated mechanical blinds
When diurnal ranges are significant
same comment as #6
Really depends on location, even good windows are poor insulators
Seems overly complex and cost prohibitive in commerical buildings
I have not seen this used in commercial construction. Probably better, and more implementable in residential. this could require a fair amount of maintenance for commercial.

8. Envelope: Green RoofUsing vegetation on the roof of a building to insulate and evaporatively cool						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	5	29	14	4	1.00	52 10
					answered question	**52**
					skipped question	**1**

Comments:
Rarely used, but could be something more important in the future.
Rarely a major energy measure
Needs to be an option when desiging to ZNE.
Really cool but there are a lot of challenges. Usually implemented primarily for reasons other than building energy savings.
This is feature that occasionally comes up in buildings that we model, but very rarely.
When solar radiation is significant
Looks good in practice, but can have structural implications (roof needs to support extra weight) and often plants go unmaintained and die out. Therefore, not seen often.
We do see this on projects; currently they use the insulation value for the thickness of dry soil, with no accounting in the model for the evaporative cooling effect.
Use PV for roof shading as well
need to grow more organic produce. Will be an added maintenance concern (winterizing, etc.). Might take space from PV. Effectiveness will depend on the size of the building

9. HVAC: Thermal Energy Storage - Ice or Chilled WaterUsing electricity during off-peak periods to freeze water into ice and then using the ice for cooling at a later time; typically during peak periods						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	4	13	19	16	1.00	52 14
					answered question	**52**
					skipped question	**1**

Comments:
Still considered in large and/or high-profile green buildings, but not very common.
Critical for T24 compliance
Will be a CRITICAL strategy for TDV calcuations. Most impactful for peak shaving/moving.

SCE is currently working on a energyplus-based thermal energy storage screener tool (TESS), which is being validated with real TES projects. Once complete in early 2016, it might be helpful to use this development for incorporating into CBECC-Comm.
More important when looking at TDV net zero than 'conventional' net zero
Can be a great design element for shifting loads.
When peak energy prices are of a concern
Generally seen in emergency/back-up cooling applications. Typically does not save energy, should save on electricity costs.
CBECC-Com doesn't address this now? Really? Dang.
It's not clear if we're asking about thermal mass, or things like ice/chilled water storage. We should have both options represented in the survey.
in 2008 Title 24 ACM
This can be important for peak load shaving, so energy cost as well as reduced usage due to a lower heat sink at night. Many various forms available (roof ponds, ice storage, etc.)
Only if using a cost/TDV metric.
Important when combined with peak generation such as PV

10. HVAC: Displacement VentilationDecreasing age of air in the breathing zone by increasing the ventilation effectiveness

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	2	10	25	15	1.00	52
						10
					answered question	**52**
					skipped question	**1**

Comments:
Used a lot in well designed new office buildings ..
Critical
Strong interest in schools for improve IAQ.
Also need the ability to model 100% outside air units
Need to make sure heating, internal loads, etc. is properly accounted for.
Used since today's modelers were little tikes - it works
Very important in auditorium-type spaces where DV is most effective
Effectiveness to reduce volume of fresh air to be conditioned. Will be less important with Heat recovery ventilators.
Probably more important from an IAQ standpoint than an NZE standpoint
More important for higher volume spaces (large ceiling heights)

11. HVAC: Demand Control VentilationCO2 Simulation

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	1	1	20	30	1.00	52
						13
					answered question	**52**
					skipped question	**1**

Comments:
An integral part of the current Title 24 Part 6 Stds for many occupancies ..
Code required in most zones.
Require by code for classrooms/conference rooms. Need to understand "real world" impact.
Include zone-based e.g. zone dampers in VAV boxes (both fan power & unpowered) and DOAS outlets. Allow choice of CO2 or occupancy (i.e. if ANY non-zero occupancy, damper opens to "minimum")
But would probably be too dependent on occupancy assumptions.
Required by energy codes for high occupancy spaces
This is a code requirement in many very common instances- astonishing that it's not already in the module.
less important for DOAS systems
is this modeling as a different algorithm than before? Quoth the raven, never more
Used on a lot of projects - university & retail (large grocery) especially
CO2 sensors are problematic, require frequent calibration or replacement
This can be an important measure for many space types, if controlled effectively. Often used, becoming a norm.
Can be a big saver depending on climate and building use. Probably less important in California.

12. HVAC: Ground Source Heat PumpUsing the ground to moderate the temperature of the outdoor unit (also called Geothermal Heat Pump)

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	2	10	26	13	1.00	51
						8
					answered question	**51**
					skipped question	**2**

Comments:
Not common in most nonresidential buildings, and usually value-engineered out after preliminary design.
Strong interest for many projects. Current methods show poor Life Cycle Cost. If the modelling was better and showed additional savings the LCCA would improve and it would be applied to more projects. Could also improve design by better estimating loop temperatures.
Packaged VAV & DOAS needs to allow water-cooled condenser
A highly efficient measure when used; first cost of system makes it infeasible for a lot of projects.
not very common in CA due to mild heating season
Somewhat imp but not in most of CA; difficult
Must be evaluated for climate zone, occupnacy type, and soil conditions, bore fields add significant construction cost that may not be justified in a life cycle analysis
Especially when trying to achieve all-electric building to be able to offset with PV.

13. HVAC: Variable Refrigerant FlowUsing refrigerant to condition zones and avoid reheating; with options for simultaneous heating, cooling and heat recovery

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	1	1	18	32	1.00	52 12
					answered question	**52**
					skipped question	**1**

Comments:
A must for almost all new nonresidential construction design and modeling.
This is really picking up traction and needs to be modeled correctly to reflect actual savings.
THIS IS CRITICAL!!!! This should be the single biggest focus until it is delivered. This is main-stream technology now.
Extremely important as it is very frequently used especially in bigger and commercial projects
Many new high rise residential projects use this. VRF functionality is very important.
We may see these more often as technology matures and it's important to be able to model them.
Make sure all unloading curves are correct at extremes, particularly partial loads at design ambients, and full loads at moderate temps (startup)
This is a very common system.

14. HVAC: Chilled BeamsUsing water to move heat through the building instead of air

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	2	6	29	15	1.00	52 5
					answered question	**52**
					skipped question	**1**

Comments:
Considered a viable option in many commercial buildings now.
Need to have VAV, and heat/cool
& DOAS
All ZNE buildings make extensive use of hydronic systems versus air side delivery
reduced fan energy is very important in trying to achieve ZNE, but climate zone is a concern due to tight humidity control requirements to prevent condensation on beams w/in spaces

15. HVAC: Radiant Surfaces - Heating or CoolingReduces the water temperature coming from the boiler and increases the radiant temperature to the room compared to baseboard heat (radiant surfaces can also be used for cooling)

Answer Options	0(Never Used / NA)	1(Rarely Important)	2(Important)	3(Very Important)	Rating Average	Response Count
	0	9	21	22	1.00	52 4
					answered question	**52**
					skipped question	**1**

Comments:
Will become more important when the T24 energy models are more sensitive to comfort conditions in each time step of the simulation.
In tandem is thermal comfort metrics, enabling these outputs from EnergyPlus into CBECC-Comm would be tremendously helpful, a #3..
include slabs?
assuming hot water is generated by a fuel-fired boiler, more difficult to achieve ZNE.

16. HVAC: Boiler Heated DHW Storage TanksUsing boiler water to heat domestic hot water through a heat exchanger in an indirect tank

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	3	18	16	14	1.00	51 8

answered question	51
skipped question	2

Comments:
Good idea, I just haven't seen it implented anywhere.
This layout is almost always included on large boiler systems.
Seems less common than it once was.
are we talking about for heating the building rather than for DHW? We should make the description more clear.
don't know whjat this is
Not important if gas is the fuel source since gas typically has no time of use pricing tiers, good for heat pumps and domestic
seems like on demand condensing boilers would be better. Assuming fossil fuel boiler here. However, another story, "very important" if heat source (boiler) is solar.
Not that familiar with this. Seems probably bad from a use standpoint, maybe good from a demand standpoint

17. HVAC: Waste Heat Hot Water BoilersBoilers that are powered by waste heat from the building

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	5	23	16	7	1.00	51
						7
					answered question	51
					skipped question	2

Comments:
Becoming more important as designers reach toward ZNE.
Haven't seen it utilized.
Yes if this "heat recovery or loop-loop heat pump." Also DHW heaters, if that is not already available.
Most commerical buildings have no high grade stream of waste heat
can be useful in certain circumstances / climates
Don't know much about this
unless the building is industrial processing with high heat value in exhaust air or other process

18. HVAC: Air Heat RecoveryExtract heat from exhaust air to use in the building

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	0	8	15	29	1.00	52
						14
					answered question	52
					skipped question	1

Comments:
Generally not cost effective for most nonresidential buildings in California, except labs and other occupancies with high process or other ventilation rates.
Critical
Becoming more popular in Desert climates
Needs to include new/current technologies.
Especially heat recovery ventilation (HRVs & ERVs) are these are growing in popularity as independent systems in low-energy buildings.
This is key
In some commercial applications this can be very beneficial
Particularly run-around loops. Allow reasonable control choices, parasitics, unbalanced flows.
This is extremely important- almost all projects that I have worked on that have a decoupled ventilation and conditioning system (i.e. radiant, VRF, chilled beams) will have exhaust air to supply air heat recovery included. It is a common and simple calculation.
Not very effective in mild southern California climate - cooling/heating savings is minimal and offset by fan energy from additional pressure drop. More effective in harsher climates.
tempering OA is a major enduse in dense occupancies and extreme climates
becoming more common, need robust equipment and maintenance. If well controlled, very effective. Also used to extract "coolth." (or add heat to exhaust air). Also enthalpy.
for 24/7 operations with high ventilation rates, e.g. labs

19. HVAC: Water Heat RecoveryExtract heat from water to use in the building

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	2	19	22	8	1.00	51
						10
					answered question	51
					skipped question	2

Comments:
Don't think I've seen this one in a real building yet ..
Have not seen this utilized.

?? not sure which water stream this refers to.
Good option for DHW in MF, hotel/motel, or other buildings with high hot water loads.
Not clear how this is different form 17. From CHW, or DHW waste, or....
Useful in climates with a lot of heating hours, and in applications with a significant heating base load.
depends on the system type, but can be important for central plant systems
interesting option but adequate source/sink is typically not available in commerical buildings
from what water? assuming ground source (though there was another question about this.
higher importance for industrial facilities

20. HVAC: Refrigeration Heat RecoveryUse the heat removed from a refrigeration case / walk-in for use in the building

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	9	18	19	4	1.00	50 6
					answered question	50
					skipped question	3

Comments:
Not common ..
Also required by code, should be actually implemented into the model.
N/A only because I don't work in this realm. But it seems like this is an important measure
Concentrate on normal buildings before supermarkets. Wait for identified issues in E+ to be solved.
only if VRF
meaning VRF? or from the chiller to a tank?

21. HVAC: Hot Water Heat PumpDomestic hot water generated by a heat pump with an indoor or outdoor evaporator

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	0	11	23	17	1.00	51 7
					answered question	51
					skipped question	2

Comments:
Becoming a lot more common in buildings with high on-site solar PV capacity and client interest ..
For LBC-type net-zero projects (no combustion) heat pumps for heating and DHW are very important
Also from CHW or CW
do we not have this?
problematic technolgy, usually coupled with elecitrc resistance as back up
have not seen much of this yet (hopefully "ZNE" includes gas (not just electric) fuel use.) Also embodied energy.
Depends on building, but most buildings don't use that much DHW

22. HVAC: Custom Setpoint SchedulesAllowing temperatures in the model to match the setpoints that will be used once the building is in operation (currently not allowed by CA Code)

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	2	7	20	22	1.00	51 15
					answered question	51
					skipped question	2

Comments:
I don't see much interest in this, since it rarely affects system size much except in extreme cases, and rarely affects compliance.
Critical
Would help to show DR potential and actual energy usage.
This will be important to ZNE buildings.
Site verification should be required for this capability.
This is incredibly important for the work I do which is usually providing feedback on both T-24 compliance as well as expected actual energy use. It's also incredibly important when we are talking about estimating PV for ZNE. But, from a compliance standpoint this would be very challenging to very implement and enforce.
This not relevant to a compliance analysis. Baseline and proposed should always be the same setpoint.
Need to keep the setpoints constant for energy code compliance, or have some way to verify any custom settings. Unverified custom setting would be open to abuse.
This would only be important if these temperatures were changed only for the proposed building, and not the baseline. Although, even if it was the same for baseline and proposed, it still affects unmet load hours.
Thermal drift could be used as an energy saving strategy
SBD is now allowing for custom schedules for incentive (non-compliance runs, as we do for VRF).
this would give a better representation of the building's actual operation, but this can't be dictated by software development - would require change to the energy code.
Not sure why this would help

needs to be calibrated to get better idea of savings. Maybe setpoint adjustments can be recommended by the modeler. The (or "a") ZNE rating should probably come from measured use, not the model. But if the rating comes from the model, this should matter.
Would be important when implementing solutions with atypical setpoints (radiant, chilled beam, etc.)

23. HVAC: Custom CurvesAllowing performance curves from the HVAC equipment used in the building to be used in the model (currently not allowed by CA Code)

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	4	7	24	16	1.00	51
						13
					answered question	51
					skipped question	2

Comments:
Could be more important in the future to capture better-performing equipment ..
Will help show actual building performnace.
This would be crucial to achieve ZNE at essentially zero cost. MUST PROVIDE INPUTS THAT CAN BE COMPELTED WITH INFORMATION AVAILBLE FROM THE MARKET. Curve Coeffcients that nobody understands will not help.
Site verification should be required for this capability.
Very important, but hard to implement while preventing people from falsely modifying the performance of equipment
Provide tools to generate curves based on COP/IPLV or EER/IEER ratios and equipment type
Need to keep the curves constant for energy code compliance, or have some way to verify any custom settings. Unverified custom setting would be open to abuse.
Absolutely vital. Since equipment runs at 100% load so infrequently, the curves are what allow you to capture savings over the baseline equipment. The baseline equipment (i.e., chiller) curves should be looked at as well (they seem to be over-stating efficiency at part load).
Need to show actual performance, particularly for our non-compliance runs.
same note as above. this could encourage designers to seek out better performing equipment
what chu talking about, Willis? Let's discuss.
too much trouble
if the rating comes from the model, this should matter

24. Controls: Thermal ComfortIndoor occupant comfort is primarily based on dry-bulb temperature, air speed, radiation and clothing. If radiation or air speed can be controlled, then setpoints can be lower during heating months and higher during cooler months, without compromising occupant comfort.

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	3	10	21	18	1.00	52
						7
					answered question	52
					skipped question	1

Comments:
Would be really interesting to see how incorporating this affects energy use, cost-effectiveness of measures, etc.
Only in the context of a compliance software. This might be too much detail.
Becoming more important as more software tools become available and as radiant systems become more prevalent
i think the description could be more detailed. need to explain why/what scenarios is occupant comfort a better metric than setpoint.
I assume you mean more individual zone control, great if you can afford it
individual occupant control can help, but can also increase energy use, depending on the occupant. I prefer a constant wide gap in ht/cl setpoints. (with possible increase in that gap based on room vacancy)
This goes hand-in-hand with 22

25. Controls: Plant StagingOperating multiple units of plant equipment based on a given load or schedule / season

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	3	9	20	20	1.00	52
						7
					answered question	52
					skipped question	1

Comments:
More flexibility in Plant Staging would be important for some projects.
Critical and Common strategy for plants. Can result in significant energy savings at no extra cost.
Site verification should be required for this capability.
Could be a significant ECM in a building's design
imp but hard to translate to compliance
having smaller, variable capacity equipment smaller loads might help depending on efficiency ratings at part load.
This could be big depending on pump configuration

26. Internal Loads: User Defined Values and SchedulesAllowing the energy modeled to match the actual internal load energy density and schedule that will be used once the building is in operation (currently not allowed by CA Code)						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	4	7	17	22	1.00	50
						15
					answered question	**50**
					skipped question	**3**

Comments:
I would be very careful about introducing this. Could be an area of gaming the model unless reasonable upper and lower bounds were set.
Site verification should be required for this capability.
Sizing PV / renewables to achieve Net Zero without accurate internal loads will result in oversized PV and loss of value to owner
See #22 comment.
More important to be able to model occupanty densities.
This should not be allowed to vary for a compliance analysis.
Need to keep the internal loads settings constant for energy code compliance, or have some way to verify any custom settings. Unverified custom setting would be open to abuse.
Same as #22, this would only be important if these inputs were changed only for the proposed building, and not the baseline. Although, even if it was the same for baseline and proposed, it still affects unmet load hours and overall savings.
This woudl be a huge can of worms... people would confuse energy modeling against compliance modeling.
Could make a difference between passing and failing, but generally since proposed and baseline schedules need to match, this isn't vital.
i struggle with this because the code is about the building design and not its operation for a particular tenant. it's an important one for ZNE anaysis, but I'm not sure it's appropriate for code compliance. If the scope of the survey is not confined to code compliance than I'd vote "2"
if the rating comes from the model, this should matter, but actual use might be difficult to accurately forecast.
Plug loads will likely be the biggest barrier to NZE in most building types. Being able to take credit for plug load reductions strategies will be key.
ideal, but hard to know what those loads would really be.

27. Daylighting: Light ShelvesReflecting daylight onto the ceiling to illuminate the space (Light Shelves can be located on the exterior and interior of a building)						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	0	18	23	11	1.00	52
						9
					answered question	**52**
					skipped question	**1**

Comments:
Somewhat common, but not so easily modeled ..
We can already simulate this elsewhere and apply
To do this and the tubular devices, among many other daylighting technologies, CBECC-Comm would have to increase the simulation resolution past split-flux, incorporating raytracing (Radiance, 3DS Max) capabilities into energy simulation workflows would be the most important capability addition in my opinion.
I'd like to see better proof of EnergyPlus' daylight results before using (compared against Radiance). I don't think CBECC-Com inputs are sophisticated enough for accurate results.
This is only important given a broader discussion or changes to how CBECC-Com models daylighting and how it interacts with Radiance.
Code required; modeling for controls will help for predictive energy use modeling, but not compliance.
Can be more important depending on the building and orientation
might be less important with LED and occ sensors and other lighting ECMs. Will need to correctly implement daylight harvesting for effective electric savings due to this measure.
Helps a lot with daylighting penetration. Could be used in most buildings

28. Daylighting: Tubular Daylighting DevicesBringing daylight into the space with a hollow reflective tube						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	2	17	21	12	1.00	52
						8
					answered question	**52**
					skipped question	**1**

Comments:
Fairly common in small commercial buildings, as in residential projects.
We can already simulate elsewhere and apply
often utilized
This is the most popular skylight option.
I'd like to see better proof of EnergyPlus' daylight results before using (compared against Radiance). I don't think CBECC-Com inputs are sophisticated enough for accurate results.
Code required; modeling for controls will help for predictive energy use modeling, but not compliance.
might be less important with LED and occ sensors and other lighting ECMs. Will need to correctly implement daylight harvesting for effective electric savings due to this measure.

Really only practical in single story buildings, or at least low-rise in general

29. Renewable: PhotovoltaicConverts solar energy into electricity						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	0	3	13	36	1.00	52 10
					answered question	**52**
					skipped question	**1**

Comments:
Important to have the performance approach incorporate this in each energy modeling time step.
ZNE
How else with ZNE be calculated?
This is EXTREMELY IMPORTANT!! The current code totally dis-incentivize all-electric buildings which use PV panels to offset their energy use
Need to be able to model PV to get to ZNE, but it's only worth adding to CBECC-com to the extent that it is available as an energy code compliance measure.
Title 24 energy compliance should align with CPUC's Renewable Energy Portfolio Standard with the goal of 33% energy from renewables by 2020; software needs the capability
Modeling for PV will help for predictive energy use modeling, but not compliance.
The most likely offset for building energy to get to ZNE, economic analysis, cost of lowering EUI versus covering EUI with PV
It seems like this is the main way currently employed to get to ZNE.
This will be needed in almost all NZE buildings

30. Renewable: Solar Hot WaterCapture the heat from the sun into water for use in the building						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	0	8	20	24	1.00	52 9
					answered question	**52**
					skipped question	**1**

Comments:
Important to have the performance approach incorporate this in each energy modeling time step.
Is utulized some.
Especially important for high-rise residential projects. It is a common renewable energy technology that should be supported as an aid to achieving ZNE.
Depends on location, can be more important
Where appropriate, DHW is an exceedingly small end use in many commerical buildings
In certain situations and climate zones (high domestic water use, pools, etc.) this can be very important.
See previous comment on DHW

31. Renewable: Battery StorageStore electricity to be discharged at a later time						
Answer Options	**0 (Never Used / NA)**	**1 (Rarely Important)**	**2 (Important)**	**3 (Very Important)**	**Rating Average**	**Response Count**
	5	16	20	11	1.00	52 13
					answered question	**52**
					skipped question	**1**

Comments:
May be more important in the future ..
industry is adopting technology
Current PV installations do little to impact demand charges. Demand Charges continue to be a bigger and bigger part of commercial power charges. Stratgies to impact the demand charge will be more important in the near future.
Very important, though it may be better suited for other developing tools at this point until a stand out simulation model has been identified. Battery chemistry and operation/staging can be very complex at the moment.
Important for TDV net-zero, not conventional net-zero
This may become more important in the future.
Same comment as question 29 (although batteries are not renewable, often used in conjunction with a renewable technology)
imp but lower priority
Generation usually matches peak load
impractical for commercial
more important for peak shavings (power rather than energy reductions), or off grid.
Seems like this is rarely use because of cost

32. Renewable: Wind TurbineTurn an electrical generator from the wind

Answer Options	0 (Never Used / NA)	1 (Rarely Important)	2 (Important)	3 (Very Important)	Rating Average	Response Count
	14	22	12	4	1.00	52
						9
					answered question	**52**
					skipped question	**1**

Comments:
Never see local wind turbines ..
Many renewable features were intentially checked as very important, we have great difficulty in getting projects to comply with the limitations of the current CBECC program not able to model code compliant equipment such as ice storage and then the building does not 'show' complinace.
Important and used frequently do not necessarily mean the same thing. All of these are important. I suggest changing for each question to match the scale at the top of the page.
I also would like to add central plant modeling capability (Heat recovery chiller/ boiler), 100% OA system modeling capability
Same comment as question 29
building mounted, not pole mounted for commercial applications, may be best left to utlity scale
can be important, depends on the resource.
Used much less often at the building level than solar

APPENDIX C – ADDING NEW FEATURES TO CBECC-COM

Developing new features in CBECC-Com is a well-defined process. The effort is divided into three phases:

- Research Phase
- Development Phase
- Testing Phase

Each phase consists of several activities. Figure 4 below provides a summary of the tasks along with a conceptual timeline of the sequence of the tasks. The color coding indicates the relationship of tasks spanning multiple phases. It is important to note that there is significant overlap in the timing of tasks across the three phases.

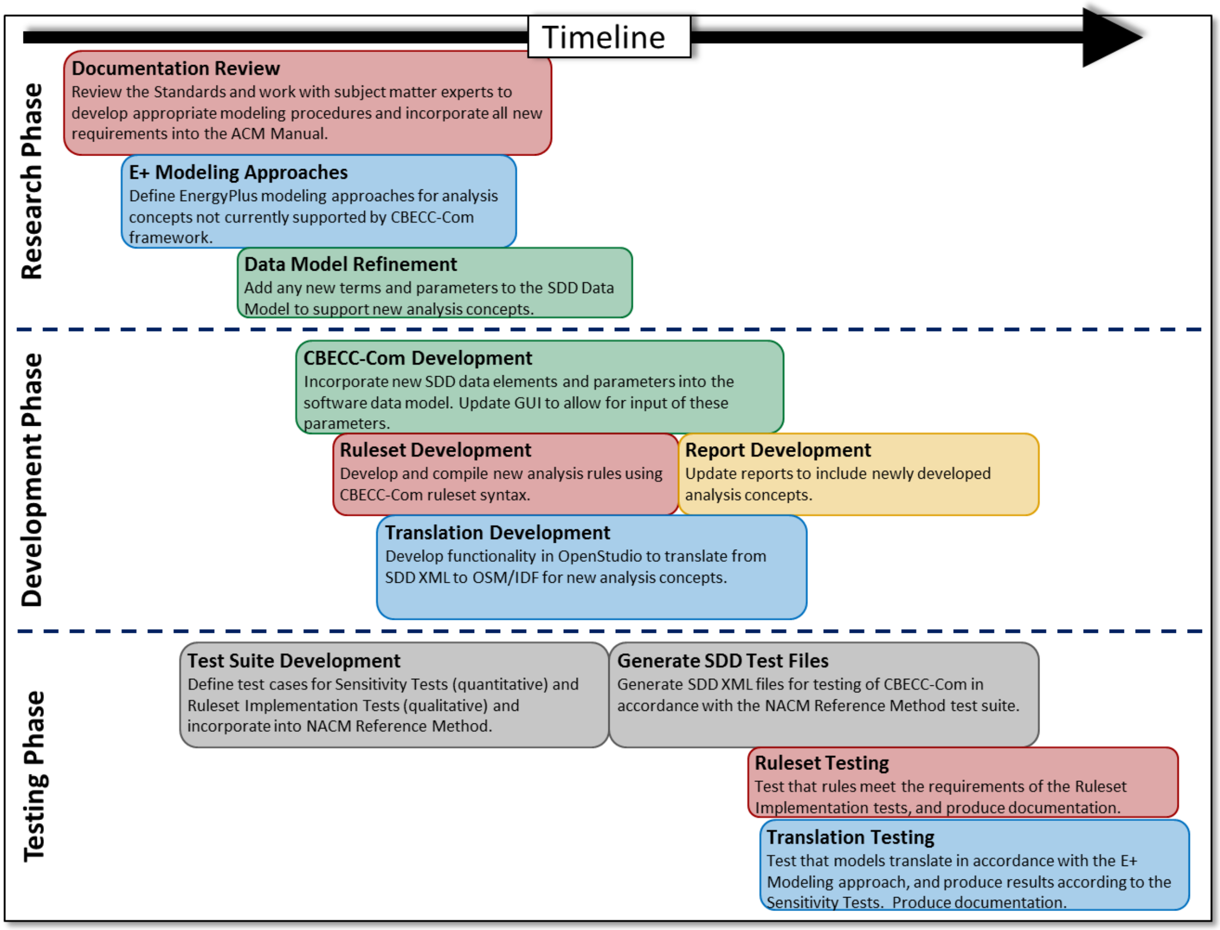


Figure 4 - Adding New Features to CBECC-Com

Research Phase Activities

- **Documentation Review** – The first step to adding any new compliance modeling feature is to document how a specific system or technology should be analyzed and modeled. The team will develop detailed language that defines procedures for both the Proposed and Standard Design models. This language will be incorporated into the Nonresidential ACM Manual and will represent the "rules" that govern how a particular design feature shall be modeled under the T24 performance approach.

- **Data Model Refinement** – The project team will identify any new data model terms and parameters that must be added to the Standards Data Dictionary (SDD) in order to represent VRF systems. All terms, definitions, parameters, units, hierarchical relationship of the SDD data model elements, and other data model properties will be defined.
- **EnergyPlus Modeling Approach Development** – The team will identify an appropriate approach for modeling each measure in EnergyPlus. The development team's energy modeling subject matter experts will define these approaches which will be used as the basis of the SDD to EnergyPlus translation functionality.

Development Phase Activities

- **CBECC-Com Development** – CBECC-Com's data model will be updated to encompass all additions to the Standards Data Dictionary. The CBECC-Com GUI will be upgraded to allow for input of any new SDD elements and parameters.
- **Ruleset Development** – The ruleset authors will write rules in the CBECC-Com ruleset syntax following the logic defined in the Nonresidential ACM Manual for each measure.
- **Translation Development** – The OpenStudio team will add functionality to OpenStudio to translate compliance models (SDD XML file format) to simulation models (OSM/IDF file format). The translation will follow the procedures defined during the EnergyPlus Modeling Approach Development.
- **Report Development** – The report development team will update the functionality of the CEC Report Generator service to enable reporting of new design features on the PERF-1 compliance forms.

Testing Phase Activities

- **Test Suite Development** – Test cases will be developed for the CEC's review and approval of the VRF system compliance modeling features.

  The test suite will consist of two types of tests:

  - Sensitivity Tests - quantitative tests that measure the sensitivity of modifying individual parameters within the software and calculating the change in TDV energy.
  - Ruleset Implementation Tests – qualitative tests that verify whether the ACM rules are properly applied by the software.

  These test cases will be documented in a format suitable for inclusion in the Title 24 NACM Reference Method tests, and will be part of the package submitted to the CEC for incorporation in the NACM Reference Manual.
- **Generate SDD Test Files** – The team will generate test files in the SDD XML file format for each of the Sensitivity Tests and Ruleset Implementation Tests.
- **Ruleset Testing** – The Rule authors will perform initial testing of the ruleset during the ruleset development stage. As rules are written, they will be compiled (by the CBECC ruleset compiler) to verify whether any syntax errors occur and any identified errors will be corrected. This syntax testing process will be done systematically, checking individual rules or groups of similar rules to ensure that errors can be easily identified before large numbers of rules are committed. The secondary testing will occur once rules are finalized by using the SDD XML files that represent the Ruleset Implementation tests. Each test file will be processed by the CBECC rules processor and the model will be reviewed to verify that the Baseline case is accurately created as per the ACM Modeling Procedures.

- **Translation and Sensitivity Testing** – The team will test the OpenStudio translator function to verify that it accurately creates simulation models according to the E+ Modeling Approach. The SDD XML files that represent the Sensitivity tests will be run to verify that the simulations produce results as defined in the Sensitivity Tests.