So you say you have built a ZNE building, prove it!

Abhijeet Pande, TRC
Rachel Allen, PG&E
Carrie Brown, Resource Refocus LLC

ABSTRACT

The goal of achieving Zero Net Energy (ZNE) buildings has gained traction over the last five years, as evidenced by the increasing number of ZNE buildings constructed across the country (~160 verified to date according to NBI). A paper at the 2014 ACEEE Summer Study presented an outline of the evaluation challenges posed by ZNE buildings due to the duality of ZNE design versus operation, occupant interactions, type of ZNE metric being used (site, source, TDV, carbon) and weather. This paper provides results from a study led by PG&E (on behalf of the California Investor Owned Utilities (IOU)) focused on developing ZNE verification methodologies to assess real world examples of ZNE projects. The paper will also outline the methodologies and varying amounts of data necessary to conclude that a building is, in fact, ZNE, and how those data needs vary by the entity/purpose of the ZNE verification and the differing definitions of ZNE itself.

Introduction

ZNE buildings have steadily increased their market share – though admittedly still in the early adopter phase of the market adoption curve. At the same time, there is increasing competition among the many flavors of ZNE buildings to get traction with practitioners, policy makers and the building owner/occupant. As outlined in Torcellini 2006, Traber 2012, and Pande 2012 there are several competing definitions for ZNE and each one of them addresses a separate aspect of ZNE – proving net zero site energy use, offsetting source energy use, offsetting Time Dependent Valuation (TDV) of energy, cost of onsite energy or offsetting site emissions. All of these definitions and policy efforts use the same short-hand for describing their building – ZNE – but in practice have profoundly different impact on the end users (designers, owners, and operators) of these buildings. From an evaluation perspective, these definitions also brings the added challenge of verifying that claims made by a ZNE practitioner or program are indeed valid.

Further, as identified in Mahone 2014, there are several critical questions that need to be addressed when evaluating claims for ZNE buildings:

1. Is the building "Designed" to be ZNE or intended to be ZNE in "Performance"?
2. What is the appropriate timeframe to evaluate before calling a building ZNE?
3. What energy uses and fuels are accounted for in the ZNE design or performance?
4. What are the impacts of human behavior on building performance and how is that captured in the evaluation?

In this paper we present findings from a study conducted by the CA IOU that address these questions raised in Mahone 2014 for the ZNE definitions prevalent in the State of California – ZNE Code, ZNE Site and ZNE Source. It is important to note that this project is not intended to develop evaluation protocols specific to individual ZNE programs or initiatives nor is it intended to address all aspects of program evaluation (e.g. free-ridership, Net-to-Gross etc.). Rather it is intended to address how gross energy savings at the unit level (ZNE Building) are to be verified at the design stage as well as once the building is constructed and under operation.

Review of Current ZNE Certification and Tracking Efforts

Table 1 shows the criteria established by seven entities broken down based on whether the ZNE definition targets ZNE Design versus ZNE Performance.

Table 1: Summary of ZNE Definitions Targeted by Various Entities

Relevant Standard/Effort	Design	Performance
2015 California Integrated Energy Policy Report (IEPR) 2016 CalGreen Tier III (ZNE Code)	Energy Design Rating (EDR) = 0 (based on TDV)	NA
ANSI/RESNET/ICC 301-2014 (ZNE Design)	Energy Rating Index (ERI) = 0 (based on site energy)	NA
New Buildings Institute (NBI) ZNE Watchlist	ZNE Emerging (Net site kBtu/sf = 0)	ZNE Verified (Net site kBtu/sf = 0)
California ZNE Recognition Program	ZNE Commitment, ZNE Emerging (Net site kBtu/sf = 0)	ZNE Verified (Net site kBtu/sf = 0)
International Living Future Institute (ILFI)	NA	Net kWh = 0
DOE Zero Energy Ready Home	HERS Rating Index (based on site energy)	NA
DOE Zero Net Energy Building	NA	Net Source kBtu = 0

Within California, the 2015 IEPR is the official document that outlines the stated policy of achieving ZNE for residential and commercial new construction. This definition of ZNE is specific to ZNE Design as it is intended to be a code mandate – hence also called the ZNE Code definition. The specifics of how the ZNE Code definition is to be calculated are still being determined by the California Energy Commission (CEC) but what is known is that the metric for ZNE Code will be based on energy simulation analysis to calculate an Energy Design Rating (EDR) of zero. The EDR itself uses the Time Dependent Valuation (TDV) metric embedded in California Title 24 compliance. EDR is intended to account for whole building energy use as well as onsite renewable generation at the project level. This ZNE Code definition is being codified through proposed 2016 updates to the state green code (CalGreen) through a voluntary Tier III for energy performance of residential new construction.

Outside of California, the RESNET HERS protocols have been codified into the ANSI/RESNET/ICC Standard 301-2014 which was re-published with updates in February 2016. The ANSI standard uses an ERI metric very similar to the California EDR metric for designating a building to be ZNE Design. In fact ERI and EDR share a lot of commonalities in their analysis methods and both the CEC and RESNET intend to further coordinate on the two metrics to fully harmonize their methodologies and results.

New Buildings Institute (NBI) has been maintaining a ZNE Watchlist for the California Public Utilities Commission (CPUC) that uses separate criteria for ZNE Design versus ZNE Performance. ZNE Emerging is the name given to those projects where the project is designed to be ZNE but may not be constructed yet. A ZNE Verified designation is given to a project that has demonstrated over a period of at least 12 consecutive months that the net site energy use is zero or negative. Net site use is computed based on converting all fuels to equivalent site kBtu/sf (Energy Use Intensity or EUI).

NBI is also developing technical criteria for a proposed California ZNE Recognition Program through the auspices of the CPUC. For this recognition program, there are two separate ZNE Design designations – ZNE Commitment is assigned to those buildings where the designers or owners have demonstrated an 'intent' to achieve ZNE design or performance; ZNE Emerging is assigned to those buildings where the building is designed to be ZNE or to those buildings where the construction is complete but less than a year of performance data is available. For ZNE performance, there is a proposed ZNE Verified designation that is the same as the one used for the ZNE Watch List.

The International Living Future Institute (ILFI) includes ZNE as part of an overall holistic design through their living buildings challenge. This voluntary recognition/labeling program is based on ZNE Performance but unlike other definitions described in this document, this program requires an all-electric design. ZNE designation is awarded to those projects where the net electricity usage onsite is zero on an annual basis.

Department of Energy (DOE) has two flavors of ZNE – for the ZNE Ready Homes[1] initiative, the ZNE designation is based on ZNE Design, whereas DOE also recently released a new definition for ZNE buildings[2] that is based on ZNE Performance. The ZNE Ready Homes definition in fact does not require renewables, rather that the home is ready for renewables. Thus it does not guarantee a ZNE Design, just the capability to achieve it if an appropriate renewable energy system is installed. The new common definition for ZNE buildings proposed by DOE is a performance metric that requires "An energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy."

Proposed Methodologies for Evaluating ZNE Building Claims in California

Based on the review of the current ZNE efforts above, the team proposed methodologies for verification of ZNE claims at the building level. Note that the methodologies are <u>not</u> for evaluation of the effectiveness of ZNE programmatic efforts that would involve further considerations like naturally occurring market adoption curves (NOMAD), net to gross savings estimating among many other considerations. The methodologies address different metrics of interest when verifying claims of ZNE building – whether design or performance.

The study recommended the following methodologies to verify ZNE claims at the building level, each of which specify the following:

- *Analysis Procedures* - Data inputs needed; calculations or data analysis to be performed; recommendations on who should conduct the analysis
- *Documentation Requirements* - Data inputs; data outputs and formats; system details on energy using and generating devices; calculation or data analysis showing building meets the ZNE criteria
- *Verification Requirements* - Who should be conducting the verification; what should they verify

[1] U.S. Department of Energy Zero Energy Ready Homes Initiative - http://energy.gov/eere/buildings/zero-energy-ready-home

[2] National Institute of Building Sciences, for U.S. Department of Energy, "A Common Definition for Zero Energy Buildings". September 2015. http://energy.gov/sites/prod/files/2015/09/f26/bto_common_definition_zero_energy_buildings_093015.pdf

Table 2: Programs and Voluntary Efforts that Require Verification of ZNE

Verification Need	ZNE Metric of Interest	ZNE Criteria	Verification Approach
Codes and Standards	ZNE Code Design (Based on TDV)	Design: EDR = 0	Design: Energy Simulation
		Performance: Site energy use	Performance: Energy Simulation calibrated for as-built conditions
Utility Incentive Programs	ZNE Code Design;	Design: EDR = 0	Design: Energy Simulation
	ZNE Site Design	Design: Net site energy use = 0	
	ZNE Performance	Performance: Net site energy use = 0	Performance: Utility Billing Analysis
Voluntary and Recognition Programs	ZNE Site Performance	Performance: Net site energy use = 0	Performance: Utility Billing Analysis
	ZNE Source Performance	Performance: Net source energy use = 0	Performance: Utility Billing Analysis with Source factors

As seen in Table 2, codes and standards savings claims as well as for programs that are based on code baselines, the primary savings claims are predicted EDR and net site energy use embedded within the ZNE Code Design and ZNE Site Design respectively. For these efforts at the design stage the verification focuses on whether the design meets the intended ZNE definition and confirms the underlying claims for net site kWh and Therm usage accounting for both energy use and renewable generation and export. ZNE Design and ZNE Code are asset ratings that establish capability of the building to perform as a ZNE building, but there is no guarantee that the building will operate at a ZNE Performance level. This is due to the expected variations in building operation from those assumed in the design analysis. Thus verification protocols for ZNE Design and ZNE Code Design are proposed to be based on energy simulation modeling that is validated against actual installation of measures, but does not specifically include assessment of building performance.

For utility incentive programs, voluntary programs, recognition programs and others where ZNE Performance is the intended goal, the verification focuses on validating savings claims and verify that the building meets the intended ZNE Performance definition based on utility meter data analysis.

ZNE performance is proposed to be verified based on a continuous 12-month period after the building is completely occupied and all building systems are operation and commissioned. This is important since most of the projects have initial periods of a few weeks to few months where the energy use may not be representative of the intended operation of the buildings – either due to lack of full occupancy, or due to the equipment onsite not functioning as intended. Thus if the first 12-months post-construction are chosen, they are likely to provide an erroneous verification of the buildings performance. Therefore the verification methodologies require that the evaluator use data from the period post-commissioning and full occupancy.

A number of projects reviewed for the study included non-building end uses such as electric vehicle charging, energy storage, secondary structures, exterior process loads (irrigation pumps) which are not included in the definitions used for ZNE buildings (design or performance) used in California. When evaluating ZNE performance, it is therefore critical that end uses like these are separated out of the utility billing analysis.

Further, many buildings size the renewable energy systems to offset these non-building end uses. When evaluating ZNE performance or design it is important to separate out the renewable output intended to offset these non-building uses so that the ZNE verification is based on the renewable output dedicated to offset building energy end uses only.

ZNE Design Verification – Residential

In this section we outline the documentation, modeling and verification procedures required for residential buildings that are designed to be ZNE. The goal of a ZNE design rating is to assign an 'asset value' to the building such that the building is 'capable of being a ZNE building, assuming the building is operated per the assumptions made in the predictive analyses. There are two flavors of ZNE at the design stage – ZNE Code Design based on the California IEPR definition; and ZNE Design based on the requirements of the ANSI/RESNET/ICC 301-2014.

Verification Requirements

As outlined in Table 2, the metric used for ZNE Code is an Energy Design Rating (EDR) of zero or negative and the metric for ZNE Design is Energy Rating Index (ERI) of zero or negative – both are to be calculated based on whole building energy simulation modeling. A designated entity must verify the model inputs and outputs to confirm that the modeled EDR/ERI = 0 or negative using inputs and calculation procedures approved for the calculations. The designated entity must verify the renewable system size, orientation, tilt and efficiency as well as confirm the renewable capacity dedicated to offset home energy uses.

Code compliance verification is the domain of local code officials within building departments, however, verifying ZNE Code or ZNE Design is not within the domain of these code officials till the building codes require ZNE Code as the condition for code compliance. In California, that is likely for residential buildings in 2020 but not for commercial buildings till 2030. In the interim, there needs to be designated entities assigned for the verification of ZNE Code or ZNE Design.

Analysis Requirements

For the ZNE Code Design metric, analysis needs to be conducted using an approved energy simulation tool by the California Energy Commission that produces an Energy Design Rating (EDR) according to CEC approved rulesets outlined in the residential Alternative Compliance Method (ACM) reference manual. The software must use default assumptions for operation schedules for all energy end uses and default assumption on unregulated loads (MELs, lighting etc) as outlined in the ACM. The energy simulation software must confirm the renewable system Sizing, Orientation, Tilt and Efficiency (including efficiency of inverters). The model shall make a note if electric vehicle (EV) charging, or electric storage is designed to be supported by the renewable output. If either or both EV and storage are to be supported by renewable output, the model must designate a specific capacity of the renewable system dedicated for EV and/or storage and designate a specific capacity of the renewable system dedicated for home energy use loads. The EDR calculation must be done using only that portion of the renewable system dedicated to offset home energy use.

For ZNE Design, the analysis must be conducted using similar methods but instead of using CEC approved tools and ACM requirements, the analysis must be done by methods outlined in the ANSI/RESNET/ICC 301-2014 standard and using tools approved for use with that standard.

Documentation Requirements

For the ZNE Code Design and ZNE Design metrics, the documentation requirements are as follows:

Table 3: Documentation Requirements for ZNE Design Verification

Topic	Subtopic	Submittal Requirements
Background	Project Team	Owner, Developer, Builder, Architect, Mechanical Engineer, Contractor, Energy Consultant, Other Consultants
	Project Goals	ZNE metric targeted; specific goals and targets relevant to ZNE
General Building Information	Project Name	
	Location	City, County, CEC Climate Zone
	Building Type	
	Building Size	conditioned area, # floors, # buildings
	Construction Type	New Construction; Addition/Retrofit
Building Construction	Building Envelope	Framing type, U-factor (wall, roof, floor), U-factor and SHGC (windows), air leakage
	HVAC System	System capacity, efficiency, # of systems
	DHW System	System capacity, efficiency, # of systems
	Lighting	Lighting efficacy (lumens/watt)
Building Occupancy	Number of Occupants	Default per standard rules
	Occupancy Schedule	Default per standard rules
	Equipment Schedule	Default per standard rules
	Lighting Schedule	Default per standard rules
Analysis Methodology	Software Used	Name and version of software
	Period of Analysis	Annual based on hourly analysis
Annual Energy Consumption Onsite	Predicted Electricity Use (kWh)	Total kWh for a 12-month period
	Predicted Fuel Use (Therm)	Total Therm for a 12-month period
	Predicted TDV Use (CA only)	Total TDV/sf for a 12-month period
Annual Renewable Energy Generated Onsite	Predicted Annual Renewable Electricity Produced Onsite dedicated to offset Home Energy Use (kWh)	Total kWh for a 12-month period
	Predicted Onsite Renewable Electricity Generation Dedicated to Offset Home Energy Use (TDV) (CA only)	Total TDV/sf for a 12-month period
Net Energy Use Onsite	Energy Design Rating (EDR)	EDR calculated using CEC approved methodologies. EDR must be Zero or Negative to show Res ZNE Code Design compliance.

Topic	Subtopic	Submittal Requirements
	Energy Rating Index (ERI)	ERI calculated using ANSI/RESNET/ICC 301-2014 methodologies. ERI must be Zero or Negative to show ZNE Design compliance.
Renewable Energy Systems	Photovoltaic (PV) System Generation Capacity (kW)	Total installed rated capacity in kW DC and AC
	Photovoltaic (PV) System Capacity Dedicated to Offset Home Energy Use (kW)	Total installed rated capacity in kW DC and kW AC dedicated to offset home energy use. Renewable capacity dedicated for Electric Vehicle (EV) or Storage needs to be subtracted from the total generation capacity to calculate this number.
	Photovoltaic (PV) Orientation and Tilt	Orientation in degrees from North (0=North, 90 = East); Tilt (angle from horizontal); If multiple panels used, provide orientation and tilt by each panel 'group'
	Photovoltaic (PV) System Location	Specify location of renewable system (e.g. Roof).
	Photovoltaic (PV) Manufacturer and Make	Make, model number, manufacturer name
	Other Renewable Energy Systems	Rated capacity, total annual output, location onsite, manufacturer and make.
Electric Vehicles	Electric Vehicle Charging	# of Electric Vehicles Predicted to be Charging
Energy Storage	Energy Storage System	Estimated Storage Capacity

ZNE Design Verification – Nonresidential

The verification methodologies for nonresidential ZNE Design verification are proposed to be similar to those of the ZNE Design verification for residential buildings with a few important changes. Unlike residential buildings where there is approved software that can be used to calculate EDR and ERI, there is no one tool available that is approved for calculating nonresidential EDR/ERI. Further, the methodologies for developing EDR/ERI are also not codified. Thus, from a verification perspective it is important therefore to establish some common protocols for analysis. These protocols include the following:

- The predictions of building energy use and onsite renewable energy generation must be done using a commercially available hourly energy simulation software – ideally the same software is used for analysis of building energy uses as well as renewable energy generation.
- The analysis must generate annual predicted total building energy use and annual predicted total onsite renewable generation in site energy terms (kWh, Therm) as well as source energy (kBtu).
- ZNE Design for Site Energy is achieved when Predicted Annual Energy Use (kWh) - Predicted Annual Onsite Renewable Generation (kWh) = zero or negative. Note that any onsite fuel consumption (e.g. Natural Gas Therms) are converted to equivalent kWh in this calculation.
- ZNE Design for Source Energy is achieved when Predicted Annual Energy Use (kBtu) - Predicted Annual Onsite Renewable Generation (kBtu) = zero or negative. Note that all onsite fuel and electricity usage is converted to source kBtu using standardized multipliers used for California Energy Efficiency programs.

Documentation and verification requirements are similar to those of the ZNE Design residential verification. Unlike residential buildings where protocols and registries such as RESNET and California HERS are available to track the documentation and verification information in a standardized manner, no such standardized approaches are available for nonresidential buildings. Thus, there is a need to establish centralized and consistent registries for commercial building energy performance ratings.

ZNE Performance Verification

Verification and Analysis Requirements

ZNE performance verification is proposed to be conducted primarily through the analysis of building utility bills and the underlying electricity and natural gas/fuel usage. For the ZNE Site metric, the energy use is expressed in terms of annual site kBtu/sf for all building energy end uses. For the ZNE Source metric, the energy use is expressed in terms of annual source kBtu/sf for all energy end uses and fuels. Site to Source energy conversion factors vary significantly across the country but for the sake of consistency, the preferred conversion factors are those proposed by the DOE for their new 'common definition' for ZNE buildings.

To generate the annual total, the building must have 12 consecutive months of energy use data. Since the building may or may not have renewable systems sized to offset EV charging or support electricity storage onsite, the analysis needs to confirm that renewable system output is pro-rated for the portion of the renewable system designated to offset building energy use.

For nonresidential buildings, completion of building commissioning is a recommended step before a building can be evaluated for ZNE performance. For residential buildings, there is typically no formal commissioning process involved but for ZNE analysis it is important that all building systems were installed correctly and that the energy use reflected in the bills are representative of how the building is supposed to operate. For this reason, it is recommended that the billing analysis be done after the building is occupied as intended and the systems are deemed functional through functional testing by the relevant trades.

Documentation Requirements

For sake of brevity we do not present information here that is similar to verification of ZNE design, but only those documentation requirements that are unique to ZNE Performance verification.

Table 4: Documentation Requirements for ZNE Performance Verification

Topic	SubTopic	Submittal Requirements
Building Occupancy	Number of Occupants	Actual average number of occupants
	Vacancy Rate	Confirm that vacancy was less than 10% on an annual basis
	Building System Operation and commissioning	Confirm that building systems were installed per manufacturer instructions and operational. Note any discrepancies.
Billing and Metering Data	Electricity Bills	Monthly electricity bills for at least 12 months post-occupancy
	Natural Gas/Fuel Bills	Monthly natural gas/fuel bills for at least 12 months post-occupancy
	Renewable Electricity Metering (Optional)	Monthly renewable electricity production for at least 12 months post-occupancy. If separate renewable Meter is not installed onsite, note source of estimate.

Annual Energy Consumption Onsite	Actual Electricity Use (kWh)	Total kWh for a 12-month period post-occupancy
	Actual Fuel Use (Therm)	Total Therm for a 12-month period post-occupancy
	Actual Site Energy Use (site kBtu/sf)	Total site kBtu/sf for a 12-month period post-occupancy
	Actual Source Energy Use (Source kBtu/sf)	Total source kBtu/sf for a 12-month period post-occupancy
	Actual Energy Use by End Use Category (Optional)	kWh and Therm by end uses - Space Cooling, Space Heating, Ventilation, DHW, Lighting, Appliances and MELs.
Annual Renewable Energy Generated Onsite	Actual Annual Renewable Electricity Produced Onsite dedicated to offset Home Energy Use (kWh)	Total kWh for a 12-month period
Net Energy Use Onsite	Net Annual Actual Energy Use (kWh)	Actual Electricity Use (kWh) - Actual Annual Renewable Electricity Produced Onsite Dedicated to Offset Building Energy Use (kWh) = Zero or Negative. (*Note: Convert Actual Fuel Use (Therm) to equivalent Site kWh)*
	Net Annual Actual Energy Use (Site kBtu/sf)	Actual Annual Site Energy Use (kBtu/sf) – Actual Annual Renewable Electricity Produced Onsite Dedicated to Building Energy use (kBtu/sf) = Zero or Negative.
	Net Annual Actual Energy Use (Source kBtu/sf)	Actual Annual Source Energy Use (kBtu/sf) – Actual Annual Renewable Electricity Produced Onsite Dedicated to Building Energy use (kBtu/sf) = Zero or Negative.

Verification of Proposed Methodologies

To illustrate the differences in ZNE verification and learn insights into practical issues with verifying whether a building is ZNE or not, the study gathered data from twelve buildings/projects that had been both designed for ZNE and then measured for ZNE performance through utility billing as well as onsite monitoring. The study examined the energy consumption and renewable generation profiles of these buildings on a monthly and annual basis. The name, location, size and other details of these buildings have been kept confidential for this paper.

The study then applied the ZNE metrics explained above to these buildings: ZNE Design, ZNE Code, ZNE Site Performance site kBtu/sf and ZNE Source Performance based on source kBtu/sf. For the site and source kBtu/sf metrics, all energy uses within the building were converted to the appropriate site and source kBtu units respectively. For the source kBtu, the study uses the DOE proposed source energy conversion factors that are constant across the country.

Review of the project data highlighted a few key limitations of data available for these projects:

- Modeled energy generation data was not available for any project, thus it was not possible to verify the ZNE Code and ZNE Design metrics that require analysis of predicted energy use versus energy generation.

- The modeled TDV metrics were not available for most projects thus preventing verification of ZNE Code.
- Most of the projects were designed as all-electric buildings and there was no natural gas consumption data available for most of these projects.

We analyzed the building modeling and performance data subject to the caveats above and **Error! Reference source not found.**Table 5 provides the result of this analysis. The Table shows that most buildings that were designed to be and intended to perform as ZNE do indeed perform as ZNE (denoted by negative numbers in the table). There are a few notable exceptions though such as building 3, which did not meet any of the performance criteria. Further analysis showed that the building includes additional end uses that were not originally intended to be part of the ZNE equation, but whose energy use nevertheless was part of the utility bills upon which the analysis was conducted. Without sub-metering of those end-uses, it is not possible to remove the energy use for those uses from the analysis. Further, removing those end uses would also raise another issue of whether the building should be called ZNE at all if it does not indeed address all onsite energy use. Buildings 10 and 11 were designed to be performing at ZNE level under the source energy metric and not expected to be performing as ZNE under the site energy metrics.

Table 5: Summary of Net Energy Performance Verification of Representative Projects

ZNE Metrics		Building											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10***	**11**	**12**
Net Site Energy	kBtu/sf	(1.76)	(4.34)	<u>8.47</u>	(3.97)	(2.32)	(5.57)	(10.08)	(4.58)	(2.02)	<u>0.45*</u>	<u>4.40</u>	(2.11)
Net Source Energy	kBtu/sf	(5.53)	(13.63)	26.62	(12.47)	(7.31)	(17.49)	(31.64)	(14.40)	(6.35)	(2.89)*	(5.60)	(6.63)

Table 6 shows that while most buildings met the ZNE performance targets using the methods proposed above, there was still significant differences between the modeled and monitored energy use for the buildings.

Table 6: Comparison of Predicted versus Monitored Energy Performance

	Modeled Energy Use			Monitored Energy Use			Difference (Monitored – Modeled)		
Bld	kWh	Therm	Source kBtu/sf	kWh	Therm	Source kBtu/sf	kWh	Therm	Source kBtu/sf
1	197,010	-	66.46	250,049	-	84.35	21%		27%
2	151,237	-	80.93	131,615	-	70.43	-15%		-13%
3	2,668,019	-	150.44	2,460,950	-	138.77	-8%		-8%
4	237,570	-	56.56	215,159	-	51.22	-10%		-9%
5	47,720	-	77.97	35,955	-	58.75	-33%		-25%
6	277,737	-	60.73	201,737	-	44.11	-38%		-27%
7	50,292	-	85.53	35,121	-	59.73	-43%		-30%
8	47,711	-	54.96	62,850	-	72.40	24%		32%
9	-	-	-	11,460	-	37.57			
10	9,220	99	34.28	9,357	65	33.78	1%	-52%	-2%
11	-	-	-	6,629	192	44.18			
12	6,424	-	33.87	6,629	-	44.18	21%		27%

The difference between monitored energy uses to the predicted energy uses is as high as a third of the predicted energy use. The fact that the building still performs as a ZNE building is likely due to the renewable generation onsite being oversized and able to handle the additional building energy use. Without reliable data on the designed capacity and predicted performance of the renewable energy generation, it is not possible to know whether the systems were sized 'correctly' or 'oversized'. Further, the differences between predicted and monitored are likely a combination of various factors – building operations, schedules, equipment efficiencies and building occupancy – but these details are hard to confirm for each building based on utility billing data or sub-metering of end uses. To understand these differences field audits and interviews are necessary along with detailed simulation file reviews to confirm the specifics. However, to say whether the buildings is ZNE or not in performance, these additional steps are not required.

Recommendations

Based on the proposed verification methodologies, this paper and the underlying study recommend the following:

There is no "One Size Fits All" for ZNE – Definitions Matter

There are many flavors of ZNE in play across the country and each flavor of ZNE requires a unique methodology. A ZNE Code Design building may be a very different building than a ZNE Site Performance building. Thus it is important that ZNE buildings be qualified as ZNE Design or ZNE Performance as well as specify the metric being used (Site/Source/TDV).

Establish Common Analysis and Verification Protocols for ZNE Metrics

Once ZNE becomes code mandates, the rules and authorities will be clearly established for ZNE Code. However, there is currently no central entity that is responsible for verification of ZNE. It is unlikely that one entity will cover the entire country for all building types. RESNET comes closest for residential buildings using the ERI metric but there is nothing similar to that for commercial buildings. Further, there is the issue of tracking the special flavors of ZNE preferred in specific locations such as California's ZNE Code metric.

Thus there is a need to establish common analysis and verification protocols so that various jurisdictions, utilities, regulatory entities across the country as well as industry adopters all use the same (or similar) level of rigor in collecting and analyzing data for ZNE verification. This is necessary in order to maintain the integrity of the ZNE brand.

Develop Standardized Registries for ZNE Buildings

Related to above, there is a need to develop standardized tracking platform that tracks ZNE Design and ZNE Performance across buildings. Currently, there is no one place where this information is tracked. NBI is tracking commercial buildings both through their efforts with NASEO as well as their efforts with the CPUC. On the residential side, the IOUs completed a ZNE Market Characterization study that identified ZNE buildings in the state, but that was a one-time activity. The Net-Zero Energy Coalition[3] as well as RESNET both are tracking ZNE buildings across the country – but they use differing definitions.

---

[3] http://netzeroenergycoalition.com/wp-content/uploads/2015/04/20150105_nzec_zero_energy_homes_report_booklet_fnl_02.pdf

Align ZNE Code Design and ZNE Design Methodologies

While there are many similarities between the ZNE Code and ZNE Design processes there are many differences still between RESNET and CEC methodologies. Thus there is a need to further align the EDR and ERI metrics or an easy cross-walk provided between the two metrics so that their results are easily understood across jurisdictions.

References

Torcellini, P., S. Pless & M. Deru, National Renewable Energy Laboratory, D. Crawley, US Department of Energy. 2006. “Zero Energy Buildings: A Critical Look at the Definition.” Presented at ACEEE Summer Study, Pacific Grove, California, August 14-16 2006. http://www.nrel.gov/docs/fy06osti/39833.pdf

Traber, A. et al., DNV GL and J. Morton, Southern California Edison. 2012. “Defining Zero Net Energy: One Utility’s Approach.” Presented at ACEEE Summer Study, Pacific Grove, California, August 12-17 2012. http://aceee.org/files/proceedings/2012/data/papers/0193-000362.pdf

Pande, A. et al., TRC, E3 Inc, CTG Energetics, Portland State University, New Buildings Institute. 2012. “Road to ZNE: Mapping Pathways to ZNE Buildings in California.” Research Report posted December 2012. http://www.trcsolutions.com/writable/images/The-Road-to-Zero-Net-Energy.pdf

Mahone, D., A. Pande, TRC, R. Kasman, D. Jones, PG&E. 2014. “An Evaluation Framework for Residential Zero Net Energy Buildings.” Presented at ACEEE Summer Study, Pacific Grove, California, August 17-22, 2014. http://aceee.org/files/proceedings/2014/data/index.htm