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RESEARCH REPORT
January 2014

2014 Getting to Zero Status Update:

A look at the projects, policies and programs driving zero net energy performance in commercial buildings

Courtesy: Jeremy Bitterman

David and Lucile Packard Foundation, Los Altos, California

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For more information about this report or about net zero energy in general, visit:

www.newbuildings.org/zero-energy

New Buildings Institute (NBI) would like to thank the many individuals and organizations that contributed to the development of the *2014 Getting to Zero Status Update*. NBI is thankful to the many owners and design teams who compiled and forwarded information for review, especially Integral Group, EHDD and PAE Consulting Engineers. This research would not have been possible without their willingness to publically disclose their data for the benefit of improving future generations of buildings. The generous exchange of results showcases these leaders as early adopters whose efforts are helping move more buildings onto the path to zero. Their time and resources were essential to discovery of projects, actual energy performance, and technologies that can serve as exemplars for future projects.

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Sponsors

Companies and organizations leading in the advancement of zero net energy performance in buildings are at the forefront of a transformation in the built environment. NBI would like to acknowledge the entities below for their support of our work in ZNE and this research report.

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Executive Summary

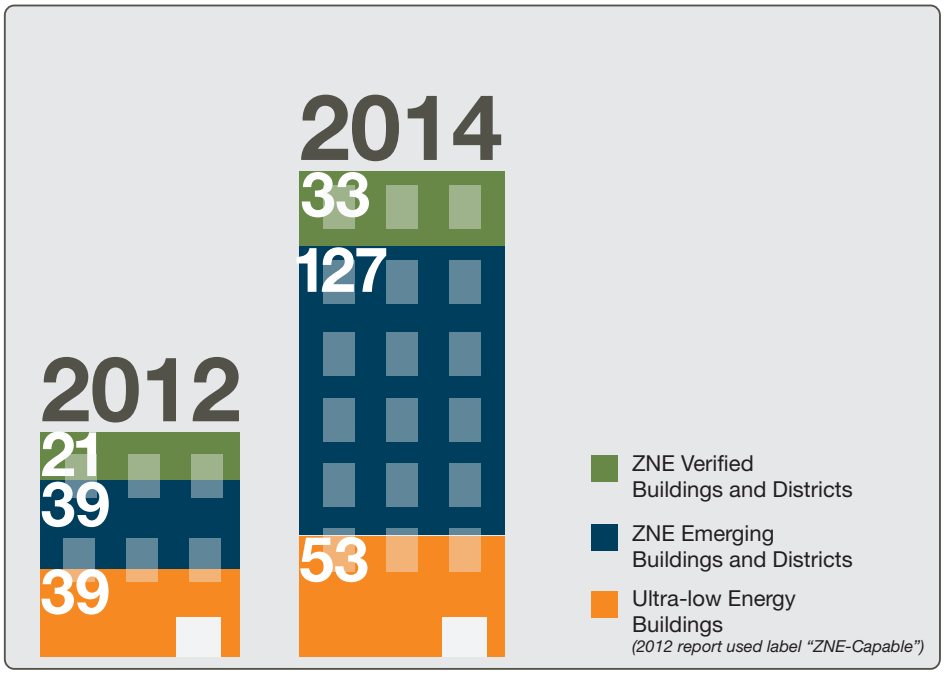
Zero net energy (ZNE) buildings[1] have captivated the minds of leading design firms, companies, schools, foundations and governments that are showing the way to a lower-carbon future. In just a few years ZNE has transitioned from an impossible concept to a quite probable future. ZNE buildings have now moved beyond a handful of small demonstration projects by universities or nonprofits to more widely mainstream building types and sizes.

This *2014 Getting to Zero Status Update* presents the findings on ZNE and ultra-low[2] energy buildings and districts across North America and builds on the *Getting to Zero 2012 Status Update* work by New Buildings Institute (NBI). The *2014 Getting to Zero Status Update* is based on extensive research by NBI as well as input from many of the key organizations, states and design firms that are leading the ZNE market. This executive summary provides highlights of our findings. The lists of all buildings that were studied appear in the full report.

Building Status

- **The ZNE verified and ZNE emerging building count has more than doubled.** The number of buildings achieving ZNE verified performance or those targeting ZNE has more than doubled in just two years, from 60 in 2012 to a listing of 160 projects in this report, although the market is still very small.
- **24% of ZNE verified projects are renovated existing buildings.** This is an interesting trend that provides validation of the potential for existing buildings to achieve ZNE through a major renovation.

Figure 1: Number of ZNE projects from 2012 to 2014



1 Zero net energy buildings are buildings with greatly reduced energy load such that, averaged over a year, 100% of the buildings energy use can be met with onsite renewable energy technologies.
2 Ultra-low energy buildings are comparable to ZNE buildings based on energy use, design strategies and efficiency technologies but do not have a stated goal of ZNE using onsite renewable energy.

Measured energy consumption of the ZNE buildings is only about one-quarter of the average commercial building energy use today.

- **ZNE buildings use only a quarter of the energy of average buildings.** Measured energy consumption of the ZNE buildings is only about one-quarter of the average commercial building energy use today[3]. The average verified Energy Use Index (EUI)[4] of these buildings is 21 kBtu/sf/yr.
- **Large ZNE buildings are becoming more common.** There has been a notable increase in the number of larger, more complex buildings. More than one quarter of the ZNE and ultra-low energy buildings are larger than 50,000 sf. Of those, half are over 100,000 sf. These larger buildings — which are more complex to design, construct and operate — clearly show the potential of ZNE for larger real estate properties.
- **ZNE buildings are now in 36 states and two Canadian provinces.** The number of states with ZNE buildings rose by 42%, from 26 states at the time of the 2012 report to 36 U.S. states and two Canadian provinces today. These locations reflect all eight of the U.S. Department of Energy (DOE) climate zones and demonstrate that ZNE can be built in most regions in North America. More than one-third of all ZNE and ultra-low energy buildings are in California, supported by aggressive state policy, utility programs and leading high performance design firms.
- **There are ZNE examples in 16 different building typologies represented.** Education comprises the largest portion of ZNE projects, with kindergarten through 12th grade (K-12), universities and general education buildings representing about one-third of all ZNE buildings, closely followed by offices. Low-rise multifamily buildings are a new trend in ZNE with over a dozen examples in this study. The building types represented also include some projects that are typically more energy intensive per square foot, such as laboratories, or unusual, such as airports.
- **Districts are a growing trend toward scaled ZNE.** In addition to the individual buildings, there is a new trend of communities and campuses adopting commitments to make groups of buildings ZNE. NBI identified 18 ZNE districts, with the U.S. Army and several universities as the leading owners.
- **Public sector leads, but private sector adoption of ZNE is increasing.** With two-thirds of all projects, government buildings and public schools comprise the largest ownership type of the ZNE dataset. Public building owners are motivated by the resiliency offered by ZNE buildings and the opportunity to educate citizens about the feasibility of ZNE performance with practical and tangible examples, especially in the case of schools. Public buildings are also first to be targeted in carbon reduction policies. Advancing on the lead in the public sector, private sector interest in ZNE is growing with 26% of the ZNE buildings in this study privately developed.

3 U.S 2003 Commercial Buildings Energy Consumption Survey (CBECS) average for non-mall buildings is 91 overall and 93 for offices.

4 Energy Use Intensity (EUI) is a metric of whole building energy use expressed in kBTU/sf/yr.

Design Strategies and Technologies

A zero target appears to have an aspirational influence beyond that of traditional “percent-better-than-code” or point-based goals. The pursuit of an absolute performance outcome helps unify the development process and demands early and ongoing integrated design and attention to operations. Project design teams employed commonly available technologies and equipment rather than highly specialized or experimental technologies.

They cited the use of passive energy strategies that included efficient envelopes with increased insulation, natural and night flush ventilation, daylighting and controls, exterior window shading and operable windows. Engineering firms moved outside of the typical ”box” of variable air volume and package rooftop HVAC (Heating Ventilation and Air-conditioning) systems to radiant heating and cooling, chilled beams, variable volume refrigerant systems and dedicated outside-air ventilation to yield significant energy benefits by reducing fan energy. Ground-source heat pumps and heat recovery were also prominent.

Achieving ZNE performance is about more than careful design and installing the right technologies. Continuous attention to building controls and performance monitoring and feedback are key components in most projects. The role of occupants becomes critical in ZNE buildings as their activities influence the energy use through plug loads, schedules and equipment procurement. In a building designed for net zero energy, plug loads can account for as much as 50% of total building energy use as the efficiencies of heating, cooling, lighting and ventilation are dramatically improved.

Courtesy: Michael Mathers

Hood River Middle School Music and Science Building, Hood River, Oregon

Policies and Programs

Policies and programs can dramatically change the landscape for ZNE buildings. Cities and states are leading the way, accompanied by community district efforts. Schools and public buildings have been identified as early targets for ZNE in several states, and public benefits program administrators have operated successful ZNE pilots in Oregon and California. Building codes are at the early stages of considering changes that could better support ZNE in the future, including a focus on stretch codes and establishing energy targets for buildings rather than prescriptive measures.

Many buildings in this study achieved Leadership in Energy and Environmental Design® (LEED) Gold or Platinum designation through the U.S. Green Building Council®, and eight have been recognized as meeting the International Living Future Institute's™ Living Building Challenge™ or requirements for their Net Zero Energy Building Certification™. The 2030 Challenge has also prompted 2030 Districts that are now established in multiple cities with a long-term goal of zero-carbon buildings. The Northeast Sustainable Energy Association is raising the profile of ZNE in that region through membership, awards and recognition.

Characterizing Costs

While this study's focus was primarily on energy performance and trends, there are some consistent findings from the research of NBI and others:

- **Costs for getting to zero are not distinguishable from overall project costs.** Energy efficiency and renewable technologies do have specific costs, but the design and technology tradeoffs due to the advanced systems blur the line of incremental costs.
- **Green, LEED and/or zero net energy building costs are within the range of other like-type buildings.** When total construction costs for these buildings are analyzed against control groups, they are approaching comparable costs.
- **Design firms and early targets reduce costs.** The experience of the team and the explicit goal of ZNE throughout the process are cited as critical to managing costs.

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Challenges

At the building level. Despite excellent design and advanced systems, achieving a ZNE target remains elusive for some buildings due to operational and occupancy variations. For others the limitations of roof and site space for photovoltaics (PVs), or initial fiscal limits on the purchase of sufficient PVs, are impediments to actual zero energy operations. In some cases a ZNE target created hesitancy on the part of building owners to provide actual energy use to this study because the building had not yet been "successful" in achieving ZNE, even in buildings with exemplary, ultra-low energy performance.

Courtesy: Maclay Architects

Coastal Maine Botanical Gardens Bosarge Family Education Center, Boothbay, ME

At the research level. Data presents a dilemma. Finding and gaining access to measured data is challenging, and often the data has errors or is incomplete. Despite decades of efficiency programs, green building programs and the more recent energy disclosure requirements, this information remains largely inaccessible. The recently released U.S. Department of Energy National Buildings Performance Database is encouraging, but all parties in the industry need to supply greater quantities of commercial building data.

Recommendations and Conclusions

The path to zero is a path to carbon reduction. It is imperative to evolve from a narrow path traveled by few to a broad, smooth road that will accelerate the pace and volume of projects getting to zero. The development of this report suggests some recommendations; other reports by NBI, the Zero Energy Commercial Buildings Consortium and other organizations contain more detailed recommendations to advance ZNE.

1. **Encourage ZNE districts.** District- or community-scale projects are increasing, and policies, programs, and planning departments need to respond and help create this opportunity. ZNE districts — as well as definitions that recognize shared, rather than just onsite, systems and renewables — will be important to serve urban areas and existing buildings where ZNE achievement on a building scale can be especially challenging.
2. **Develop standard data collection protocols for all programs and pilots.** More robust data is needed to facilitate learning from early examples to educate and expand the market. Benchmarking and disclosure policies are an appropriate place to start.

3. **Develop a building energy codes roadmap.** If ZNE buildings are to become commonplace or standard, they must be supported and/or required by building codes. A roadmap builds the ZNE strategy over time as the market progresses in its understanding of the necessary design, construction and operational strategies, and as costs of achieving ZNE are reduced and the value of achieving ZNE is better understood.
4. **Expand utility programs to support ZNE.** Initial pilot program efforts in California and Oregon have been successful in creating more ZNE and ultra-low energy buildings. There is market interest in ZNE, and these early efforts illuminate lessons learned that should be emulated by others.
5. **Target schools and public buildings for pilots and demonstration projects.** These markets are already shown to be early adopters and can provide a broad base of constituents with practical and tangible examples of low- and zero-energy buildings.
6. **Support the achievement of ZNE in existing buildings.** While a number of fully renovated existing buildings have shown that ZNE can be achieved in existing buildings, tools and prototypes are needed to streamline decision making and prove there are simpler and easier ways to reach ZNE, especially for common building types.
7. **Conduct additional research to bridge the gap from design to operations.** ZNE outcome is highly dependent on the decisions and actions of the operator and occupants. New relationships between design and post-occupancy energy use are needed.

NBI's *2014 Getting to Zero Status Update* shows that low energy use is the foundation to ZNE buildings and that low and zero energy are being achieved today in buildings of all types, sizes and locations. All of the individuals and firms involved in the 213 ZNE and ultra-low energy buildings and districts in this report, as well as the early developers of programs and policies, deserve recognition for their efforts to achieve dramatic improvements in energy performance. They are paving the path to zero for many others to follow.

Introduction

Zero net energy (ZNE) buildings, those that consume no more energy over the course of a year than they generate with onsite renewable sources, are a growing trend in the commercial building industry. The goal of zero energy buildings provides an aspirational and clear focus for owners and design teams and underscores the importance of ongoing attention to operations and occupancy — energy end uses that are currently not regulated in energy codes yet are critical to low energy performance.

Documented cases of achieving ZNE are increasing, and more projects are in the pipeline at the planning, construction or early operations phases. In the two years since New Buildings Institute published its *Getting to Zero 2012 Status Update: A First Look at the Costs and Features of Zero Energy Commercial Buildings* the number of ZNE buildings has increased by 52%, and projects on the path to zero have increased by 182%.

Low energy buildings are the foundation for those taking the path to ZNE. They set the stage for the most practical level of renewable energy technologies to be applied at the building or site.

Low energy buildings are the foundation for those taking the path to ZNE and set the stage for the most practical level of renewable energy technologies to be applied at the building or site. The *2014 Getting to Zero Status Update* highlights the growing trends of ZNE buildings and districts. The report also includes valuable, whole-building measured energy performance data for both ZNE and ultra-low energy (defined below) buildings. All of the highlighted projects are pursuing an aggressive goal with a wide range of variables that can make getting to zero elusive despite best practices. Some projects will not achieve this goal in the first year and may be fine-tuning operations or adding photovoltaics for success in subsequent years. Regardless of whether a project ultimately achieves zero net energy or simply comes close, all these examples have something to teach commercial building professionals, owners and policy makers about our capability of creating a built environment with extremely low energy needs and low carbon outputs.

Terminology: How You Define ZNE Matters

There are multiple zero-energy-related definitions scattered throughout the energy industry, nonprofit organizations and in the design, construction and ownership communities. NBI recognizes the benefit of consistent terms but also the reality of preferences and need for diversity to address varying scenarios and entities. The topic of terms and definitions is evolving at the national, regional and state levels. Those selected by NBI for use in this study are explained below.

Zero Net Energy Buildings are buildings with greatly reduced energy loads such that, averaged over a year, 100% of the building's energy use can be met with onsite renewable energy technologies. In this study ZNE is comprised of ZNE verified buildings, ZNE Emerging buildings and ZNE Districts as defined below.

ZNE Verified buildings (or districts) have been documented to have met, over the course of a year, all net energy use through onsite renewables. The energy use of all fuels (electric, natural gas, steam, etc.) is counted and offset by production from onsite renewables.

Courtesy: Walgreens

Walgreens ZNE Store, Evanston, Illinois

ZNE Emerging buildings (or districts) have a publically stated goal of ZNE but do not yet meet the definition of ZNE verified. These may be in the planning or design phase, under construction or have been in operation for less than a year. Others may have been operating for 12 months or longer, but their measured energy has either yet to achieve net zero or the measured data to document ZNE verified status was not available for this study.

ZNE Districts are groups of buildings such as a city district, community or campus with a stated goal of ZNE. They might be verified or emerging according to the definitions above and are counted as a single project for purposes of this study. The quantity of buildings in the districts was not known for this report.

Ultra-low Energy Buildings in this report are all "verified" in that they have shared, with NBI or publically, 12 or more months of measured energy use data that documents energy performance dramatically better than the industry average. This serves to increase the data set of measured performance. Ultra-low energy buildings are comparable to ZNE buildings based on type, energy use, design strategies and technologies but do not have a stated goal of ZNE and do not meet all their energy needs with onsite renewables, although they may have renewable resources onsite. In some cases they have provided the structure and wiring that will easily incorporate photovoltaics at a later date.

Energy Use Intensity (EUI) is a metric of total building energy use commonly used in benchmarking. EUI is the sum of all fuels used in the building per year divided by the building's floor space and is expressed in thousands (kilos) of British Thermal Units (BTUs) per square foot (sf) of occupied space per year (i.e. 25 kBtu/sf/yr). This study relies solely on site EUI, as opposed to source EUI that includes energy from transmission and production. National average EUIs for commercial building energy use are from CBECS[5].

Verified How?

NBI accepted three methods for verification. The first method applied to the majority of buildings, with NBI staff reviewing monthly measured energy consumption data for all fuels and the renewable energy production data as provided by the ownership/design team. The second approach was representation by a third-party entity of the measured data via an evaluation report, published article, presentation, or citation in an award or other public forum. The third verification method accepted in this research was through the International Living Future Institute (ILFI) as part of the Living Building Challenge or Net Zero Energy Building Certification. The ILFI definition requires 100% of the project's site energy to be carbon neutral (zero direct use of gas and other fossil-based fuels at the site) and supplied by renewable energy on a net annual basis.

NBI's ZNE verification for this study does not restrict gas or other fuels but required that all fuels be accounted for in the whole building energy total EUI. Documented onsite renewable production must then equal or exceed the energy use of all fuels over the course of a year. Verification of the actual energy performance of buildings has long been part of NBI's work to research and recognize best practices and leaders and to increase measured performance feedback that can improve the next generation of buildings. NBI's ZNE and ultra-low energy building registry is publicly available for owners and design firms to submit buildings for ongoing studies and verification.

To submit a high performance building project, visit: www.newbuildings.org/share

Additional discussion of the data sources, research and verification methods is in Appendix C.

5 The U.S. Energy Information Agency's 2003 Commercial Building Energy Use Survey (CBECs)

How Many Are There?

The ZNE Verified List

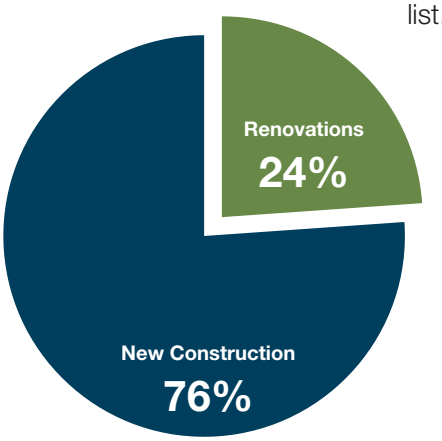
The ZNE target drives an interest in, and need to measure, actual performance. Actual energy results provide the proof of performance that can influence additional projects to be ZNE. There are 32 ZNE verified buildings and one ZNE verified community district[6] included in this research. Table 1 lists these 33 projects and provides general characteristics (location, size and type) as well as energy consumption and renewable energy production data. This set of ZNE verified buildings has a highly impressive average EUI of just 21 kBtu/sf/year — just one quarter of the national average for commercial buildings[7]. Overall EUIs for most of the verified buildings range from 3 to 33 kBtu/sf/year[8]. Further discussion is in the Measured Energy Performance section on page 19.

Net energy use is represented in the equation:

19	-	19	=	0
BUILDING'S TOTAL EUI		RENEWABLE PRODUCTION EUI		BUILDING'S NET EUI

The Energy Equation: *Renewable EUI is a representation of onsite energy production from renewables; Net EUI is the difference between the energy consumed and energy produced at the site. A zero net EUI means the building is producing the same energy as it consumes over a year, while a negative symbol indicates its use is less than its production (also called Net Positive).*

Figure 2: Percent of ZNE New Construction Projects and Existing Building Renovations



Notable are the number of renovation projects on the ZNE verified list. As shown in Figure 2, almost one quarter of the ZNE verified projects are renovations. Of these eight projects, six are small offices, one is a public assembly and one is a district with multiple buildings. This demonstrates the applicability of ZNE during a major renovation or building renewal.

6 Anna Maria Historic Green Village is made up of former single-family homes renovated to meet ZNE as small mixed-use commercial with retail. In this study districts are counted as a single project.
7 CBECS average for non-mall buildings is an EUI of 91 kBtu/sf/yr.
8 Of the three outliers, one had a low EUI of 0.1, and two were high at 48 and 92 kBtu/sf/yr.

Table 1: ZNE Verified Buildings

2014 List of Zero Net Energy Verified Buildings

Year Completed	Name	Location	State	Building Type	Size (sf)	Total Building Actual EUI	Site Renewable EUI	Net Building EUI
2000	Oberlin College Lewis Center	Oberlin	OH	Education- higher	13,600	32	36	-4
2001	Environmental Technology Center Sonoma State	Rohnert Park	CA	Education- higher	2,200	3	4	-1
2002	Challengers Tennis Club	Los Angeles	CA	Other	3,500	9	9	0
	Leslie Shao-Ming Sun Field Station	Woodside	CA	Education- higher	13,200	4	6	-2
2003	Audubon Center at Debs Park	E Los Angeles	CA	Other	5,020	17	17	0
	Science House	St. Paul	MN	Other	1,532	18	18	0
2005	Hawaii Gateway Energy Center	Kailua-Kona	HI	Other	5,600	28	31	-3
2007	Aldo Leopold Legacy Center	Baraboo	WI	Office	11,884	16	18	-2
	IDeAs Z2 Design Facility (1)	San Jose	CA	Office (R)	6,557	21	25	-4
2008	Camden Friends Meeting Social Hall	Camden	DE	Public Assembly	2,864	18	20	-2
	Environmental Nature Center	Newport Beach	CA	Other	8,535	18	28	-10
	Hudson Valley Clean Energy Headquarters	Rhinebeck	NY	Other	5,470	13	13	0
2009	Bacon Street Offices	San Diego	CA	Office (R)	4,500	13	22	-9
	Chrisney Library	Chrisney	IN	Library	2,400	15	18	-3
	Living Learning Center at Tyson Research Center (1)	Eureka	MO	Education- higher	2,968	24	24	0
	Omega Center for Sustainable Living (1)	Rhinebeck	NY	Other	6,200	13	21	-8
	Pringle Creek Painter's Hall (1)	Salem	OR	Public Assembly (R)	3,600	21	21	0
	Putney Field House	Putney	VT	Education- K-12	16,800	10	10	0

(R) - Indicates a building renovation project.
UA - Building EUI and Renewable EUI information is unavailable, but the overall net was verified.
(1) - Building is ZNE certified by the International Living Future Institute

Year Completed	Name	Location	State	Building Type	Size (sf)	Total Building Actual EUI	Site Renewable EUI	Net Building EUI
2010	Bertschi School Science Wing (1)	Seattle	WA	Education- K-12	1,425	48	48	0
	Dovetail Construction Headquarters Barn	Richmond	VA	Office (R)	6,800	UA	UA	0
	DPR Construction San Diego Net Zero Office	San Diego	CA	Office (R)	24,000	15	17	-2
	Energy Lab at Hawaii Preparatory Academy (1)	Kamuela	HI	Education- K-12	5,902	11	11	0
	Hood River Middle School Net-Zero Addition	Hood River	OR	Education- K-12	5,331	27	27	0
	NREL Research Support Facility	Golden	CO	Office	222,000	33	33	0
	Richardsville Elementary School	Bowling Green	KY	Education- K-12	72,285	18	18	0
2011	Anna Maria Historic Green Village	Anna Maria	FL	District (R)	District	28	35	-7
	Locust Trace AgriScience High School Campus	Lexington	KY	Education- K-12	70,000	10	11	-1
	TD Bank Branch - Ft Lauderdale	Fort Lauderdale	FL	Other	3,970	92	96	-4
	Vacaville Transportation Center	Vacaville	CA	Other	261,360	0.1	0.2	-0.1
	ZHome - Issaquah (1)	Issaquah	WA	Multifamily	5,813	21	22	-1
2012	David and Lucile Packard Foundation	Los Altos	CA	Office	49,161	24	28	-4
	DPR Construction Phoenix Regional Office (1)	Phoenix	AZ	Office (R)	16,533	27	30	-3
	Leon County Cooperative Extension	Tallahassee	FL	Office (R)	13,000	19	19	0

(R) - Indicates a building renovation project.
UA - Building EUI and Renewable EUI information is unavailable, but the overall net was verified.
(1) - Building is ZNE certified by the International Living Future Institute

ZNE Buildings: Verified and Emerging

ZNE buildings include the ZNE verified list in Table 2 above as well as ZNE Emerging buildings (or Districts) listed in Appendix A. ZNE emerging buildings or districts have a publically stated goal of ZNE but do not yet meet the definition of ZNE verified. These may be in the planning or design phase, under construction or have been in operation for less than a year. Others may have been operating for 12 months or longer, but their measured energy has either yet to achieve net zero or the measured data to document ZNE verified status was not available for this study.

The status of ZNE buildings show clear growth in every category previously reviewed for the *Getting to Zero 2012 Status Update.* In this *2014 Getting to Zero Status Update,* NBI found a total of 160 ZNE buildings and districts compared to 60 in the 2012 report. The ZNE totals for 2014 include 32 buildings and one district that have verified energy performance and 110 buildings and 17 districts that are emerging projects. The 2014 ZNE Emerging list shows the greatest increase — a 182% increase from the 39 buildings identified in 2012. These totals are summarized in Table 2.

Table 2: ZNE Totals from 2012 to 2014 Study

Year	ZNE Verified		ZNE Emerging		Total ZNE Projects
	Buildings	Districts	Buildings	Districts	
2012	21		39		60
2014	32	1	110	17	160

RENOVATION SNAPSHOT

DPR San Diego Office

Courtesy: Dave Hewitt

Courtesy: Anne Garrison

Building Size: 33,400 SF
DPR Office Size: 24,000 SF
Location: San Diego, California
Construction Type: Renovation
Construction Year: 1984, 2010
Building Type: Small Office
CA Climate Zone: 7

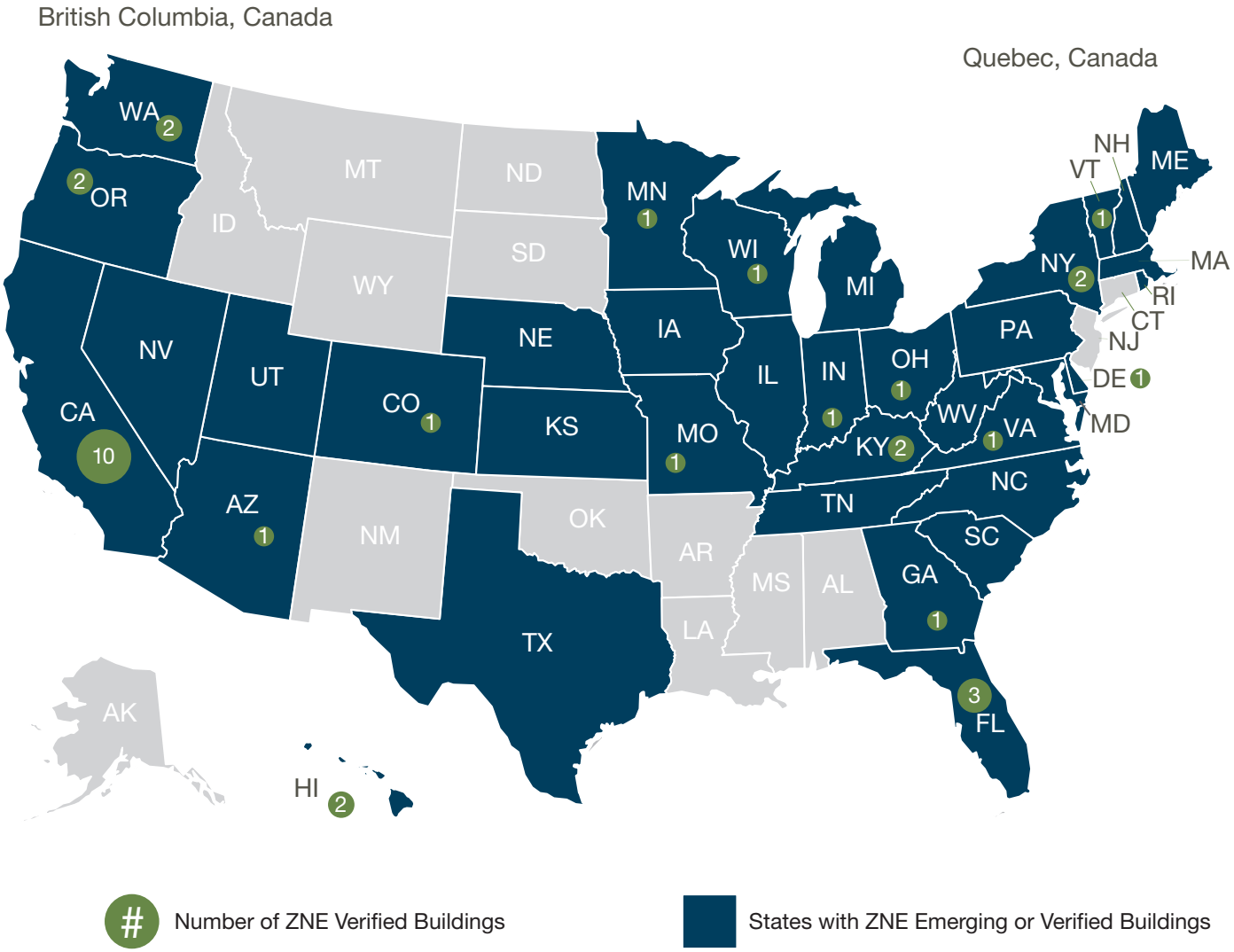
DPR rehabbed a near-obsolete, 1984 building into a vibrant, zero-net-energy multi-tenant office. DPR's new 24,000 SF, LEED® Platinum tenant improvement includes an open office space along with 11 conference rooms, a large gathering area and a space dedicated to building information modeling technology. The building takes advantage of the mild climate, relying on cross and stack ventilation strategies that significantly reduce the amount of time the mechanical HVAC system is used.

Improving the penetration of natural light was a main focus of the tenant improvement project. Natural light now fills the space, unlike before the renovation when acoustic tiles and an eight-foot ceiling height minimized daylighting opportunities. Strategies include the addition of 36 Solatubes, operable roof monitors and skylights and glass garage-style doors Stripping the film from the existing windows also increased the amount of light. Energy is saved due to photosensors that automatically turn off electric lights when 30 footcandles are available from daylighting. Occupants can control their own task lights.

Locations. ZNE buildings and districts are located in 36 U.S. states and Canada. In Figure 3 the 36 states with ZNE buildings — either verified or emerging — have a dark solid color and reflect a wide variety of climate zones[9]. ZNE Verified buildings are located in 17 states and the quantity per state is shown in the circle. California is a leader with ten ZNE Verified buildings, and Florida has three.

Table 3 provides further details on the ZNE building and district count by locations. Although California is a major leader with 47 total ZNE projects, there is broad geographical diversity by region there are now ZNE buildings in all eight of the U.S. DOE major climate zones.

Figure 3: Locations of ZNE Buildings and Districts



9 The project locations cover all U.S. Department of Energy Climate Zones

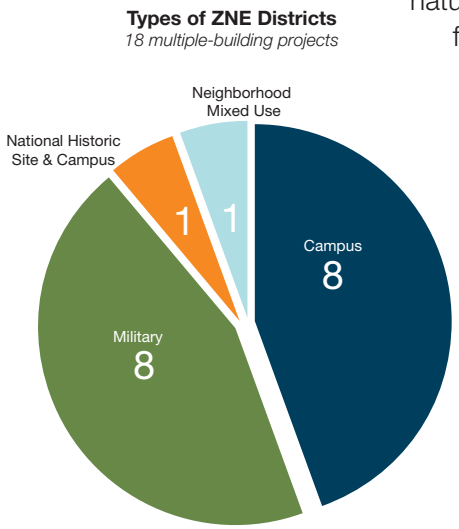
Table 3: Number of ZNE Buildings or Districts by State and in Canada

State	ZNE Verified	ZNE Emerging	Total ZNE Projects
AZ	1	5	6
CA	10	37	47
Canada		6	6
CO	1	6	7
DE	1		1
FL	3	5	8
GA		1	1
HI	2	2	4
IA		1	1
IN	1		1
IL		2	2
KS		1	1
KY	2	1	3
MA		6	6
MD		2	2
ME		2	2
MI		1	1
MN	1	1	2
MO	1		1
NC		5	5
NE		1	1
NH		1	1
NV		1	1
NY	2	6	8
OH	1	1	2
OR	2	8	10
PA		2	2
RI		1	1
SC		1	1
TN		2	2
TX		7	7
UT		2	2
VA	1	2	3
VT	1	1	2
WA	2	3	5
WI	1	3	4
WV		1	1
36 states	**33**	**127**	**160**

Districts. In the *Getting to Zero 2012 Status Update* lessons from single buildings were described as a pathway to achieving zero-energy goals on a district or regional basis. Today that is happening as adoption of ZNE targets across a set of multiple buildings is a growing trend.

One ZNE district on the verified list — the Anna Maria Historic Green Village in Florida — has documented ZNE performance for their set of renovated buildings but is also targeting ZNE in small-scale mixed-use commercial and retail. There are 17 additional district-scale projects on the ZNE Emerging list (Appendix A) that have commitments across multiple buildings to get to zero net energy performance. Figure 4 shows that many of these are military properties resulting from the U.S. Army ZNE Pilot Initiative at eight sites across the United States. Universities and community colleges are also setting goals to get their campus buildings to net zero including eight district-scale projects on the list. The synergies of bundling sets of buildings is a natural and efficient strategy to leverage economies of scale from design, financial, district heating/cooling and energy production systems.

Figure 4: Count of District ZNE Projects by Type



For districts there is a need to look beyond the definition of renewable energy produced only at the specific building. District-scale systems can be less expensive to construct and may offer benefits in terms of maintenance and reliability. For existing buildings in urban settings, onsite solar may be difficult or impossible due to space limitations, shading from neighboring structures and/or the need to serve large, multi-story buildings with limited roof area. The unique requirements and barriers of district-scale systems require more investigation, but they should be included as an option to meet ZNE goals.

In addition to the ZNE districts identified above, there are five current 2030 Districts[10]. In Pittsburgh, Seattle, Cleveland, Boston and Denver groups of building owners have joined forces

10 2030 Challenge

DISTRICT SNAPSHOT

Anna Maria Historic Green Village

Courtesy: Raymond Kaiser

Number of Buildings: 4 historic
Total Building Size: 8,000 SF
Location: Anna Maria Island, Florida
Construction Type: renovation
Construction Year: 1911/1915, 2012
Building Type: Multi-use District
Climate Zone: 2A

The Anna Maria Historic Green Village is an unusual combination of historic preservation and modern technology. Owners, Mike and Lizzie Thrasher have worked diligently to preserve four 100-year old buildings and merge history with state of the art green technology all while bringing jobs and economic development to local residents. The aim of the Historic Green Village is to prove the viability of advanced technologies and to serve as an inspiration for all those to follow. The net zero aspects of the project are guided by three key components: (1) insulation, (2) geothermal and (3) renewable energy.

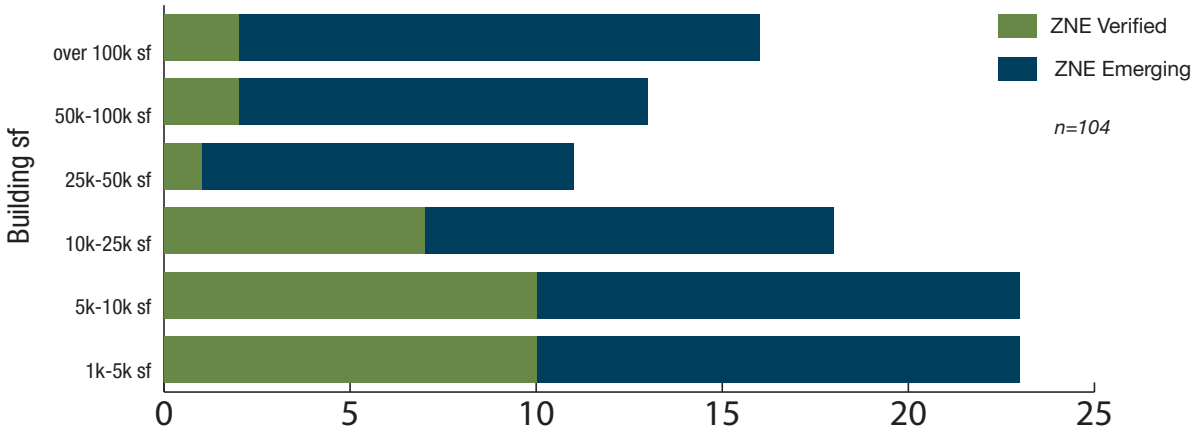
Insulation is one of the key aspects of Anna Maria Historic Green Village. Every structure is insulated above code levels and has high performance windows. One small 1,000 SF building is so super-insulated that its total electric bill never exceeds $20/month. A geothermal system uses the constant 72 degree aquifer on the barrier island to reject heat from air conditioning which is more efficient than transferring heat into humid air. The Historic Green Village also includes 17 solar inverters on arrays totaling over 90 kW for an annual savings of $11,200/year.

to designate urban areas committed to meeting significant energy, water and transportation emissions reduction targets. These districts have made commitments to the ultra-low energy outcomes shown in this report and together represent over 100 million sf of commercial space. This private-sector leadership and shared resources is a gateway for market transformation and the potential for getting to ZNE.

Size. Large ZNE buildings (those 50,000 sf or larger) are increasing. In 2012 only a dozen large buildings were ZNE; now there are 29, 16 of which are over 100,000 sf[11]. Of the 142 ZNE buildings in this study[12] NBI was able to obtain accurate floor area for 104. The sizes of these 104 are shown in Figure 5, with large buildings making up 28% of this dataset. Buildings under 25,000 sf remain the highest proportion with 62% of the total.

11 Two of the buildings over 100,000 sf are warehouses.
12 Districts are not included in the Buildings By Size Figure.

Figure 5: ZNE Buildings by Size

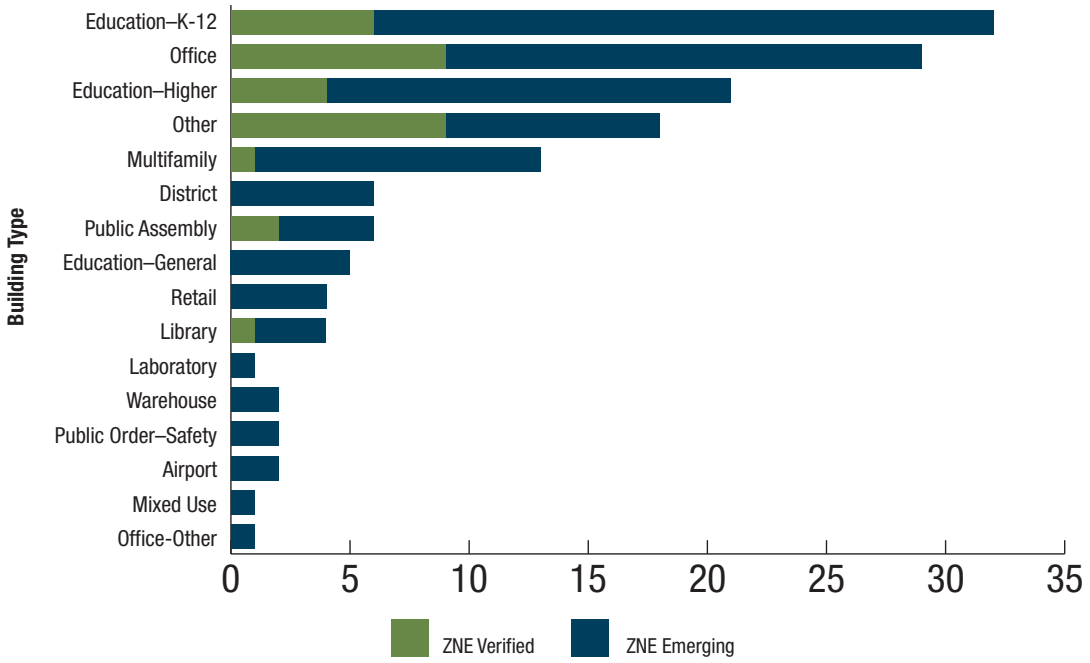


Use Types. The variety of ZNE building use types has more than doubled since the 2012 report with 16 different ZNE building types shown in Figure 6. Education buildings make up the largest portion — 36% — of the ZNE buildings and districts. Of the 58 education buildings, 32 are kindergarten through 12th grade, 21 are higher education and five are general education. Office buildings also comprise a large segment (19%) of the ZNE data set. Of the 30 ZNE office buildings, nine are verified and 21 are emerging.

Low-rise multifamily projects have begun to pursue ZNE. There are 12 multifamily projects that are ZNE emerging and one that has been verified. Within the ZNE Emerging districts two additional projects indicated that they include multifamily[13]. In addition, there are some multifamily projects taking a step toward ZNE by adopting zero net electric.[14] While these projects do not meet NBI's ZNE definition for this study, which includes all fuels to be zero net energy, they can provide some possible lessons and insights for full ZNE through their efforts.

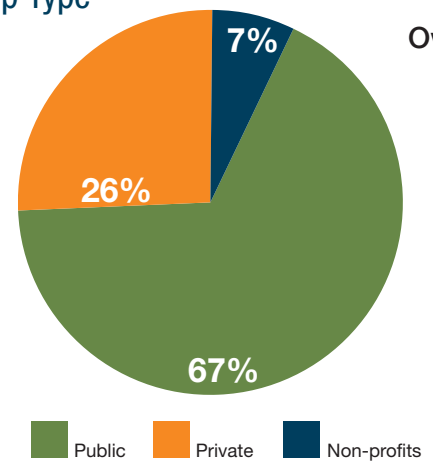
13 It is not known, through this study, if the Military ZNE Districts include housing.
14 Colorado Court, Solara and Los Vecinos — all affordable housing projects in California — are examples of zero net electric projects.. NBI tracks these as ultra-low energy but this study lists only those that have verified energy data.

Figure 6: ZNE Buildings by Type



Education. The impact of schools and universities as early leaders in ZNE has influence on the entire marketplace and an especially powerful effect on the next generation of citizens and leaders. Education buildings offer highly visible projects that are seen by a wide range of community members. Success stories of public funds that return lower operating costs and healthier student environments provide documentation that can be leveraged by others. At over 10 billion square feet, education buildings are the fourth largest use of building floor space in the U.S. This sector offers national and regional education forums and associations that can facilitate the transfer of best design and operational practices.

Figure 7: Ownership Type of ZNE Buildings



Ownership. A rise in private development of ZNE buildings is a trend that shows that some market entities have determined a there is a business rationale to moving their real estate assets to zero energy. Of the 160 ZNE buildings and districts, over 25% are privately owned and developed, as shown in Figure 7.

Measured Energy Performance

In this section the measured performance of ZNE verified, emerging and of ultra-low energy buildings is looked at compared to like-type buildings. All ZNE verified projects have measured performance data, while only some of the ZNE emerging projects do — for example, those that have been in operation, but perhaps have not hit the ZNE target yet. The ultra-low energy buildings are also added to this data set. Ultra-low energy buildings provide the same sets of lessons on performance outcomes, increase the number of projects with measured performance in the data set, and warrant recognition for their accomplishments. Appendix B provides a complete list of the ultra-low energy buildings, their characteristics and measured performance energy use.

From 2012 to 2014, the increase in the number of overall projects identified in these studies that are targeting and achieving ZNE and comparable ultra-low energy buildings has more than doubled from 99 in 2012 to 213 in this current study as indicated in Table 4.

Table 4: ZNE and Ultra-low Energy Projects from 2012 to 2014 Study

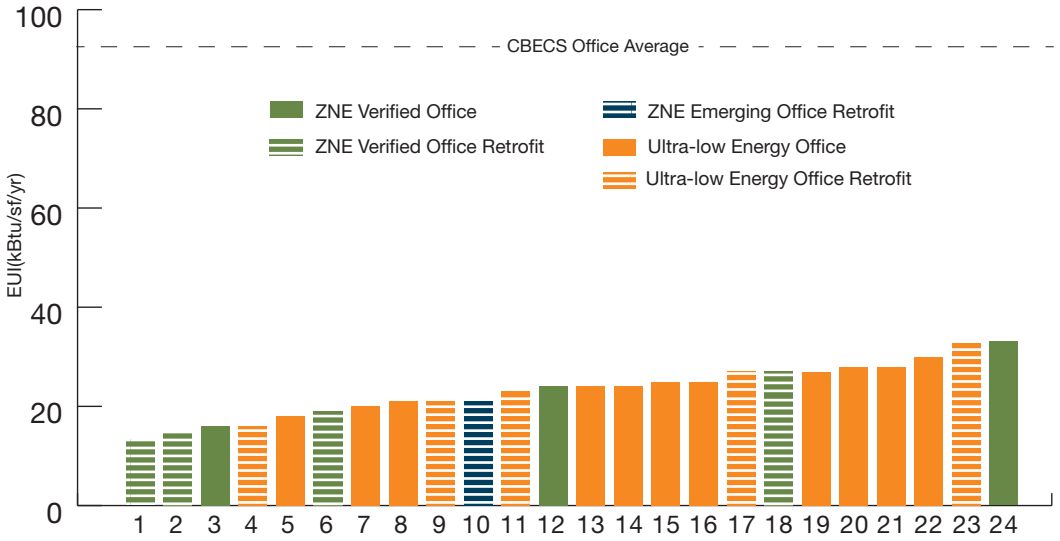
Year	ZNE Verified Buildings & Districts	ZNE Emerging Buildings & Districts	Ultra-low Energy Buildings	Totals
2012	21	39	39	99
2014	33	127	53	213

Offices. Using measured performance data from the ZNE and ultra-low energy lists, one begins to get an understanding of what performance targets are achievable today. Figure 8 shows the EUI of the 25 new construction and office renovation projects. The 'Average Building' number (noted by a dotted horizontal line) is taken from CBECS (the source most often used to represent typical building energy use) and is 93 kBtu/sf/yr for office buildings[15].

The range of EUI for any office with measured performance in this building dataset is from 13 to 33 kBtu/sf/yr. The average EUI for all of the ZNE verified office projects is only 19 kBtu/sf/yr — over 75% below the national average. Even the average ultra-low energy office is a mere 24 kBtu/sf/year, still well below the national average.

15 A code building would represent an even more comparative metric but requires that buildings be grouped by the code applicable to their project at the time of construction — a level of analysis and information not available within this study.

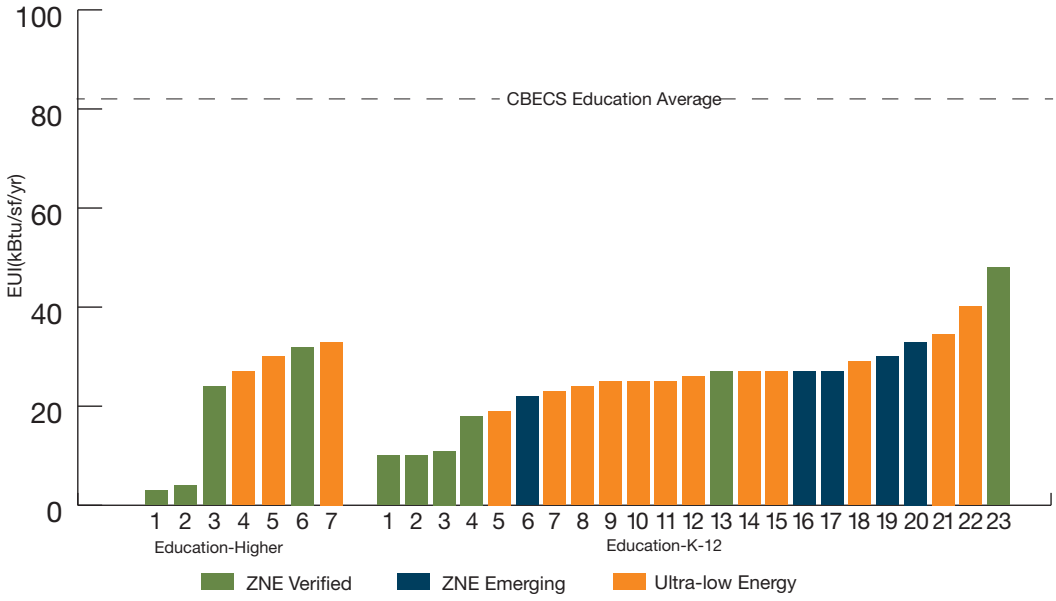
Figure 8: Measured EUI of ZNE and Ultra-low Energy Office Buildings



Education. Figure 9 shows EUIs for educational building projects split between K-12 and higher education. Again, the CBECS values of 83 kBtu/sf/yr for education buildings is represented by a dotted horizontal line. All but one of the education buildings are operating at less than half the national average.

ZNE verified education buildings have a larger EUI range (from 3-48 kBtu/sf/yr). This represents a diversity of uses within the education sector ranging from buildings that may not be continuously occupied to those that focus on higher energy uses, such as science facilities. Despite this range, the average ZNE K-12 education building has a EUI of just 22 kBtu/sf/yr. Ultra-low energy buildings EUIs range from 19 to 40 with an average EUI of only 27.

Figure 9: Measured EUI of ZNE and Ultra-low Energy Educational Buildings



Technologies and Strategies

All of the projects highlighted in this study use design approaches and state-of-the-shelf technology already proven and readily incorporated into most high performance buildings. Most of these buildings also include passive design features that have been used for centuries: higher window head heights to allow daylight deeper into the building, the use of daylight as the primary light source, orientation to solar and shading to control heat and light, natural ventilation and operable windows, passive and evaporative cooling, and individual control.

Resulting low energy outcomes are highly dependent on two factors that go beyond the scope of codes, design and construction — operations and occupancy. In most of these buildings the occupants are engaged in the green objectives of both the space and building, plug load strategies are incorporated, and operators are continually maintaining and modifying systems to ensure optimum performance.

Several efforts used in these high performance buildings should be adopted more broadly, including design team involvement during the initial year of operations, ZNE-specific commissioning and the actual implementation of a measurement and verification plan. Operations team and occupant training and engagement are also key. Project teams noted that it takes all of these strategies during the occupancy phase to get to ZNE.

This section gives an overview of the methods most commonly used in three categories: 1) Design Approach, 2) Technologies, and 3) Operations and Occupancy. It's important to note that these trends are based on published

TECHNOLOGY SNAPSHOT

Putney Field House

Building Size: 16,800 SF
Location: Putney, Vermont
Construction Type: New Construction
Construction Year: 2009
Building Type: K-12 Education
Climate Zone: 7A

The Putney Field house is located on a 461-acre parcel with areas designated to forestry, education and agriculture. The state-of-the art field house and wellness center was built to provide winter recreational opportunities to residents of the boarding school and includes a multi-purpose gym, offices, social gathering area, weight room, ski waxing room and yoga/flex space. When designing a new space, the school's strategic plan dictated that the construction conform to the highest environmental standards, namely LEED® Platinum and Zero Net Energy.

The building is elongated east-west to promote daylighting and passive solar. The Building uses R-20 for under-slab insulation, R-45 in the walls and R-60 in the roof. Triple paned windows have a U-value of 0.19. The steel frame is insulated under the concrete footings to decrease heat loss through conduction. In addition to providing for high quality daylight in the various spaces, building openings are designed for passive night flushing and stack ventilation to cool the building. Four energy efficient air-to-air heat pumps with energy recovery ventilation keep the building warm in winter and cool in summer.

and/or provided representations as well as outreach and communication with design teams or owners. Also, this study did not include details on types of renewable equipment, renewable metering and building integration components. Deeper research to investigate the frequency of the solutions, selection process and measured outcomes at the system level would be a valuable next step to provide key lessons, validation and ongoing education.

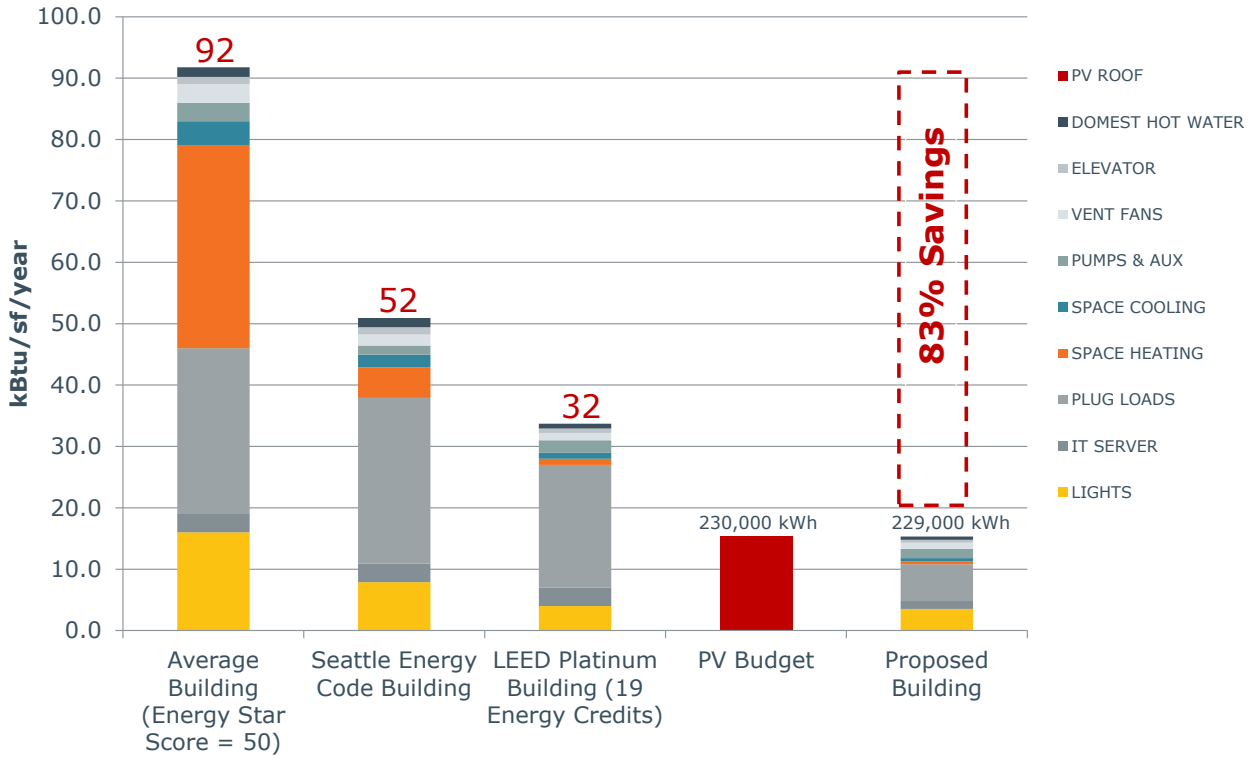
Design Approach and Strategies

Many of these ZNE and ultra-low energy projects shared a critical design approach: the inclusion of an explicit energy performance target in the design program as an outcome requirement. This performance energy specification was included in all design documentation and carried through to terms with subcontractors.

Beginning with the end in mind, teams often set a "solar budget" that calculates the renewable energy production opportunity at the site. This provided a guideline for the energy use targets and helped to drive decision-making during the design, construction and operations phases. The energy target is broken into energy end-use budgets for areas of equipment and is

Figure 10: Net Zero Energy in Seattle: Energy Use & Solar Budget

courtesy of PAE Consulting Engineers



In some cases the owner began with an interest in a high performance or high profile building … In other cases, leading design firms were the gateway to the ZNE concept for owners and served as the catalyst for these exceptional projects.

critical to understanding how energy will be used in the building, including by occupants and their plugged-in devices. Figure 10 illustrates how the energy use at the Bullitt Center in Seattle was reduced to meet the project's photovoltaic (PV) budget.

The Bullitt Center, a six-story 52,000 sf office building, designed a roof that slightly extended over the exterior walls of the building and calculated that the selected solar panel system could then meet their energy use in an average year. For a ZNE building the solar budget becomes the cap for the building and its occupant's energy use.

These solar and energy budgets are introduced as early as the initial design charrettes. Design teams get the various parties involved in design, construction, commissioning, operations and ownership and/or occupancy in the early phases resulting in an "integrated design approach." Integrated design was frequently credited with maintaining low energy features and specifications by the studied projects compared to the traditional approach of value-engineering — a practice that modifies design features deemed too expensive but which can compromise the efficiency of the entire building.

Having a strong advocate providing the vision, business rationale and leadership on energy performance goals resulted in project buy-in and inspired others. In some cases the owner began with an interest in a high performance or high profile building and selected a design firm that brought the relevant expertise and a portfolio of experience. In other cases, leading design firms were the gateway to the ZNE concept for owners and served as the catalyst for these exceptional projects. In all cases, it is the influence of individuals that helped realize the outcomes presented in this study.

TECHNOLOGY SNAPSHOT

David and Lucile Packard Foundation

Courtesy: Jeremy Bitterman

Building Size: 49,161 SF
Location: Los Altos, California
Construction Type: New
Construction Year: 2012
Building Type: Office
CA Climate Zone: 4

The overarching goals for the David and Lucile Packard Foundation office were to provide a range of public and private work spaces that encourage collaboration and are outfitted for virtual work opportunities, have a transparent presence that interfaces well with the local community, and create a project to target zero net energy use and LEED ® Platinum certification. The new building features two long, two-story wings connected by enclosed walkways and organized around a landscaped courtyard. The program includes private offices, open work areas, communal spaces and conference rooms for approximately 120 employees.

A cooling tower provides chilled water to a 50,000 gallon storage tank that is passively cooled during nighttime hours. The water is circulated throughout the building to chilled beam exchangers. These chilled beams cool the localized air, allowing it to sink into the space and displace warm air. Outside ventilation air is provided by a secondary dedicated outdoor air system (DOAS). Building occupants are notified by an icon that appears on their computers when it is appropriate to open operable windows.

As for the design itself, project teams relied on tried-and-true high performance strategies. Teams referenced orientating the building for solar access and control of heat and glare based on the site whenever possible. The need for light coupled with the avoidance of unwanted solar gain and glare was resolved with attention to window-to-wall ratios, varying window size and shape on different sides of the building, and incorporating highly efficient glazing and exterior shading devices to cut off peak-day sun angles.

For building configuration and space planning the design team added energy optimization to the list of usual drivers of space needs, use, site constraints and budget. Some projects were able to design for a narrower footprint and/or single story that optimized daylight and toplight access and reduced electrical lighting demand to the majority of the space. The configuration and the envelope are also highly influential on heating and cooling demands. These projects cited high levels of insulation, the use of green or cool roofs, and increased thermal envelope efficiencies as foundational practices to reduce overall energy use.

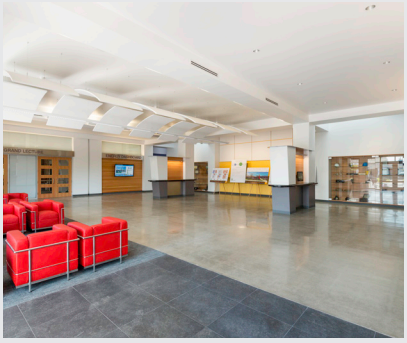
The interior design of many of the buildings also played a part in the low energy outcomes, with daylight as a primary consideration. Light shelves extend the penetration of light deeper into the space, allowing more electric lighting to be turned off. Light-colored interior paint and fabrics increase the efficacy of natural light, and low or no partitions create an open work area that allows daylight and ventilation to flow more effectively. Another emerging design factor that combines architecture and interior design is making stairways an attractive and highly accessible part of mobility in the building. This reduces transport energy used by elevators or escalators as well as exemplifying the message of health that is inherent in green buildings.

Summary of the design process approach and strategies:

- ❑ Energy performance target set at the start
- ❑ Integrated design approach
- ❑ Champion(s) and experienced team to provide vision and leadership
- ❑ Site orientation, building configuration and space planning optimized for daylight access
- ❑ Improved envelope performance
- ❑ Window glazing type, ratio to walls, size and orientation optimized
- ❑ Exterior window shading used to reduce peak day sun
- ❑ Interior design incorporated light shelves, light colors and low partitions
- ❑ Stairways made to attract and facilitate movement within the building, reduce transport energy

TECHNOLOGY SNAPSHOT

IBEW Local 595 ZNE Training Center



Courtesy: Chad Ziemendorf

Building Size: 46,000 SF
Location: San Leandro, California
Construction Type: Retrofit
Construction Year: 2013
Building Type: Education- general
CA Climate Zone: 3

When it came time to upgrade their training facility, the IBEW Local 595 and NECA chapters targeted net zero energy. They wanted to demonstrate that this goal was achievable and train their electrical contractors on the latest, cutting-edge energy efficiency strategies and renewable energy sources. If California hopes to achieve its goals of all new residential construction being ZNE by 2020 and new commercial ZNE by 2030, it is critical that there be a workforce in place that has the skills to install, operate and maintain the lighting and building automation systems as well as the renewable systems used throughout the project. The building features both flat and tilted roof-mounted photovoltaic panels, a dual-axis solar tree which tracks the sun for maximum generation, and three 12 kW wind turbines.

In order to achieve the ZNE goal, the team started early and worked iteratively ensuring that the building systems, design and occupants were being considered simultaneously. The design team started with a list of over 60 different ideas that were eventually whittled down to the handful that were implemented in the building. The building primarily relies on a passive heating and ventilation system aided by roof monitors that also promote a high quality daylighting design. Mechanical heating and cooling is provided by four Variable Refrigerant Flow (VRF) units which circulate refrigerant to remove and redistribute warm air within the building. This configuration allows for a high level of zonal control (only conditions spaces that are occupied rather than the whole building) and can efficiently provide simultaneous heating and cooling when needed.

Technologies

Passive systems, high performance building envelopes and the evolution of technologies for monitoring and controlling energy systems are key developments toward extremely low energy buildings. These ZNE buildings take advantage of free resources from the sun and wind to light buildings without electricity, as well as provide heating, cooling and ventilation, thus reducing the load on mechanical systems.

Advanced lighting controls that reduce or eliminate electric lighting in response to natural light or occupancy variations is a frequent technology in these projects. Lighting and daylight controls are now code in many jurisdictions, but the ZNE buildings go beyond code to integrate layers of lighting technologies that provide task, ambient and common-area light that responds to occupant needs with efficient lamps, ballasts, responsive controls and effective design. Addressable ballasts provide the ability to create and easily modify lighting zones down to the level of individual fixtures. These advanced luminaire-level controls have an added functionality of providing energy monitoring and ability for demand response.

The technology area moving furthest “outside the box” is heating, ventilation and air-conditioning (HVAC). The two most common HVAC systems in

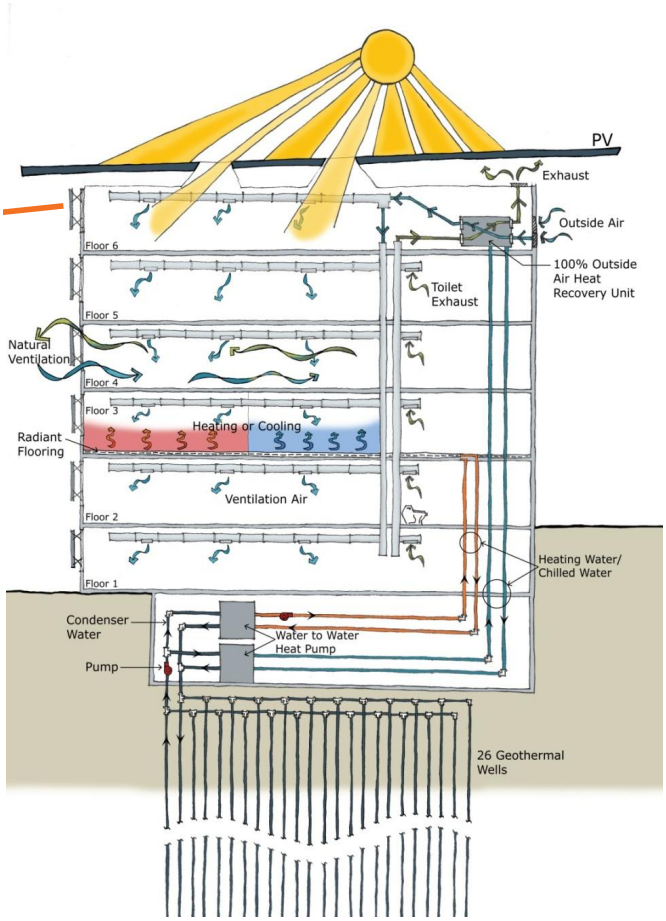
Getting to zero is not possible without addressing plug loads, which fall outside of code and the typical design process purview.

standard commercial building — rooftop package units and variable air volume systems — take a backseat in this building set to systems that are more advanced, efficient and represented to be more thermally comfortable.

A major HVAC trend in these buildings is decoupling ventilation air from space conditioning for optimal efficiency. This trend away from forced-air systems significantly reduces energy loss from ducts and fan power. One approach common among these projects is to separate supply ventilation air into dedicated outside air supply (DOAS) units. This allows an efficiency design focused to meet load and occupant thermal comfort needs while isolating code requirements for outside air in a unit that provides only ventilation air as efficiently as possible. Ground-source heat pumps are widely used in these projects along with radiant heating and cooling, chilled beams and natural ventilation, meeting comfort with energy reductions on the order of 30-60% over standard HVAC.

Ongoing measurement and feedback is critical in these buildings. Controls and energy information systems that monitor building energy use and performance, diagnose problems, and provide detailed data and high-level dashboards for operators and occupants are standard in the majority of the buildings. Establishing the key performance indicators appropriate to the building size, systems and audience along with a routine of data review and action are what make this technology an important factor on the path to zero.

Renewable production was provided in all cases by PVs. In a handful of buildings, additional energy was produced by small onsite wind turbines. The cost of PVs has been descending rapidly this decade while the production efficiency has been increasing making the path to zero more attainable. Project budgets, however, were invested first in energy efficiency in order to reduce the expense and size requirements of renewables. For some of the ZNE emerging projects in this study, the purchase of sufficient PVs within the initial budget was not feasible. Most plan to add additional PVs in a future budget cycle to meet their ZNE goals.



The Bullitt Center in Seattle blends a number of systems to meet indoor comfort, ventilation requirements and energy optimization. These include operable windows, dedicated outside air with heat recover, night flush, ground source heat pump, and radiant floors.

Courtesy: PAE Consulting Engineers

Summary of Technologies:

- ❑ **High performance HVAC systems.** Ground-source heat pumps, radiant heating and cooling, chilled beams, energy recovery ventilation, natural ventilation, operable windows, night flush of the thermal mass, demand controlled ventilation (DCV) through CO_2 monitoring, variable volume refrigerant systems with dedicated outside-air systems for ventilation (DOAS), underfloor air distribution, ice storage, and evaporative cooling
- ❑ **Advanced Lighting and Controls.** Efficient design with low LPD (lighting power density), daylight photosensor controls, occupancy sensors, luminaire-level controls, layered design strategies with task, ambient and common areas, LED task lights, T5 fluorescent lamps, skylights, clerestories
- ❑ **Monitoring and Feedback.** Wiring for system-level monitoring, energy information and building automation systems, diagnostics, key performance indicator dashboards
- ❑ **Renewables.** Photovoltaics on the building or adjacent to the site, solar hot water, and some site wind turbines in use to supplement PVs

EDUCATION SNAPSHOT

Redding School of the Arts

Courtesy: Steve Whittaker

Building Size: 77,000 SF
Location: Redding, California
Construction Type: New
Construction Year: 2011
Building Type: Education
CA Climate Zone: 11

Redding School for the Arts in Northern California connects education and arts for K-8 students in a community of 90,000 people. The school was originally created in August 1999 in response to the rapid decline of arts programs in local schools. In 2011, the charter school opened a new facility with an ambitious goal of Zero Net Energy, while dedicating only 2% of the budget to renewable energy systems. In this project, these systems were characterized as photovoltaic solar panels, wind generation and included geothermal bore fields.

The two-story, 77,000 SF building includes classrooms, art rooms, music and dance spaces, a library and information center, a cooking classroom and a technology room.

Despite being in a climate with hot, dry summers and rainy, cool winters, more than half of the school's learning spaces are outdoors, protected by roof overhangs and operable garage-style doors. The design orients classrooms to the north to maximize daylighting with minimal heat and glare. Lighting controls reduce or eliminate electric lighting in response to daylighting to encourage natural light as the primary source of illumination in spaces and 'learning streets.' The school utilizes a geothermal HVAC system. Windows are sized and located to provide occupant control and cross airflow through classrooms.

Operations and Occupancy

In the hands of a growing stable of leading firms in low and zero energy buildings, the design and technology practices outlined above deliver buildings with great promise for high efficiency. From there, the path to ZNE becomes highly reliant on the operations and occupancy factors.

The projects go beyond current practices for ongoing building optimization and include occupant engagement as a key strategy toward the low energy targets. In many cases these projects shared the same issues that are prevalent in all new buildings or major renovations in regard to achieving predicted energy use — different than expected occupancy density and behavior, demand from plugged-in devices and hours of operations that vary from original estimates. These types of changes are a reality for building operators, and the approaches used by these buildings helped drive energy use down toward the targets, and in some cases below expectations. For example, one environmental learning center was designed to be net zero but did not achieve its target because the space was so popular among the students that the annual energy use was significantly higher than expected.

A new label for commissioning (Cx) was coined by a project lead in this study — ZNE Commissioning, or ZNE Cx. This term reflects that the commissioning for buildings with integrated renewables and advanced energy systems entails a deeper set of skills than standard Cx. Many owners and firms invested in, and cited key energy results from, extensive commissioning.

Some form of building monitoring system was common in almost all of the buildings. Real-time feedback on system performance was cited as foundational to both the operations needs and influencing occupants. The monitoring provided key performance indicators such as energy by hour or 15-minute increment, which readily identifies schedule-related control issues. Evening and night setbacks for lighting and HVAC have large impacts on energy use. Monitoring also typically diagnoses control and operation problems within the HVAC system, red-flagging areas for the operator's attention.

The largest new area of focus for building energy use is plug loads — the energy demanded by items plugged into outlets by occupants. For these types of buildings, since they are already addressing energy use in design and technologies, plug loads can account for as much as 50% of total building energy use. Getting to zero is not possible without addressing these loads, which fall outside of code and the typical design process purview.

Strategies used to manage plug loads included hardware such as advanced plug strips with occupant and schedule controls, controlled wall outlets, and procurement of best-in-class equipment and appliances. Software was used in some buildings through the Information Technology (IT) department to centrally ensure monitor and computer setbacks and off settings. Occupant engagement helped deliver savings through behavior changes in response to energy dashboards in central areas or directly on individual computers, green campaigns, end-of-day email prompts and notices to shut off equipment, as

well as utilization of green teams, competitions and procurement policies. A few projects cited requiring attention to energy use or green practices as a part of the lease agreement.

Summary of Operations and Occupancy Strategies:

- ❑ ZNE and continuous commissioning
- ❑ Energy monitoring system and dashboards
- ❑ Plug load assessment and purchasing of low plug load equipment
- ❑ Controlled Plug Load at the circuit, through IT department, and with power strips
- ❑ Occupant engagement and feedback
- ❑ Server Closet / Data Center efficiencies
- ❑ Top Ten[16] and Energy Star equipment/appliances
- ❑ Green leases

TECHNOLOGY SNAPSHOT

TD Bank

Turner Construction

TD bank

Building Size: 3,970 SF
Location: Ft Lauderdale, Florida
Construction Type: New Construction
Construction Year: 2011
Building Type: Retail Bank
Climate Zone: 1A

TD Bank has been an environmental leader since 1990. As one of the ten largest banks in the United States, they chose to move beyond LEED® certification to pilot a Zero Net Energy design for a retail bank branch in Fort Lauderdale, Florida. By enhancing the already high-performance building components standard in their portfolio, the design and construction team focused their attention on further reduction of energy loads and installation of renewable energy on the site. Their concerted and ongoing effort toward this net zero result helped TD Bank achieve their goal.

The process started with a green prototype to develop a cost effective base building. This standard design was adapted to the local community through a pre-defined kit of parts. More than 80% of the building components are the same as those in their typical branch design. Building commissioning uncovered a number of challenges with the systems and controls. It also revealed that plug loads represented 40% of total energy consumption and needed to be actively managed. For example, the standard 3 hot plate coffee maker was replaced with an insta-hot 'eco' version, saving 660 kWh/year (91% over standard practice).

16 Top Ten USA at http://www.toptenusa.org

Characterizing Costs

Determining the costs for creating a low or zero energy building is difficult calculus. Yet understanding incremental costs for achieving ZNE is vital and frequently identified in market surveys as one of the topics most important to address. This study's primary focus was on measured energy performance, building features and the status of ZNE and ultra-low energy buildings and policies. In the research for this information NBI requested cost information and documentation from design teams and owners and received a few quantitative sources along with anecdotal responses. In addition, a few recent studies have tackled this topic and their outcomes can be characterized to provide some analysis on the issue of costs.

Specific building case studies are the best resource for reviewing a comparable building design, technologies, climate and size, and some do include cost data. For example, the David and Lucile Packard Building, one of the most expensive ZNE buildings on a cost-per-square-foot basis, has an objective of transparency and shared learning. They have many resources on the development of their building and identify specific items such as their "replicable shell" with descriptions of what it would of cost for them to achieve ZNE without the expensive finishes they included in the project. NBI has sets of ZNE case studies online at www.newbuildings.org/zero-energy and additional sources of more detailed case studies are listed in Appendix C.

NBI Findings

Through this research NBI can characterize the following:

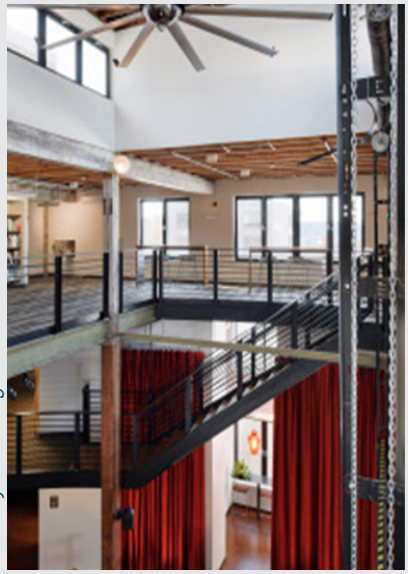
- Very few projects are able to disaggregate the cost of efficient design and technologies from the overall cost of a new building.
- The addition of renewable energy technologies, most commonly photovoltaics, is usually identified as a discrete equipment cost. However, the full cost of integrating the renewables with the building systems and metering may be embedded in other labor associated with electrical, wiring and installation.
- The cost to add renewable energy was identified as a barrier to getting to full ZNE at the time of construction. Several projects planned to incrementally increase PV over time to meet their goals.
- Improved energy efficiency in buildings beyond code is a widespread practice due to the last decade of green and utility efficiency programs. This complicates the ability to establish a benchmark to compare the cost of building to zero net energy construction.
- The caliber and experience of the firms that worked on these buildings applied their growing knowledge of low and zero energy design to identify cost reductions in some areas (eg. reduced HVAC sizing) that were used to manage the overall project cost.

Integral Group High Performance Buildings Cost Study

The cost information NBI did gather was shared with Integral Group for their more specific statistical analysis on high performance and ZNE buildings.

TECHNOLOGY SNAPSHOT

Rice Fergus Miller



Courtesy: Rice Fergus Miller

Building Size: 39,000 SF
Location: Bremerton, Washington
Construction Type: Major Renovation
Construction Year: 1948, 2011
Building Type: Office
Climate Zone: 4C

Rice Fergus Miller breathed new life into an abandoned 1948 Sears Automotive Center and positioned their new office solidly on the path to net zero. This urban infill transformation project took a dilapidated structure that had been abandoned for 23 years and turned it into a catalyst for the revitalization of downtown Bremerton. The goal of ultra-low energy started early in the design process when they established a target energy budget based on potential solar production at the site and started using energy modeling to evaluate options. They achieved their goal at only $109/SF.

The shell is super insulated is reported to exceed Passivhaus Space Heating and Cooling requirements by a factor of two. The efficient building also uses a hybrid natural and mechanical system while maintaining a high level of personal comfort. Passive systems are utilized first so that HVAC systems can be turned off when not needed - approximately 40% of the time. Passive systems, including operable windows and ceiling fans, take advantage of the mild, marine environment. High efficiency Variable Refrigerant Volume (VRF) heat pumps, located in 23 separate zones across the space, are the prime source of mechanical cooling.

The Integral Group study is due out in early 2014 and includes analysis of buildings that are green, LEED platinum and ZNE and includes the building types of community centers, K-12 schools, low-rise office buildings and wet labs. A few initial findings were presented by Integral in fall of 2013, including:

- The cost for going green or zero is not distinguishable within the overall budget.
- Costs overall are approaching conventional buildings. The study group of green, LEED platinum and ZNE buildings costs were in comparable ranges with a variety of control group buildings of like type.
- Those study buildings that were at the high end of costs were demonstrations, high profile buildings with mission work (eg. Packard Foundation), or included green or zero costs unique to their building type (eg. school kitchen equipment upgrades or swimming pool technologies).

California ZNE Cost Study

In 2012 Pacific Gas and Electric (PG&E) commissioned a report on behalf of the ZNE Energy Utility Programs in California. The report, *California Zero Net Energy Buildings Cost Study*[17], was prepared by Arup and Davis Energy

17 California Zero Net Energy Buildings Cost Study is available at http://www.energydataweb.com/cpucFiles/pdaDocs/904/California_ZNE_Technical_Feasibility_Report_Final.pdf

Group and found similar outcomes as the references above. Three of these from the Executive Summary of that report are:

- There is significant variability in the costs of both code compliant and high performance commercial buildings. ZNE commercial buildings put the focus on energy performance goals, while conventional buildings may focus on building amenities and treatments. Industry experts suggest that it is possible to construct ZNE commercial buildings at little or no incremental cost.
- Commercial buildings offer greater opportunities for realizing cost tradeoff benefits which can reallocate construction cost savings from HVAC downsizing to other areas, such as architectural/ envelope improvements, high efficiency lighting, and higher efficiency equipment. Maximizing performance synergies that reduce first costs and generate energy savings is a key part of the commercial building integrated design process.
- Incorporation of precise and well thought out building energy use targets in construction contracts is widely recognized as an effective mechanism in focusing the design team's effort on an appropriate design solution. The electrical subcontractor from NREL's ZNE Research Support Facility building suggested that following this approach resulted in a several percent cost savings in their overall bid.

Cost Summary:

- ❑ Costs for getting to zero are not distinct from overall project costs. Energy efficiency and renewable technologies do have specific costs, but the design and technology tradeoffs due to the advanced systems blur the line of incremental costs.
- ❑ Green, LEED and/or Zero net energy buildings can be achieved within the range of other like-type buildings. When total construction costs for these buildings are analyzed against control groups they are comparable to conventional building costs.
- ❑ Design firms and early targets reduce costs. The experience of the team and the explicit goal of ZNE throughout the process are cited as critical to minimizing costs.
- ❑ Cost is the wrong question. The value, outcome, operating savings and market position of ZNE buildings are all, like cost, difficult to quantify but clearly recognized by the leaders in ZNE design and ownership.

ZNE Policy Trends

Policies and programs can dramatically change the landscape for ZNE buildings. There is burgeoning market interest in ZNE, and policies and programs can foster and grow that interest through leadership, direct support, and the reduction of risks and uncertainties.

Survey of State and Local Energy Officials

As part of this study, NBI conducted an informal survey of approximately 300 state energy officials, practitioners and owners at the annual conference of the National Association of State Energy Officials (NASEO). In Figure 11 the responses on the current best markets for ZNE policies are well aligned with the trends shown in this study, perhaps due in part to the work of these individuals in their home states.

An interesting outcome of the survey was that environmental groups were seen as the most likely and influential advocates for ZNE buildings within their state policy structure. This is followed by the design community, which has been a growing active force in participating in the green and ZNE policies of some states, as shown in Figure 12. An important strategy for furthering the aspirations of ZNE will be to align with key environmental groups toward the mutual mission of an improved world through lower carbon use.

Figure 11: Best Current Market Types for ZNE Policy or Program Support

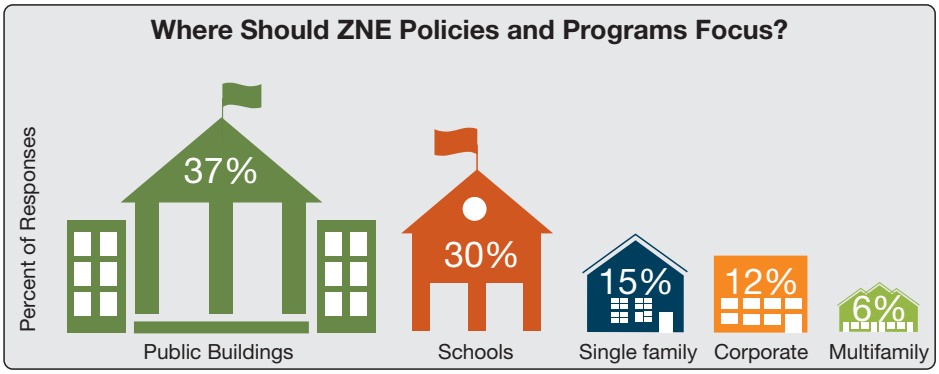
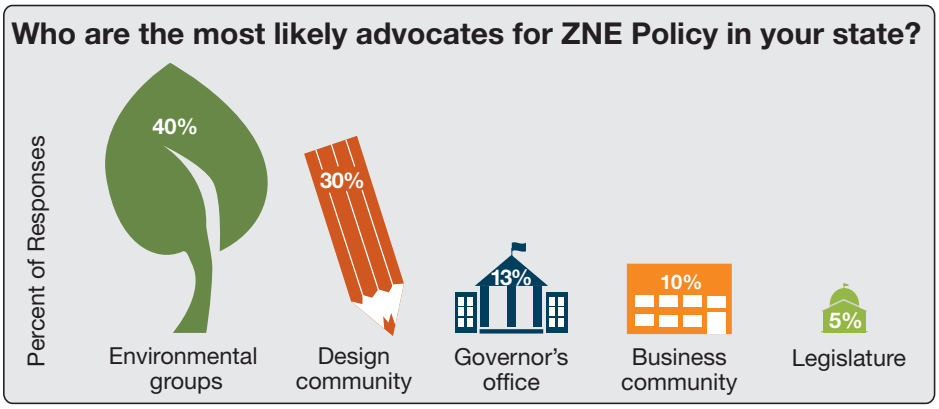


Figure 12: Most likely Advocates for ZNE Policy



Policy Pathways

The policy approaches below depict many of the best options for advancing ZNE buildings and districts. Each is briefly described, followed by examples of where the strategy is being piloted or has been put into practice. Links to more information can be found in Appendix D.

1. **Develop a building energy codes roadmap.** If ZNE buildings are to become commonplace or standard, they must be supported and/or required by building codes. While broadly requiring ZNE buildings seems far in the future, a codes roadmap that progressively updates codes incrementally over time is an important policy and a clear signal to the marketplace. A roadmap builds the ZNE strategy over time as the market progresses in its understanding of the necessary design, construction and operational strategies, and as costs of achieving ZNE are reduced and the value of achieving ZNE is better understood. However, energy codes as currently formulated do not impact plug loads and other types of energy use such as vertical transport, nor do they assure the quality of building operations, two key factors in achieving ZNE performance.

   Ideally a codes roadmap would be aligned with voluntary and incentive programs to ease market transformation. Elements could include:

- Establishment of a long-term goal for the level of future energy codes and requiring progressive steps over time. For example, Oregon has legislated that ZNE will be required by 2030, California requires all new buildings to be ZNE by 2030 and half of public building floors pace by 2025, and Washington State legislation requires a 70% reduction in energy use relative to the base code of 2009 by the year 2027.

- Use of stretch or reach codes (those requiring better energy performance than code minimum) on a more limited basis for government buildings, within self-selected communities, or as the basis of incentivized programs. Massachusetts, Oregon and California have established stretch codes; national model green codes (ASHRAE 189 or International Green Construction Code) could also be referenced.
- Establishment of *measured* energy targets in code for commercial building types. This strategy is being pursued by the European Union to achieve "nearly Zero Energy Buildings" (nZEB)[18]. This policy focuses on measured energy outcomes and to date has concentrated on achieving energy efficiency goals rather than directly requiring renewable energy. At least two states and several cities are investigating this approach in North America.

2. **Establish annual benchmarking and disclosure policies and aggregate energy use data to set local energy reduction targets.** A better understanding of how much energy buildings actually use provides an important foundation for setting actual energy consumption goals. A number of cities have implemented mandatory benchmarking requirements, usually beginning with larger buildings. New York City and Seattle are two of the better established examples. The benchmarking data is just beginning to be analyzed, along with other sources of data, to understand what energy use levels should be targeted for various objectives. Some benchmarking and disclosure policies require disclosure of an Energy Star score. Since the Energy Star score is a relative comparison and not actual measured energy consumption, it is not the best gauge for any program targeting ZNE
3. **Establish net energy metering and rate policies that acknowledge the changing role of utilities.** Net metering is a powerful incentive in areas with high utility costs or high tiered rates structures. Current utility rate structures developed over the past century in response to regulated monopolies and a stable and fixed asset base. More flexible rate structures, such as variable rate blocks, net energy metering and time-of-day pricing, can better address the real value of both energy efficiency and renewable generation. The benefits of distributed solar and targeted demand reduction, especially for summer peak demand, should be more fully considered. More than 20 states have some form of net energy metering policy.

18 Analogous to ultra-low energy buildings in this study. Buildings not actively seeking ZNE but with exemplary low energy performance.

4. **Provide supportive programs by utilities or program administrators.** Incentive programs and technical assistance can reduce the risks inherent in piloting new approaches to design and construction. Many utility programs offer some form of incentive, ranging from single-measure support to comprehensive strategies. Other programs help defray the cost of energy modeling or to facilitate an integrated design process by paying for the cost of early design meetings called eco-charrettes.

   It is also important to realize that ZNE buildings may rely on passive strategies that are difficult to incentivize since they can actually eliminate the need of systems. As noted earlier, plug loads controlled by occupants and quality operations after occupancy can also be an issue for programs. These limitations on the current incentive structure challenges utilities and public purpose funds administrators to look beyond technology-based incentives and consider incentives that pay based on actual energy performance.

   Another innovative strategy to facilitate ZNE buildings is to provide a financial incentive for design firms to remain involved in the building operation over the first year. This would be similar to the eco-charrettes incentive but would occur at the end of the design process.

   In California, the Savings By Design commercial new construction program has a Path to Zero program element, and in Oregon the Energy Trust of Oregon ran a pilot ZNE program. The two programs were similar in design, featuring early design assistance (such as eco-charrettes), additional technical assistance to resolve design or research problems, and additional financial assistance for deeper measures. The programs required performance at least 40% better than state energy code. More than 20 buildings participated in California and nine in Oregon, with most targeting ZNE performance. Two other states are planning similar pilots.

   Other utility efforts in California include support for ZNE training, research, monitoring and design competitions. The Northwest Energy Efficiency Alliance and the utility-funded Integrated Design Labs in Washington, Oregon and Idaho have also conducted research, monitoring and training activities.

5. **Create incentives for ZNE at the local government level** (e.g. funding, fast track permitting, technical assistance, awards). Local governments can expand zoning regulations to encourage ZNE, using well-established tools such as density bonuses, accelerated permitting and many others. It is also important to review local zoning and code enforcement to ensure unintended restrictions don't apply to ZNE; new approaches may require changes to

older language and regulations to ensure compatibility. Many local jurisdictions have strategies to support green construction or other public goals such as affordable housing that can be expanded to support ZNE. In addition, Development Commissions can tie public support of building projects to ZNE and measured energy performance targets.

6. **Set ZNE goals for government and other public buildings.** Local and state government buildings are an excellent sector in which to demonstrate ZNE and interim energy reduction targets based on measured performance. It is particularly important for government to lead by example both for educational purposes and to establish credibility of other policy efforts. A California Executive Order requires ZNE performance for both new and existing State-owned buildings owned by 2025.

   Target market efforts should encourage demonstration projects. Seeing and experiencing ZNE buildings firsthand can be a strong influence and inspiration to other local designers, policymakers and building owners. Seeing that these buildings typically use off-the-shelf systems and technologies, feel comfortable and look relatively typical can help promote an interest in pursuing a nontraditional building model. These buildings also provide examples of design methods, contract processes, costs and financing models.

EDUCATION SNAPSHOT

Turkey Foot Middle School

Courtesy: Wes Battoclette

Entrance

Building Size: 133,000 SF
Location: Edgewood, Kentucky
Construction Type: K-12 Education
Construction Year: 2010
Building Type: New Construction
Climate Zone: 4A

Turkey Foot is revolutionizing the way kids learn, all within a new building that uses half the energy of the previous school despite doubling the size. Turkey Foot leveraged the practices and experience on other high performance goals in the district. For example, Turkey Foot has significantly less glazing than other schools in the district. The District learned from last projects that windows can be strategically located to enhance daylighting, minimize glare, and improve thermal performance. This, plus increased insulation level through use of insulated concrete form walls, allowed the design team to downsize mechanical systems, saving first costs.

Designers convinced the Kentucky Department of Education to allow for reduced footcandle levels required by electric lighting system as long as it was supplemented through high quality daylight design. This allowed for a substantial first cost reduction, as fewer light fixtures were needed in the 36 classrooms. Side lighting high on the window wall as well as solatubes direct daylight deep into spaces. Additionally, two light sensors per classroom monitor the amount of natural light available and adjust the electric lights as needed.

7. **Identify and Support Target Sector efforts.** Some commercial building market sectors are better targets for ZNE than others due to energy use patterns, ownership and leadership opportunities. Identification and structured support of target markets can accelerate activities related to ZNE as each commercial building market has a distinct ownership structure, patterns of development, financing opportunities, networks, trade associations and publications. As was true with Energy Star and U.S. Green Building Council's LEED[19] program, K-12 schools, colleges/universities and government buildings (especially small buildings and renovations) appear to be the early adopter target markets.

   The State Energy Office of Kentucky has championed school energy efficiency for many years, resulting in a series of ZNE schools built at a market-average cost. Northeast Energy Efficiency Partnerships has identified public buildings as a leadership market for ZNE, published a strategy document and worked with public buildings in several northeast states. NBI has established an early adopter process in California to help state and local governments, as well as school districts, achieve ZNE performance levels.

8. **Support community-scale renewable energy systems.** Renewable energy systems located beyond the boundaries of a single building site offer economies of scale for installation and maintenance over time and in many instances may be preferable to individual building systems. Certainly for campus-level installations the broader scale makes sense, but a variety of options exist for noncontiguous sites too. Community scale will be valuable in serving the existing building stock, especially in urban downtowns where dense development, shading and taller structures limit the ability of onsite PV to provide sufficient renewable energy. Policies that encourage community-scale renewable energy production while guaranteeing transaction credibility are needed at the state, local and utility regulatory levels.

   Examples include West Davis Village on the campus of UC Davis, which will include student housing and a variety of other university buildings. Also, the town of Lancaster, California, with its nearly ideal solar location in the Mojave Desert, powers 96% of city facilities with a series of scalable systems. EcoDistricts promotes urban community-scale solutions, as do the 2030 Districts established in Pittsburgh, Seattle, Cleveland, Denver and other cities.

19 Leadership in Energy and Environmental Design

9. **Support improved appliance standards to reduce energy use that falls outside the scope of building energy codes.** Because plug loads matter in ZNE buildings, appliance standards play a critical role in reducing energy consumption. Many appliances are covered by federal standards and cannot be further regulated at the state and local levels. For equipment not covered by federal standards, California has typically led the way for effective standards, and many other states have adopted all or most of the California-developed standards.

RENOVATION SNAPSHOT

Exploratorium at Pier 15

Building Size: 330,000 SF
Location: San Francisco, California
Construction Type: Major renovation
Construction Year: 1914, 2013
Building Type: Public Assembly - other
CA Climate Zone: 3

When the Exploratorium outgrew its old location at the Palace of Fine Arts, the City of San Francisco offered to provide piers 15 and 17 on its historic waterfront as a larger relocation option for the science museum. After structurally shoring up the historic piers, the design team embarked on transforming the 9 acre site into the Exploratorium's campus. This included retrofitting the massive pier 15 shed and constructing a small new structure to house a café and bay observation deck at the end of the pier. The retrofitted shed houses the exhibition spaces as well as a mezzanine level for classrooms, conference rooms and office space.

After a year of study, it became clear that the building could use its location above the San Francisco bay, and its relatively constant temperature, as a heat source or a heat sink depending on the climatic conditions. Water to water heat pumps heat or cool the bay water to meet the load required. Heating and cooling is provided to the building through a radiant concrete slab that conditions the space where the building occupants are. A four-pipe system provides either heated or chilled water to a 200,000 foot network of tubing imbedded in the concrete slab. Ventilation is provided by a separate dedicated outdoor air system (DOAS).

Findings Summary

Zero Net Energy buildings have captivated the minds of leading design firms, companies, schools, foundations and governments that are showing the way to a lower-carbon future. In just a few years ZNE has moved from an impossible concept to a quite probable future. ZNE buildings have moved beyond a handful of small demonstration projects by universities or nonprofits to more widely mainstream types and sizes.

NBI's *2014 Getting to Zero Status Update* shows that low energy use is the foundation to ZNE buildings, and achieving low and zero energy could become a standard practice for most commercial buildings today.

Overview

The lists below provide an alternative quick overview by topic area of the research findings.

In just a few years ZNE has moved from an impossible concept to a quite probable future. The types, number, sizes and locations of ZNE buildings have increased rapidly, although the market is still very small.

In just a few years ZNE has moved from an impossible concept to a quite probable future. The types, number, sizes and locations of ZNE buildings have increased rapidly, although the market is still very small.

- The study identifies 160 ZNE projects: 32 verified ZNE buildings and one district, and 110 emerging ZNE buildings and 17 districts.
- This is compared to 60 ZNE buildings listed in the *Getting to Zero 2012 Status Update.* The largest increase is in ZNE emerging, with a 182% increase since 2012.
- An additional 53 ultra-low energy buildings with verified energy performance are listed in this study for a total of 213 specific projects compared to 99 total projects in 2012.

ZNE requires early energy and renewable goals, integrated design teams and project champions.

Renovated existing buildings can reach ZNE.

- 24% of the ZNE verified projects are renovations providing lessons on how to transform significant portions of the existing commercial building market.

Districts are an increasing and highly valuable trend; there are 18 ZNE projects identified as targeting multiple sets of buildings, with military, universities and community colleges being most common.

- The synergies of bundling sets of buildings is a natural and efficient strategy to leverage economies of scale from design, financial, district heating/cooling and energy production systems.
- In addition to ZNE committed districts, the 2030 Districts target ultra-low energy and represent a very large set of buildings and commercial floor space that can be a gateway to ZNE renovations.

There is growth and opportunity in repeatable buildings (schools, banks, small offices).

Types, Sizes and Locations

The range of building types has more than doubled since the 2012 report. There are now 16 different types of ZNE buildings ranging from retail to offices, from laboratories to airports.

There is over 5.3 million square feet of ZNE buildings identified[20].

There is a notable increase in larger, more complex buildings (50,000 sf or larger). These 29 large buildings now represent 28% of all the ZNE buildings[21], and over half are greater than 100,000 square feet.

Smaller buildings (under 25,000 sf) are still the most common and represent 62% of the total ZNE buildings[22].

Education represents the largest portion of ZNE projects.

- K-12, universities and general education are 36% of all ZNE buildings, followed by offices at 19%.
- Education buildings offer highly visible projects that can influence community members and the next generation of citizens.
- Success stories of public funds that return lower operating costs and healthier student environments provide documentation that can be leveraged by others.
- Education buildings are the 4th largest building floorspace in the U.S. with over 10 billion square feet.
- This sector offers national and regional forums and associations to facilitate the transfer of best design and operational practices.

The number of states with ZNE buildings has expanded since the 2012 report.

- ZNE buildings are now in 36 states, up from 26 at the time of the 2012 report, and reflect all climate zones and regions across the U.S. and Canada.

Low-rise multifamily buildings are a new trend in ZNE with over a dozen examples in this study.

Ownership

Private sector development of ZNE buildings is growing.

- Over 25% of the buildings were privately developed, strong evidence that the market is recognizing the value of ZNE.
- Corporate leadership in ZNE is gaining attention. PNC Bank, Walgreens, TD Bank and Melink Corporation all have prototypes, buildings or have adopted ZNE policies for their portfolios.

20 The actual number is much larger as there are 44 ZNE emerging buildings in the study that did not have square footage identified at the time of this report and 18 districts comprised of multiple buildings targeting ZNE.
21 28% of those ZNE buildings (104) that had square feet available at the time of this report.
22 62% of those ZNE buildings (104) that had square feet available at the time of this report.

- Architects, engineers and green construction firms are walking the talk by making their own buildings ZNE and identifying new business opportunities.

Government and education continue to create the proving ground for public investment.

- Public ownership remains the most dominant sector, representing 67% of the projects. Nonprofits make up the remaining ownership type.

Energy

Energy use in ZNE buildings is approximately 25% of an average building energy use today.

- The average for the ZNE verified buildings in the study is an EUI of 21 kBtu/sf/yr. Most of the buildings have an EUI of less than 30, putting them in the lowest third of their type[23]. The ZNE office average EUI is just 21.

Renewable production is met by photovoltaics in all ZNE buildings. A few projects also supplemented with wind generators.

Buildings can go beyond net zero and be net-positive[24] as several of these projects demonstrated.

Ultra-low energy buildings — those performing at ZNE levels but without the explicit target of zero - are also increasing.

- These provide the same lessons and performance data of ZNE and help build the case for the mainstreaming of low energy buildings. This study includes a list of over 50 buildings with measured energy use in the lowest quartile of comparable building types.

Programs and Recognition

LEED buildings are pushing beyond the Energy and Atmosphere (EA) credits and leading the path to ZNE. Within NBI's ZNE verified list half (16) are LEED Platinum or Gold.

The Living Building Challenge has four buildings certified as "Living" and an additional four with "Net Zero Building Certification."

Utility program support for design assistance and efficiency measures as well as some tax credits were cited as valuable.

Many of the buildings were identified through leading award and recognition programs such as the American Institute of Architects Committee on the Environment Top Ten Green Project awards, the Northeast Sustainable Energy Association Net Zero Energy award, and recognition in *High Performing Buildings* magazine and *Net Zero Buildings* magazines.

Government and education continue to create the proving ground for public investment. Public ownership remains the most dominant sector, representing 67% of the projects.

23 U.S 2003 Commercial Buildings Energy Consumption Survey (CBECS) average for non-mall buildings as 91 and 93 for offices.
24 Net-Positive: When annual production from renewables exceeds annual energy use.

Alameda County Library, Castro Valley, California

Design and Technologies

Design strategies and technologies used to achieve ZNE are widely available and in use in other high performance buildings. The most oft-cited energy efficiency measures were:

- High performance envelope and glazing, passive design strategies (such as orientation, daylighting, natural ventilation), exterior window shading, green and cool roofs, interior design focused on access to daylight.
- Advanced lighting systems, including daylight controls, occupancy sensors, LED task lights and lighting schedule controls.
- High performance HVAC systems, including radiant panels, ground-source heat pumps, chilled beams, variable refrigerant flow and evaporative systems. Separation of ventilation and space conditioning, carbon dioxide (CO2) sensors that track occupancy levels and adjust HVAC also made the list.

Plug loads make up an increasingly large percentage of energy use in ZNE and ultra-low energy buildings.

Attention to operations and occupant loads is critical. The following were widely used:

- Energy monitoring and measurement systems for real-time feedback on performance, renewable production and identification of system issues.
- Dashboards in public and tenant spaces to drive awareness of energy use and inspire behavioral changes to reduce energy.
- Plug load reduction methods such as controlled plug strips, outlets or IT software. Best-in-class computers and appliances.
- Green procurement requirements.
- Occupant engagement through campaigns, email prompts, competitions and green leases.

Costs

Costs for getting to zero are not distinguishable from overall project costs. Energy efficiency and renewable technologies do have specific costs but the design and technology tradeoffs due to the advanced systems blur the line of incremental costs.

Green, LEED and/or zero net energy buildings are within the range of other like-type buildings. When total construction costs for these buildings are analyzed against control groups they are approaching comparable costs.

Design firms and early targets reduce costs. The experience of the team and the explicit goal of ZNE throughout the process are cited as critical to managing costs.

Policies

Cities and states are leading the way with ZNE policies, accompanied by community, organization and district efforts.

Strong energy codes can support the path to zero, but outcome-based codes are critical.

ZNE means jobs. Moving more buildings toward this goal requires increasing individual's skills and the numbers of firms to design, install, operate and maintain these buildings and renewable energy systems, thus dovetailing with government policies of reducing energy use and creating jobs.

Challenges

Data is a dilemma. Finding and gaining access to measured data is challenging, and often the data has errors or is incomplete requiring a high degree of quality control.

Continual commissioning required. Commissioning the metering and building systems requires is an ongoing dynamic need.

Zero success is feared. If the zero energy target was not yet met, there was hesitancy by some firms to share results despite excellent performance.

Defining ZNE is difficult. Communicating the terms and definitions can be difficult.

It is hard to be zero. Buildings rarely land exactly on zero and, if they do, it is only for a given period of time. It is a process, not a static outcome.

Appendices

Appendix A: List of ZNE Emerging Buildings

ZNE emerging buildings (or Districts) have a publically stated goal of ZNE but do not yet meet the definition of ZNE verified. These may be in planning, design, under construction or have been in operation for less than a year. Others may have been operating for 12 months or longer, but their measured energy has either yet to achieve net zero or the measured data to document ZNE verified status was not available for this study.

Project Completion	Name	Location	State	Building Type	Size (sf)
2005	Melink Corporation Headquarters	Milford	OH	Office	30,000
2007	Prairie Hill Learning Center	Roca	NE	Education- general	2,940
2008	Aquarium of the Pacific Watershed Addition	Long Beach	CA	Education- general	2,500
	Hillandale Elementary School	East Flat Rock	NC	Education- K-12	Unknown
	Mills River Elementary School	Mills River	NC	Education- K-12	Unknown
2009	da Vinci School High Performance Classroom	Portland	OR	Education- K-12	1,485
	Oak Ridge National Lab Office Building 3156	Oak Ridge	TN	Office (R)	6,900
2010	Bagley Classroom University of Minnesota Duluth	Duluth	MN	Education- higher	2,000
	Center for Energy Efficient Design	Rocky Mount	VA	Education- K-12	3,600
	Evie Garrett Dennis E12 Campus (Denver Schools)	Denver	CO	Education- K-12	186,468
	Lowell Trial Court	Lowell	MA	Other	Unknown
	Magnify Credit Union	Lakeland	FL	Retail	4,151
	Palmetto Bay Municipal Center	Palmetto Bay	FL	Office	25,000
	Turkey Foot Middle School	Edgewood	KY	Education- K-12	133,000
2011	Centennial PK-12 School	Denver	CO	Education- K-12	64,000
	Centre for Interactive Research on Sustainability (CIRS)	Vancouver	Canada	Education- general	76,223
	Coastal Maine Botanical Gardens Bosarge Family Education Center	Boothbay	ME	Education- general	8,200
	EcoFlats Building	Portland	OR	Multifamily	19,860
	Frito-Lay Casa Grande Snack Factory	Casa Grande	AZ	Other	188,000
	George V Leyva Middle School Admin Building	San Jose	CA	Office	9,200
	June Key Delta Community Center	Portland	OR	Public Assembly	2,700
	McCormick Spice Net Zero Warehouse	Belcamp	MD	Warehouse (R)	369,000
	NASA Propellants Facility at Kennedy Space Center	Kennedy Space Center	FL	Office- other	9,540
	Pierce College Maintenance & Operations Facility and Net-Zero Central Plant	Los Angeles	CA	Other	42,000
	Portland Community College Newberg Center	Newberg	OR	Education- higher	13,000

Project Completion	Name	Location	State	Building Type	Size (sf)
2011	Redding School for the Arts	Redding	CA	Education - K-12	77,091
	Rice Fergus Miller Office & Studio	Bremerton	WA	Office (R)	39,000
	Sangre de Cristo PK-12 School	Mosca	CO	Education- K-12	8,000
	VanDusen Botanical Garden Visitor Centre	Vancouver	Canada	Public Assembly	19,000
	West Irving Library	Irving	TX	Library	25,876
	Wilson Air Center - Chattanooga Airport - West Side Aviation Development -	Chattanooga	TN	Airport (R)	9,015
2012	Bullitt Foundation Cascadia Center for Sustainable Design and Construction	Seattle	WA	Office	52,000
	Colonel Smith Middle School	Fort Huachuca	AZ	Education- K-12	88,693
	Conrad N. Hilton Foundation	Agoura Hills	CA	Office	22,240
	Franklin Regional Transit Center	Greenfield	MA	Other	24,000
	La Valentina North	Sacramento	CA	Multifamily	19,875
	Maharishi University of Management Sustainable Living Center	Fairfield	IA	Education- higher	6,900
	Morphosis Architecture Studio	Culver City	CA	Office	11,600
	North Shore Community College Health and Student Services Building	Danvers	MA	Education- higher	58,000
	Paisano Green Community	El Paso	TX	Multifamily	55,202
	Phipps Center for Sustainable Landscapes	Pittsburgh	PA	Public Assembly	24,350
	Sacred Heart Schools Stevens Family Library	Atherton	CA	Library	Unknown
	Sail Lofts	Thomaston	ME	Multifamily	Unknown
	Skaneateles Village Hall	Skaneateles	NY	Office	3,723
	St Petersburg Net Zero Office (Sierra Club)	St Petersburg	FL	Office	Unknown
	Student Services Center at Mesa College	San Diego	CA	Education- higher	85,000
	UC Davis West Village (eco district)	Davis	CA	Multifamily	District
	UniverCity Childcare Centre	Burnaby	Canada	Education- K-12	5,690
	Vernonia School k-12	Vernonia	OR	Education- K-12	135,000
	Lady Bird Johnson Middle School	Irving	TX	Education- K-12	152,000
2013	Beckstoffers Mill Senior Housing Complex	Richmond	VA	Multifamily (R)	8,000
	Berkeley West Branch Library	Berkeley	CA	Library	9,300
	Blackford School Multi-Use Building	San Jose	CA	Education- K-12	Unknown
	Bright 'n Green	Brooklyn	NY	Multifamily	Unknown
	Centre of Excellence at Okanagan College	Kelowna	Canada	Education- higher	61,100
	Delta Building - NYC	Brooklyn	NY	Mixed Use	2,700
	Ewa Elementary School Portable Classroom	Oahu	HI	Education- K-12	Unknown
	Exploratorium	San Francisco	CA	Other	330,000
	Foundry Court by Nexus Homes	Philadelphia	PA	Multifamily	Unknown
	General Aviation Terminal	Appleton	WI	Airport	8,000

Project Completion	Name	Location	State	Building Type	Size (sf)
2013	IBEW Local 595 Zero Net Energy Center	San Leandro	CA	Education- general	46,000
	Lane Community College, Downtown Academic Center	Eugene	OR	Education- higher	Unknown
	Lenawee Intermediate School District Center for a Sustainable Future	Adrian Township	MI	Education- K-12	Unknown
	Park Slope Brooklyn ZNE Brownstone	Brooklyn	NY	Multifamily	7,000
	PNC Net-Zero Branch - Ft. Lauderdale	Ft Lauderdale	FL	Retail	4,900
	Salt Lake City Public Safety Building	Salt Lake City	UT	Public Order-safety	175,480
	Sandy Grove Mid. School	Lumber Bridge	NC	Education- K-12	74,000
	Sokol Blosser Winery Tasting Room	Dundee	OR	Retail	5,000
	Solterra EcoLuxury Apartments	San Diego	CA	Multifamily	Unknown
	Taliesin West Net Zero Retrofit - Frank Lloyd Wright	Scottsdale	AZ	Multifamily	District
	UC San Diego J Craig Venter Institute	La Jolla	CA	Laboratory	45,000
	Wayne Aspinall Federal Building and Courthouse	Grand Junction	CO	Other (R)	41,562
	Walgreens Evanston Store	Evanston	IL	Retail	14,000
ZNE EMERGING IN PLANNING, DESIGN, CONSTRUCTION OR DATE UNKNOWN					
	435 Indio	Sunnyvale	CA	Office	30,000
	64 Catherine Street	Boston	MA	Multifamily	1,416
	Abondance - Montreal Multifamily Net Zero	Montreal	Canada	Multifamily	3,048
	Arlington Agricultural Research Station	Arlington	WI	District	District
	BEST Center at Laney College	Oakland	CA	Education- higher	District
	Boy Scouts of America The Summit Bechtel Reserve Treehouse	Glen Jean	WV	Public Assembly	Unknown
	California Department of Motor Vehicles	Various	CA	Office	Unknown
	California DOT SFOBB Phase 2 Warehouse	San Francisco	CA	warehouse	Unknown
	Cambridge MA - MLK School	Cambridge	MA	Education- K-12	Unknown
	Camp Parks	Dublin	CA	Military	District
	Charlotte-Douglas Airport - Fire Rescue and Fire Facility	Charlotte	NC	Public Order-safety	Unknown
	College of the Desert West Valley Campus	Palm Springs	CA	Education- higher	Unknown
	Craftsbury Outdoor Center Lodge	Craftsbury Common	VT	Other	Unknown
	East Bay MET School	Newport	RI	Education- K-12	16,800
	Electrical and Computer Engineering Building and University of Illinois	Urbana/Champaign	IL	Education- higher	250,000
	Family Pet Hospital	Clovis	CA	Other	Unknown
	Fort Bliss	Fort Bliss	TX	Military	District
	Fort Carson	Fort Carson	CO	Military	District
	Fort Detrick	Frederick	MD	Military	District

Project Completion	Name	Location	State	Building Type	Size (sf)
	Fort Hunter Liggett	Jolon	CA	Military	District
	Georgia Peanut Commission HQ	Tifton	GA	Office	Unknown
	Green Leaf Inn	Delavin	WI	Other	Unknown
	Green Phoenix Learning Center	Phoenix	AZ	Education- K-12	Unknown
	Greensburg Kansas Net Zero Community	Greensburg	KS	Campus	District
	Hanover Page Mill Building	Palo Alto	CA	Office	Unknown
	Kaiser Permanente Antelope Valley Specialty Medical Office Building	Lancaster	CA	Office	136,800
	Kalaeloa NZE Community	Honolulu	HI	District	District
	Keene State College Technology, Design and Safety Building	Keene	NH	Education- higher	Unknown
	King County Housing Authority Administration Building	Tukwila	WA	Office	36,000
	La Escuelita Education Center	Oakland	CA	Education- K-12	123,000
	Los Angeles Harbor College Sciences Complex	Los Angeles	CA	Education- higher	Unknown
	Lowry Redevelopment Multifamily ZNE	Denver	CO	Multifamily	Unknown
	LPL Financial Center at La Jolla Commons	San Diego	CA	Office	415,000
	Massachusetts Division of Fisheries & Wildlife - Field Headquarters Building	Westborough	MA	Office	45,000
	New Century Elementary School	Fayetteville	NC	Education- K-12	Unknown
	Oregon National Guard	Multiple	OR	Military	District
	Orangewood Middle School and studio project	Phoenix	AZ	Education- K-12	Unknown
	P.S. 62	Staten Island	NY	Education- K-12	68,000
	Renewable Energy Experimental Facility	Reno	NV	Other	Unknown
	Richard J. Lee Elementary School	Coppell	TX	Education- K-12	Unknown
	Salt Lake City District Attorney Office	Salt Lake City	UT	Office	Unknown
	Sierra Army Depot	Herlong	CA	Military	District
	Sierra Nevada Aquatic Research Lab Multiuse Classroom and Lecture Hall	Mammoth Lakes	CA	Education- higher	Unknown
	SMUD Net Zero Campus - East Campus-Operations Center	Sacramento	CA	Office	Unknown
	Student Success and Retention Center at East Los Angeles College	Los Angeles	CA	Education- higher	136,000
	UC Davis Jess S. Jackson Sustainable Winery Building	Davis	CA	Education- higher	8,000
	UC Merced	Merced	CA	District	District
	UC Santa Barbara Recreation Center	Santa Barbara	CA	Education- higher	Unknown
	UC Santa Barbara Student Services Buildings	Santa Barbara	CA	District	District
	UniverCity	Burnaby	Canada	District	District

Project Completion	Name	Location	State	Building Type	Size (sf)
	University of South Carolina Darla Moore School of Business	Columbia	SC	Education- higher	250,000
	West Point USMA	West Point	NY	Military	District
	York Elementary School	Pearland	TX	Education- K-12	Unknown
	Zero Energy Research Lab at University of North Texas	Denton	TX	Education- higher	Unknown

Appendix B: List of Ultra-low Energy Verified Projects

Ultra-low energy buildings are comparable to ZNE buildings based on energy use, design strategies and technologies but do not have a stated goal of ZNE. They may or may not have onsite renewables; they may provide structure and wiring to easily incorporate photovoltaics at a later date. All ultra-low energy buildings in this report are verified in that they have shared, with NBI or publically, 12 or more months of measured energy use data that documents energy performance dramatically better than the industry average.

Project Completion	Name	Location	State	Building Type	Building Size (sf)	Building Energy Use EUI	Site Renewable EUI	Net Building EUI
1994	Wampanoag Headquarters	Gay Head	MA	Office	8,700	30		30
1995	Durant Road Middle School	Raleigh	NC	Education-K-12	148,500	25		25
	Ridgehaven Office Building	San Diego	CA	Office	78,000	24		24
1996	Claiborne & Churchill Winery	San Luis Obispo	CA	Office	2,585	20		20
1998	Vermont Law School Oakes Hall	South Royalton	VT	Education-higher	23,500	27		27
2000	IAMU Office and Training Headquarters	Ankeny	IA	Office	12,500	25		25
	Zion Comfort Station	Springdale	UT	Other	2,400	20		20
2002	Colorado Court Affordable Housing	Santa Monica	CA	Multifamily	29,900	39	2	37
	Georgina Blach Intermediate School	Los Altos	CA	Education-K-12	71,741	33		33
2003	Bazzani Associates Headquarters	Grand Rapids	MI	Office (R)	9,480	27		27
	EcoDorm at Warren Wilson College	Swannanoa	NC	Multifamily	9,000	23		23
	Lower Windsor Township Community Center	Wrightsville	PA	Public Assembly	37,100	31		31
	Rinker Hall	Gainesville	FL	Education-higher	47,470	30		30
	Schlitz Audubon Nature Center	Bayside	WI	Other	35,387	28		28
	South Rim Maintenance & Warehouse Facility	Grand Canyon	AZ	Public Order- Safety	72,000	22		22
	Southern York County Library	Shrewsbury	PA	Library	10,095	32		32
	Woods Hole Research Center	Falmouth	MA	Office (R)	19,200	16	5	11
2004	Doyle Conservation Center	Leominster	MA	Office	22,000	27	4	23
	Escalante Science Center	Escalante	UT	Education-general	21,101	31		31
	Lovejoy Opsis Building	Portland	OR	Office (R)	20,000	33		33
	Suwannee River Visitor Center	Fargo	GA	Other	7,015	26		26
	Westmont High School Science Education Facility	Campbell	CA	Education-K-12	12.362	19		19

Project Completion	Name	Location	State	Building Type	Building Size (sf)	Building Energy Use EUI	Site Renewable EUI	Net Building EUI
2004	Wind NRG Partners, LLC	Hinesburg	VT	Other	46,000	22		22
2005	Denali Visitor Center	Denali National Park	AK	Public Assembly	13,991	17		17
	Jane D'Aza House of Formation	San Rafael	CA	Other	6,200	7		7
	Kirsch Center For Environmental Studies at De Anza College	Los Altos	CA	Education-higher	21,600	33	10	23
2006	Kinard Junior High	Fort Collins	CO	Education-K-12	112,735	25		25
	Stoller Winery	Dayton	OR	Other	23,000	30		30
2007	Center for Children & Families-CSU San Marcos	San Marcos	CA	Education-general	20,200	28		28
	Garthwaite Center for Science & Art	Weston	MA	Education-K-12	20,000	27		27
	Plano Elementary School	Bowling Green	KY	Education-K-12	81,147	27		27
2008	Carlton Hills Modernization	Santee	CA	Education-K-12	56,159	26		26
	Carlton Oaks Modernization	Santee	CA	Education-K-12	61,675	24		24
	Eco Office	Atlanta	GA	Office	10,100	24	2	22
	Sycamore Canyon Modernization	Santee	CA	Education-K-12 (R)	52,100	23		23
2009	CMTA Office Building	Louisville	KY	Office	20,000	18	2	16
	High Tech High	Chula Vista	CA	Education-K-12	44,370	40	14	26
	Los Vecinos	Chula Vista	CA	Multifamily	51,000	19	9	10
	Watsonville Water Resources Center	Watsonville	CA	Laboratory	19,800	35		35
2010	355 11th Street: The Matarozzi/ Pelsinger Multi-Use Building	San Francisco	CA	Mixed Use (R)	14,000	10	9	1
	Greensburg Kansas K-12 School (Kiowa County Schools)	Greensburg	KS	Education-K-12	123,405	29	2	27
	Northwest Maritime Center	Port Townsend	WA	Mixed Use	26,550	30		30
	Suzuki Public School	Windsor	Canada	Education-K-12	58,482	25	3	22
2011	Alameda County Library	Castro Valley	CA	Library	34,537	64	47	17
	Iowa Utilities Board / Office of Consumer Advocate	Des Moines	IA	Office	44,640	21	2	19
	Ramona Apartments	Portland	OR	Multifamily	230,760	19	1	18

Project Completion	Name	Location	State	Building Type	Building Size (sf)	Building Energy Use EUI	Site Renewable EUI	Net Building EUI
2012	NASA Sustainability Base	Mountain View	CA	Office-other	50,000	53	5	48
2013	31 Tannery Road	Branchburg	NJ	Office	41508	28	19	9
	Aventine	La Jolla	CA	Office	253,000	23		23
	M.E. Group Omaha Office	Omaha	NE	Office	6,200	28		28
	Navy Building 850	Port Hueneme	CA	Office	17,000	25	11	14
	NREL Wind Site Entrance Building (SEB)	Golden	CO	Other	160	45	29	16
	Takoma Village Cohousing	Washington	DC	Multifamily	51,000	26		26

Appendix C: Research Method

The number of case studies on green and ZNE buildings has grown in recent years yet measured energy performance is rarely documented through these public sources[25]. To meet the objective of presenting actual energy use and ZNE trends, the research team cast a wide net throughout North America in search of commercial buildings targeting or achieving Zero Net Energy. Buildings with very low energy outcomes (i.e. ultra-low energy buildings) were also included in the research because, with the exception of the renewable production, they mirror the processes, technologies and operational aspects necessary to get to zero.

Sources

As a starting point for this study NBI reviewed its internal database. Buildings in the database include those identified via previous studies by NBI and others, the *Getting to Zero 2012 Status Update* research and those that land on a watch list as they come to the attention of staff and colleagues. These leads were supplemented with review of publications, journals and awards; buildings referenced or presented at trade meetings or conferences; outreach with design, engineering firms and owners with a record of high performance buildings; and pursuing lists through utility and green building programs. In addition, NBI issued a widespread public call for ZNE or ultra-low energy project information and established a ZNE Registry to collect the following base-level information:

- Basic building characteristics (location, size, use, certifications and awards, etc.)
- Identification of design strategies and installed energy conservation measures
- Documentation verifying 12 months of energy use for all fuels used
- Documentation verifying 12 months of onsite energy production, if applicable
- Cost information, if available

Energy Data

Energy performance information is notoriously difficult to collect, even with strong working relationships with many of the sources. Data comes in many forms such as copies of utility bills, tracking software outputs, numerous iterations of spreadsheets, 15-minute interval data and/or energy dashboards. Interestingly, not all dashboards represented the information in a way that was consistent with the research protocols. In those cases, additional follow-up with a building representative was necessary to dive deeper into the software and find the relevant information. Some projects were simply unable to compile and deliver the requisite information due to time constraints or lack of data availability.

The absence of measured data shared publically or with NBI would result in a project that may actually be performing at ZNE to remain on the ZNE

25 Sources for building case studies and performance data are listed in the Appendix D.

emerging list. Additionally, data that was incomplete or showed the project did not achieve the zero target also stayed on the ZNE emerging list. All ultra-low energy buildings are verified and were added to the data set because additional measured performance data is critical to help move the focus to actual energy use versus modeled or estimated outcomes. Additionally, some of the ZNE emerging projects with measured performance (for example, those that have not yet met the zero target) were included in the analysis in the "Measured Performance" section of this report. Again, this was done to expand the number of project with measured performance data for this research.

Verified How?

NBI accepted three methods for verification. The first method applied to the majority of buildings, with NBI staff reviewing monthly measured energy consumption data for all fuels and the renewable energy production data as provided by the ownership/design team. The second approach was representation by a third-party entity of the measured data by means such as an evaluation report, published article, presentation, or citation in an award or other public forum. The third verification method accepted in this research was through the International Living Future Institute (ILFI) as part of the Living Building Challenge or Net Zero Energy Building Certification. The ILFI definition requires 100% of the project's site energy to be carbon neutral (zero direct use of gas and other fossil-based fuels at the site) and supplied by renewable energy on a net annual basis.

NBI's ZNE verification for this study does not restrict gas or other fuels but required that all fuels be accounted for in the whole building energy total (EUI). Documented onsite renewable production must then equal or exceed the energy use of all fuels over the course of a year. Verification of the actual energy performance of buildings has long been part of NBI's work to research and recognize best practices and leaders and to increase measured performance feedback that can improve the next generation of buildings. NBI's ZNE and ultra-low energy building registry is publicly available to submit buildings for ongoing studies and verification.

Appendix D: References

Some of the programs, policies and resources that support ZNE are listed below.

The Energy Trust of Oregon. The Energy Trust provides technical assistance for early design, energy modeling, additional energy-related design studies, energy efficiency equipment, renewable technologies and commissioning. The Energy Trust offered a Path to Net Zero Pilot program of enhanced energy incentives for owners achieving exceptional levels of energy savings and those aiming for net zero energy use. http://energytrust.org/commercial/pilot-programs/path-to-net-zero.aspx The Evaluation of the Path to Net Zero Pilot Program offers interesting lessons learned for others considering a ZNE pilot. The evaluation is available at: http://energytrust.org/library/reports/121204_PTNZ_Report.pdf

California's Savings by Design. The Savings by Design program provides educational opportunities and financial support for design teams and buildings that achieve energy savings above Title 24 code. This includes support for design teams, help with additional modeling and assistance with technical resources. Savings by Design has managed a Net Zero Energy pilot program for teams pursuing aggressive ZNE goals. For more information see: www.savingsbydesign.com

ZNE Communications Toolkit. This is a first-of-its-kind set of materials developed by NBI and Resource Media to help address commonly asked questions about ZNE, provide messaging for consistent communications about this ultra-efficiency goal and support advocates in advancing toward California's aggressive ZNE goals. The toolkit includes a messaging platform, presentation template and communication guide, available at: http://newbuildings.org/index.php?q=zne-communications-toolkit

CPUC Zero Net Energy Commercial Action Plan. As part of the California Long Term Energy Efficiency Strategic Plan, the California Public Utilities Commission (CPUC) developed the Zero Net Energy Commercial Action Plan to help achieve the strategic plan goals and engage industry leaders, relevant agencies, stakeholders, utilities and other key influencers. An ongoing group continues to coordinate Action Plan activities. Find both plans at: http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/

The Road to ZNE, Mapping Pathways to ZNE Buildings in CA. A study conducted by the Heschong Mahone Group Inc. and funded by Pacific Gas and Electric Co. on behalf of the California Investor Owned Utilities. Find the full report at: http://www.energydataweb.com/cpucFiles/pdaDocs/899/Road%20to%20ZNE%20FINAL%20Report_withAppendices.pdf

California Zero Net Energy Buildings Cost Study. This study explored the cost-effectiveness of ZNE buildings in the current residential and commercial marketplace through a review of literature, case studies, and interviews with ZNE experts familiar with residential, commercial, and community-scale projects. Read the report at http://newbuildings.org/sites/default/files/PGE_CA_ZNE_CostStudy_121912.pdf

Kentucky Public Schools. The State of Kentucky Department for Energy Development and Independence helps school districts understand energy use in schools and improve their energy performance. Program information is available at: http://energy.ky.gov/Programs/Pages/ESschools.aspx

Massachusetts Executive Office of Energy and Environmental Affairs. Massachusetts is working to transform energy use in new and existing buildings. The Zero Net Energy Buildings Task Force and Inter-Agency ZNEB Team work to ensure the 2009 Getting to Zero plan for transforming the building sector is implemented. Find out more at: http://www.mass.gov/eea/energy-utilities-clean-tech/energy-efficiency/zero-net-energy-bldgs/

Northeast Energy Efficiency Partnership (NEEP) Roadmap for Zero Net Energy Buildings. NEEP has developed a report that recognizes the leadership potential of public buildings in the approach to ZNE. Their roadmap presents five steps that states and municipalities can do now to make zero net energy public buildings a reality across the northeast. More information about the roadmap is available at: http://www.neep.org/public-policy/energy-efficient-buildings/high-performance-public-buildings/roadmap-for-zero-net-energy-buildings

Living Building Challenge. Managed by the International Living Future Institute, the Living Building Challenge and Net Zero Energy Certification are intended to inspire design and construction of zero impact, restorative buildings. Several commercial projects have been completed and more are in progress. Find out more at https://ilbi.org/lbc

EcoDistricts. EcoDistricts is a non-profit organization that connects people with tools, services and training to help cities and urban development practitioners create resilient, vibrant, resource efficient and just neighborhoods. They have an EcoDistrict Framework to guide innovative district-scale development projects from concept through implementation. Find out more at http://ecodistricts.org/

The Zero Energy Commercial Buildings Consortium (CBC). The CBC published two reports in 2011. The first, *Next Generation Technologies Barriers and Recommendations,* describes barriers to achieving net zero energy related to key building systems, as well as recommendations for system improvements that would accelerate the transition to net zero energy. The second, *Analysis of Cost & Non-Cost Barriers and Policy Solutions,* analyzes barriers due to market and policy conditions and provides policy, financing, and other recommendations to address these barriers.

The CBC reports can be downloaded at: http://zeroenergycbc.org/resources/cbc-reports

Reach Codes. "Reach" or "Stretch" codes go beyond the minimum codes to reduce energy. Seen as an important tool to advance state and local policy toward advancing climate goals, they have been adopted in over 275 states, counties, and cities. Find out more about reach codes at: http://energycodesocean.org/research-topics/green-codes#

Benchmarking and Disclosure Policies. Currently two states and nince cities have policies that require benchmarking, rating and disclosure of energy performance information from commercial buildings. Requirements are unique to each locality. These are summarized at: http://www.buildingrating.org/content/us-policy-briefs

Net Metering Policies. Net metering policies allow those that generate renewable energy to feed surplus electricity back to the utility grid. Policies vary by state. Learn more about net metering at the Energy Efficiency and Renewable Energy website of the U.S. Department of Energy: http://apps3.eere.energy.gov/greenpower/markets/netmetering.shtml

International Approach. The European Union has three primary directives that regulate energy policy: The Energy Performance of Buildings Directive, the Energy Efficiency Directive, and the Renewable Energy Directive. Each of the EU member states develops their own approach to achieving the broad goals set out in the directives. The Buildings Performance Institute Europe hosts a data hub about energy use in Europe and maintains links to other data sources, policies and programs at: http://www.buildingsdata.eu/

***High Performing Buildings* magazine.** ASHRAE's HPB Magazine includes articles and in-depth case studies with technology and energy performance information: http://www.hpbmagazine.org/home

***Net Zero Buildings* magazine.** Net Zero Buildings magazine highlights projects, applications, strategies, and products utilized in NZE buildings: http://www.nzbmagazine.com/

Net Zero Energy Design: A Guide for Commercial Architecture. Hootman, Tom 2012. This book provides a practical guide for architects and related construction professionals who want to design and build net zero energy commercial architecture. Written by an architect who is the director of sustainability for at PNL Architects — a global architecture firm.

Net Zero Energy Buildings: International Projects of Carbon Neutrality in Buildings. Voss, K.; Moss, E. 2013. This book is the result of work since 2008 through the International Energy Agency. The objective is to analyze exemplary buildings that are near a zero-energy balance in order to develop methods and tools for the planning, design and operation of such buildings. The results are documented in this publication and include presentation of selected projects with a focus on relaying knowledge and experience gained by planners and builders.

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New Buildings Institute (NBI) is a nonprofit organization working to improve the energy performance of commercial buildings. We work collaboratively with commercial building market players — governments, utilities, energy efficiency advocates and building professionals — to remove barriers to energy efficiency, including promoting advanced design practices, improved technologies, public policies and programs that improve energy efficiency.