Getting to Zero: The 2014 Net Zero Energy Status Report Findings for Commercial Buildings

Amy Cortese, Cathy Higgins and Mark Lyles, New Buildings Institute

ABSTRACT

Getting to Zero Net Energy (ZNE) has moved from an abstract concept demonstrated at a few universities and nonprofits to a more widely adopted objective. Design firms and owners are now actively pursuing ZNE in commercial buildings. This paper presents the findings from the *2014 Getting to Zero Status Update* (2014 Update), a study of net zero commercial buildings in North America. The paper provides data on the number of ZNE buildings by location, type, size and energy use and highlights the trends since publication of the *Getting to Zero 2012 Status Update*.

The findings show a more than 160% increase in ZNE buildings since the 2012 report – from 60 to now over 160 documented buildings. While ZNE projects in 2012 were found in five U.S. states, recent findings show that 36 states now have ZNE projects. Building types have also diversified, with strong growth in education buildings and district- and community-scale projects.

ZNE's absolute energy performance target, compared with conventional references of 'percent-better-than', is part of the attraction. Results of ZNE verified buildings show very low energy buildings using only one-fifth of the national average, with an average Energy Use Index (EUI) of just 20 kBtus/sf/year to be met by renewables. Authors discuss this performance in terms of design strategies, common technologies, ongoing operations and occupant engagement to accomplish ZNE. The paper combines this performance data and market trends with brief summaries of the ZNE policies and cost information from this and related research that are critical for program and policy considerations.

Introduction

ZNE has captivated the minds of leading building owners, design firms, schools, foundations and government agencies that are leading the way to a lower-carbon future. The *2014 Getting to Zero Status Update* (NBI 2014) presents findings on ZNE and ultra-low energy buildings and districts across North America.

Terminology

The commercial building industry lacks a consistent definition for ZNE. Some definitions, such as the International Living Future Institute's (ILFI) Living Building Challenge and Net Zero Energy Certification (ILFI 2014) require ZNE without any natural gas consumption; California has adopted a time-dependent valuation approach to ZNE (CEC 2011); and sometimes owners and designers refer to a building with both gas and electric as ZNE when they are offsetting only the electric consumption with photovoltaics.

When developing an inventory of ZNE buildings, definitions matter a great deal. For purposes of this paper, we use the definitions established in the *2014 Update* focused on whole-building energy consumption and measured energy outcomes. The definitions are:

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. Buildings on the ZNE Verified list are not restricted to electric-only buildings even though renewables typically offset only electric load.

ZNE Emerging buildings (or districts) have a publicly 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 made 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 number of buildings in the districts was not always known for this report.

Ultra-low Energy Buildings are comparable to ZNE buildings based on their low energy use, design strategies and technologies but do not have a stated goal of ZNE and do not offset all their annual energy consumption with onsite renewables. In this study, they are all "verified" with 12 or more months of measured energy use data that documents energy performance dramatically better than the industry average. Including these buildings in the study provided a greater data set of reference buildings with low energy outcomes. These buildings may have some renewable resources onsite or have provided the structure and/or wiring to incorporate renewable energy sources at a later date.

Study Methodology

The study team cast a broad net throughout North America to identify commercial and multifamily buildings targeting ZNE. Buildings with very low energy outcomes (ultra-low energy buildings) were also included because, with the exception of renewable energy production, they mirror the processes, design strategies, technologies and operations of ZNE buildings.

Sources included an internal database maintained by researchers, review of publications, presentations and awards programs, outreach to design and engineering firms and owners as well as a public call for project information to be submitted via an online ZNE Registry.

The minimum level of information sought included:

- 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

- Documentation verifying 12 months of onsite energy production, if applicable
- Cost information, if available

Energy performance information is notoriously difficult to collect. Data comes in many different forms. Energy dashboards did not necessarily provide information in a way that was consistent with the study approach. In those cases, follow-up from the owner or design team clarified results. Some of the 127 ZNE Emerging projects were simply unable to compile and deliver the requisite information due to time or resource constraints or lack of data availability.

ZNE verified designation for a building required review of documented monthly energy use and renewable production resulting in ZNE performance. Three methods were accepted: (1) utility bill statements, (2) publicly available report, data source, award or presentation, and (3) ILFI certification. ZNE verification for this study does not restrict gas use so long as all fuels are counted and, over the course of the year, the building consumes less than what was produced by renewables on the site.

The absence of measured data resulted in a project being placed on the ZNE emerging list even though it may actually be performing at ZNE. Additionally, data that was incomplete or showed the project did not achieve the zero target also stayed on the ZNE emerging list along with projects that are in design, under construction of not yet occupied for a full 12 months.

Counting ZNE: How Many Are There?

Interest in ZNE is growing rapidly among both public and private commercial building owners. Though the numbers are still small, it appears that ZNE serves as a quantifiable and aspirational goal that captures the interest of motivated owners and their design teams. Since the publication of the *Getting to Zero 2012 Status Update* (NBI 2012), the number of ZNE buildings, including ZNE verified and ZNE emerging, has more than doubled in North America. In 2014, researchers verified 32 ZNE buildings and 1 ZNE district. These numbers are summarized in Table 1.

Table 1. Number of ZNE and Ultra Low

Energy Projects from 2012 to 2014 Study

	2012	2014
ZNE verified	21	33
ZNE emerging	39	127
ZNE TOTAL	60	160

Table 1 shows there are now 160 ZNE buildings. The number of ZNE verified buildings has increased by 50% since the *2012 Getting to Zero Status Update* (NBI 2012), and the number of ZNE emerging projects has increased more than twofold. These 160 ZNE buildings are located in 35 U.S. states and Canada, as shown in Figure 1. These locations reflect all eight U.S. Department of Energy 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 (CA PUC 2011), utility programs (EUC 2014) and leading high performance design firms.

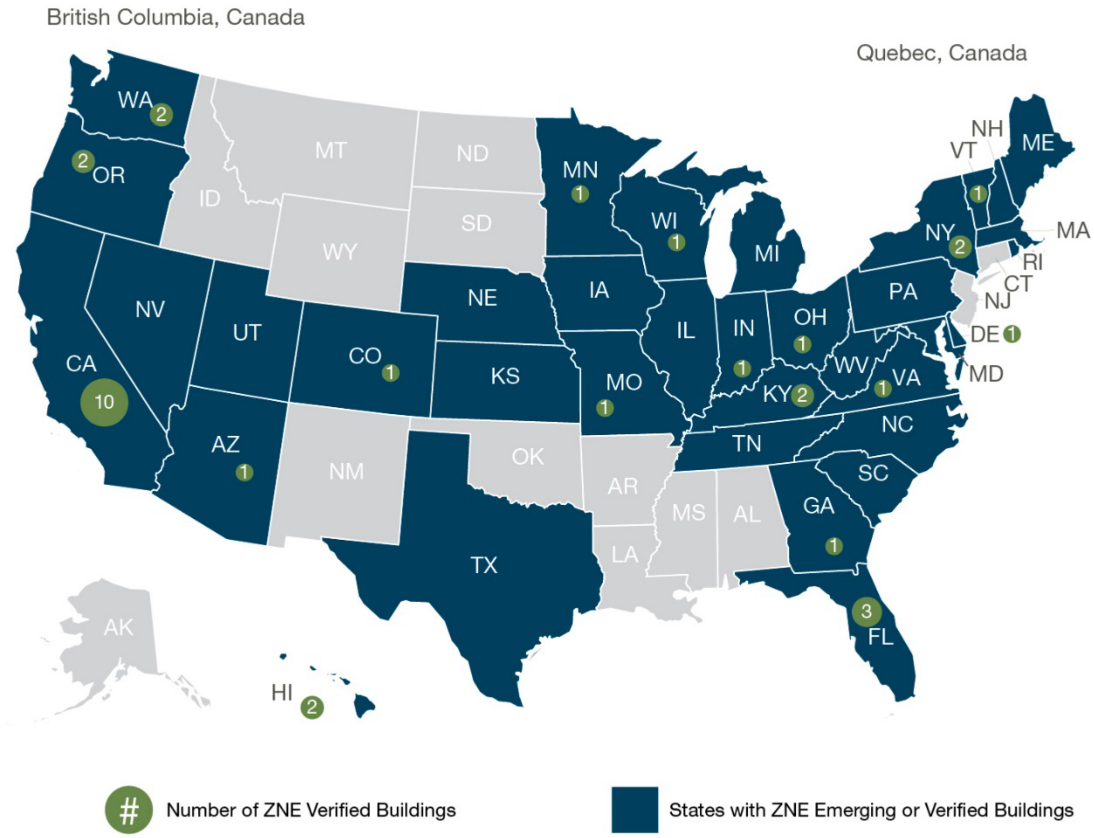

Figure 1. Locations of ZNE Buildings and Districts. *Source:* NBI, 2014.

As shown in Figure 2, the majority of ZNE buildings are small, although large buildings are also included in the ZNE data set. 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.

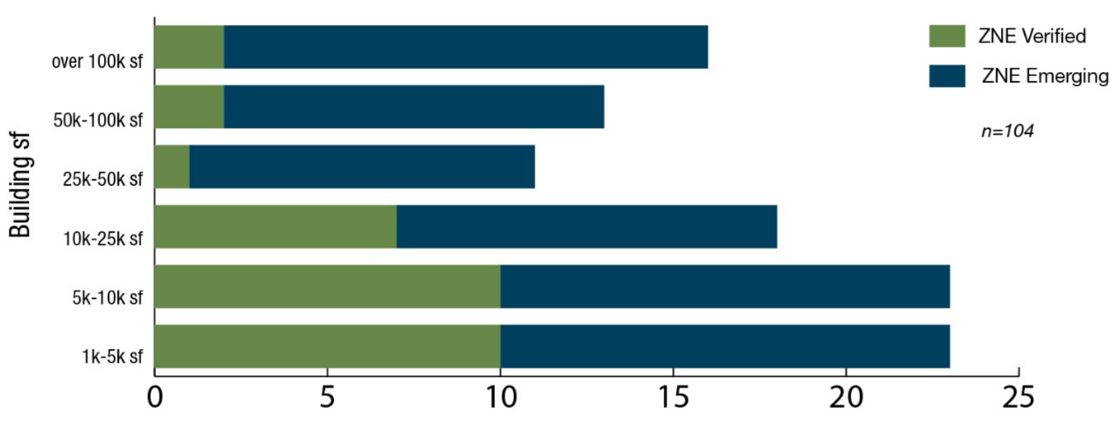

Figure 2. ZNE Buildings by Size. *Source:* NBI, 2014.

Sixteen different building typologies are represented on the list as shown in Figure 3. 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, followed closely by offices. Low-rise multifamily buildings are also represented on the ZNE list 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 science facilities, or unusual typologies, such as airports.

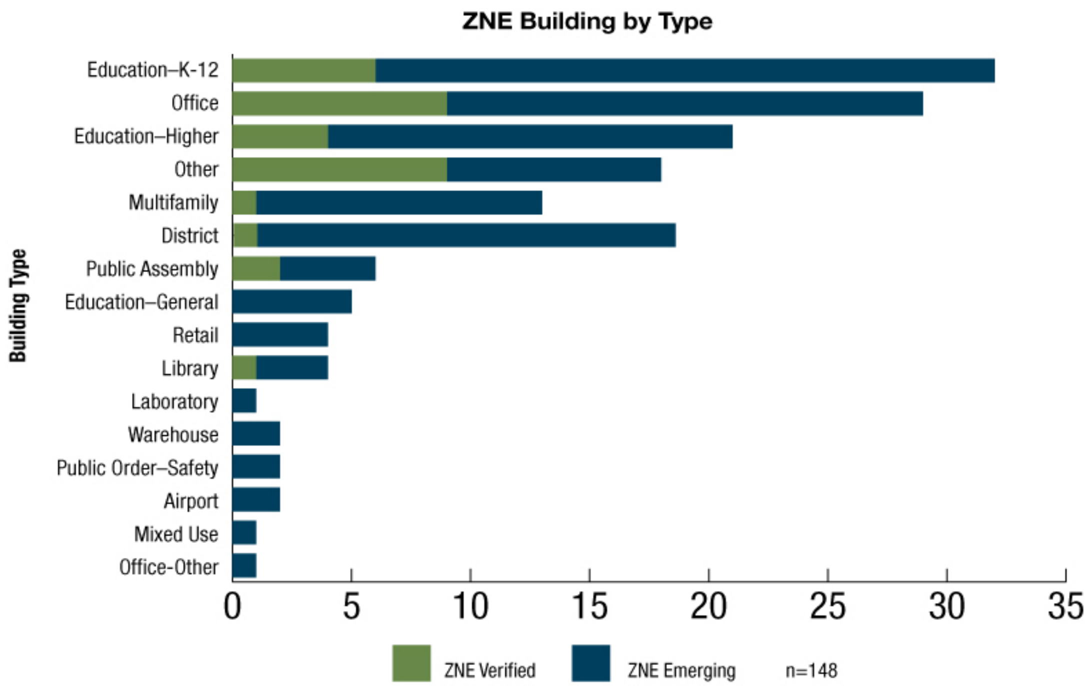

Figure 3. ZNE Buildings by Type. *Source:* NBI, 2014[1].

The research revealed four more noteworthy trends:

- First, 24% of the 33 ZNE verified buildings are renovations of existing buildings. This validates the potential for existing buildings to achieve ZNE through deep energy retrofits and the addition of photovoltaics during a major renovation.
- Second, districts are a growing trend toward scaled ZNE. Communities and campuses are adopting commitments to make groups of buildings ZNE. The U.S. Army and several leading universities were the major contributors to the final count.
- Third, two-thirds of all projects are government buildings, with public schools comprising the largest ownership type. Public owners are motivated by life-cycle cost savings, the resiliency offered by ZNE buildings, and an opportunity to educate, especially in the case of schools. Public buildings are also first to be targeted in carbon reduction policies.

[1] Note that this chart has been revised since the 2014 Update. An error has been corrected.

- Fourth, while public buildings are the early adopters, interest in ZNE is growing among private developers, with 25% of the buildings in the study privately developed.

Increase in the private sector adoption of ZNE in this study seems to be driven by two factors: (1) many are owner occupied and or providers of green services such as architects, engineers or contractors that want their building to be a showcase for their work or mission, and (2) recognition of increased market value through green building practices and attention to a label such as ZNE. Studies undertaken on certified green buildings have determined a rental rate premium for green buildings exists in many cases. (World Business Council for Sustainable Development 2013)

Energy Performance: Outcomes and Obstacles

In addition to verifying ZNE buildings, researchers investigated the measured energy performance of ultra-low energy buildings. These were verified using the same methods as ZNE buildings, however they did not include sufficient renewable energy production to offset all fuel use. 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.

The measured energy performance of two building types, offices and schools, was investigated more thoroughly. This information combined with the ZNE data begins to provide an understanding of what performance targets are achievable today. In the analysis, the "Average Building" numbers are taken from the Commercial Building Energy Consumption Survey (CBECS 2003). This is the source most often used to represent typical building energy use in the United States.

Figure 4 shows the EUI of 24 different ZNE verified and ultra high performance office buildings. The measured EUIs ranged from 13 to 33 kBtu/sf/year. The average EUI for all ZNE verified office projects (in green) is only 19 kBtu/sf/year, over 75% below the CBECS national average of 93 kBtu/sf/year (the horizontal dotted line in Figure 3). Even the average ultra-low energy office (in gold) is a mere 24 kBtu/sf/year, still well below the national average.

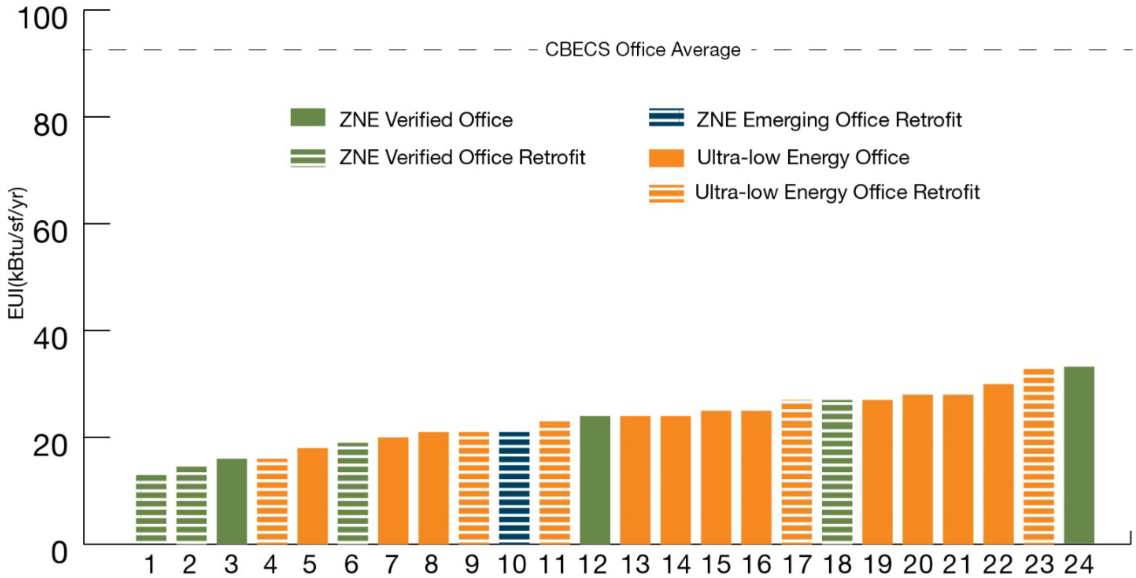

Figure 4. Measured EUI of ZNE and Ultra-low Energy Office Buildings. *Source:* NBI, 2014.

Figure 5 represents the energy performance of education buildings, split between K-12 schools and higher education. For educational facilities, the CBECS average is 83 kBtu/sf/year (the horizontal dotted line in Figure 5). All but one of the education buildings are operating at less than half the national average. ZNE verified education buildings (in green) have a larger EUI range of 3-48 kBtu/sf/year. 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 (in green and blue) has an EUI of just 22 kBtu/sf/year. The EUIs of ultra-low energy educational facilities range from 19 to 40, with an average EUI of just 27.

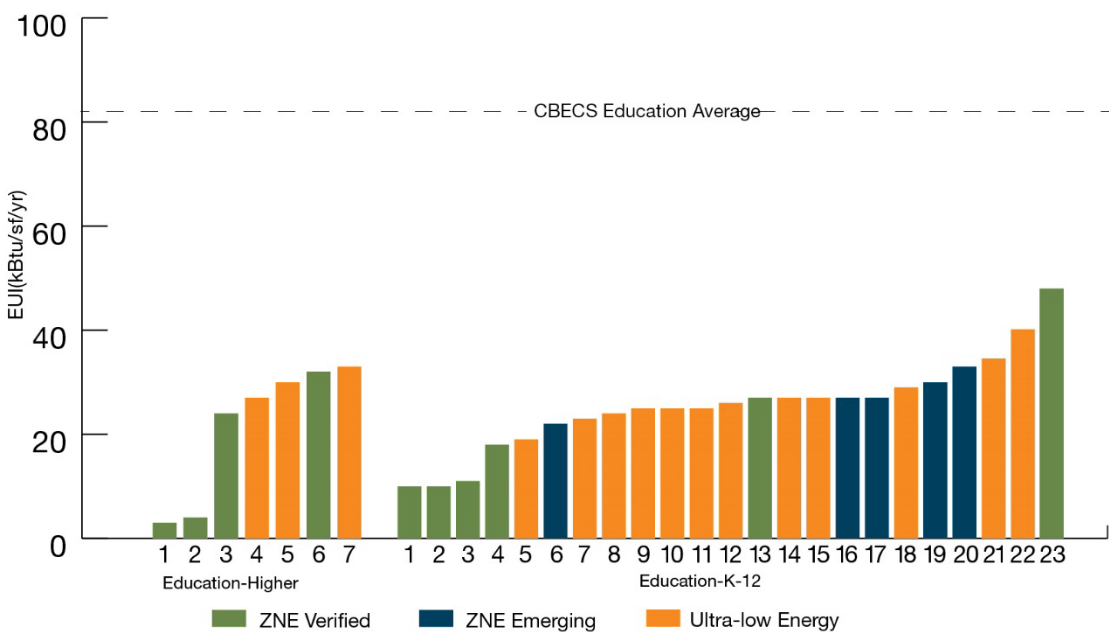

Figure 5. Measured EUI of Educational Buildings. *Source:* NBI, 2014.

Obstacles

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 (PV), 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.

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 DOE Buildings Performance Database (Energy.gov 2014) is encouraging, but all parties in the industry need to supply greater quantities of commercial building data.

Technologies and Strategies

A zero target appears to have an aspirational influence beyond that of traditional "percent-better-than" 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 rather than highly specialized or experimental technologies. The following section outlines some of the trends seen in the technologies and strategies employed to make the buildings ultra-low energy.

Process

Early consideration of the interactions of all systems, and occupants, simultaneously is expressed well by Don Campbell, Executive Director at National Electrical Contractors Association (NECA) during the development of the International Brotherhood of Electrical Workers (IBEW) ZNE Training center. (Forbes 2013)

"What came out loud and clear through our conversation was that – first and foremost – the creation of net zero buildings involves a highly complex, and potentially difficult exercise in coordination. Buildings are complicated organisms, and they include numerous systems which must be integrated. Our design and construction team needed to work together seamlessly in order to achieve this."

Success of ZNE buildings is predicated on a committed and motivated owner. Having a strong advocate providing the vision, business rationale and leadership on energy performance goals resulted in project buy-in and inspired others.

Additionally, many of these ZNE and ultra-low energy projects shared a critical design approach: 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.

These terms led to the development of a solar budget, developed early in the design process that calculates the renewable energy production opportunity at the site. This calculation of the amount of solar that can be generated at the site provided a guideline for the energy use targets and helped 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 critical to understanding how energy will be used in the building, including by occupants and their plugged-in devices.

Technical Approach

Projects looked at as part of this study used design approaches and state-of-the-shelf technology already proven and readily incorporated into high performance buildings. Most of these buildings also include passive design features such as appropriate solar orientation, the use of daylight as the primary light source, shading to control heat and glare, and natural ventilation including operable windows. Advanced lighting controls that reduce or eliminate electric lighting in response to the presence of natural light or vacancy by occupants are commonly used in the building set. These buildings go beyond code-required controls to layers of lighting (task, ambient and common area) and even control at the luminaire level.

Heating, ventilation and air conditioning (HVAC) systems move well beyond standard packaged units and variable air volume systems that address both space conditioning and ventilation requirements distributed by fans through ductwork. Instead, four HVAC trends stood out in the study group: (1) decoupling ventilation air from space conditioning, (2) including energy recovery on the return air supply, (3) moving away from forced-air ducted distribution systems, and (4) integration of ground source heat pumps.

Dedicated outside air supply (DOAS) units meet 100% of the ventilation air requirements and were a part of the HVAC approach at many of these projects. This allows for a more efficient design approach to meeting heating and cooling loads and occupant thermal comfort needs while isolating code requirements for outside air with a unit that provides ventilation air as efficiently as possible. Energy recovery systems coupled with the DOAS units, or with any HVAC system, temper the incoming air by transferring the heat or cooling from the air being vented out of the building to the incoming air. This reduces the difference in temperature that must be made up by the HVAC system. The retreat from forced-air systems was a move to reduce the significant portion of HVAC energy that is consumed by fans within the air distribution system. Radiant heating, chilled beams and variable refrigerant flow heat pumps are examples of these non-ducted systems. In addition, ground-source heat pumps, which served both ducted and radiant-based systems, were used at many projects.

The new Bullitt Foundations Headquarters building in Seattle, Washington is an example of a building that used a DOAS system (Schwer 2013). Figure 6 illustrates the integration of natural ventilation, daylighting, ground-source heat pumps serving radiant heating/cooling and a DOAS as some of the key strategies to get to ZNE.

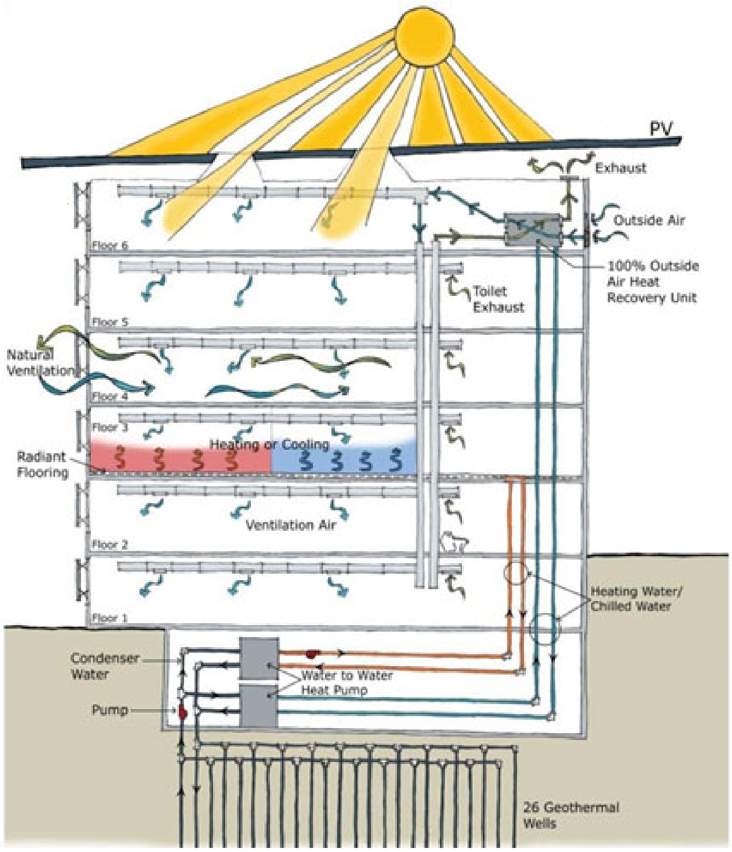

Figure 6. Integrated Systems at the Bullit Foundation Headquarters Building.

Renewable production was primarily through photovoltaic solar panels, though some projects had small onsite wind production. The rapid reduction in the cost of PVs has clearly made the path to zero more attainable. Still, some projects remained on the ZNE emerging list because they cited the cost of purchasing sufficient solar arrays to offset consumption as a barrier. Most plan to ultimately add PVs in future budget cycles to meet ZNE goals.

Operation and Occupancy

In addition to design approach and technologies, resulting low energy outcomes are highly dependent on two critical factors: operations and occupancy. Ongoing measurement and feedback is provided by systems that monitor building energy use and performance and provide targeted information to particular constituents, such as facilities managers or occupants. For the operator, these key performance indicators, along with a routine of data review, facilitate the need to continually maintain and modify systems to ensure optimum performance and an ongoing net zero result.

In ZNE and ultra-low energy buildings occupants become a larger part of the energy use, sometimes accounting for up to 50% of the total building load (Berton 2013), so these ZNE projects integrated plug-load strategies and occupant engagement strategies. Plug-load measures included controlled outlets, occupant sensing or controlled plug strips, optimum power management settings on equipment and selection of low-energy appliances and equipment through procurement. Occupants were engaged in the green objectives of the building through operations of windows in buildings with natural ventilation strategies, e-prompts regarding energy use systems, green campaigns encouraging plug loads to be turned off at night and competitions to promote occupant engagement.

Costs

While the primary focus of this research was on energy, collecting cost information was also an important objective as a secondary focus. Determining the costs for a low or zero energy building is difficult. With the exception of photovoltaic systems, very few projects are able to disaggregate the cost of efficient design and technologies from the overall cost of a new building. Yet understanding “incremental costs” for achieving ZNE is vital and frequently identified in market surveys as one of the most important topics to address.

One challenge is that ZNE buildings often rely on passive strategies and approaches which are more of a fundamental change in how the budget is allocated than an incremental adder. For example, at the Bullitt Foundation building in Seattle the design team created “the irresistible stairs” to discourage the use of elevators and promote occupant health and well-being (NY Times, 2013). This and other more traditional passive design strategies are difficult to incentivize since they can actually eliminate the need for systems.

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 PVs 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. 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 that were used to manage the overall project cost, such as energy load reduction and the associated reduced HVAC sizing.

Summary and Conclusions

ZNE has captivated the minds of leading building owners, design firms and others who are leading the way to a lower carbon future. In just a few years, ZNE has moved beyond a handful of demonstration projects to more mainstream building types and sizes.

The *2014 Getting to Zero Status Update* shows that low energy use is the foundation of ZNE buildings, and achieving low and zero energy can become standard practice for most commercial buildings today. State-of-the-shelf technology combined with a committed owner and design team, an early and ongoing integrated design process, passive systems, and attention to operations and occupancy are all critical to success.

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, as occupant loads in high performance buildings can comprise almost 50% of the overall building load in ZNE buildings.

Policy approaches can dramatically change the landscape for ZNE buildings. Cities and states are leading the way. Targeting schools and public buildings as early targets for ZNE has already happened in states such as Kentucky, and public benefit program administrators and utilities have already 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 measured energy targets for buildings rather than prescriptive measures. This can serve to advance codes to include traditionally "non-regulated loads" like plug loads. Data collected from benchmarking and disclosure policies is one source of information to establish these targeted outcomes. These targets can be used by government agencies, utilities and/or program administrators to reduce the risks inherent in piloting net zero projects and can accelerate the widespread adoption of ZNE into the mainstream.

References

Berton, B. 2013. An Environmental Model for the Next 250 Years: Seattle's Bullitt Center. http://urbanland. uli. org/news/an-environmental-model-for-the-next-250-years-seattles-bullitt-center/. Urban Land, November 26, 2013.

CA PUC (California Public Utility Commission), 2011. California Energy Efficiency Strategic Plan, Net Zero Energy Action Plan: Commercial Building Sector 2010-2012. Developed by ZNE Stakeholders, June 2011 Update.

CBECS (Commercial Building Energy Consumption Survey). 2003. http://www. eia. doe. gov/emeu/cbecs/cbecs2003/detailed_tables_2003/detailed_tables_2003. html#enduse03. Washington D. C.: U. S. Department of Energy

CEC (California Energy Commission) 2011. *Time Dependent Valuation of Energy for Developing Building Efficiency Standards*, Energy Environment and Economics, February 2011.

Energy.Gov Office of Energy Efficiency and Renewable Energy 2014. Building Performance Database available at http://energy.gov/eere/buildings/buildings-performance-database .

Energy Upgrade California, An alliance of the California Public Utilities Commission, California Energy Commission, utilities, regional energy networks, local governments, businesses and nonprofits, http://energyupgradeca.org/en/.

Forbes Magazine, June 2013. Kelly-Ketwiller, Peter, Building the Capacity to Increase Net Zero Construction.

ILFI (International Living Future Institute), 2014. Net Zero Energy Certification. Available at http://living-future. org/netzero. Seattle, WA.

NY Times (New York Times Square Feet). 2013. *A Building Not Just Green, but Practically Self-Sustaining.* Available at http://nyti.ms/10uGOss. April 2, 2013.

NBI (New Buildings Institute) 2012. New Buildings Institute. 2012. "Getting to Zero 2012 Status Update." http://newbuildings. org/sites/default/files/GettingtoZeroReport_0. pdf.

NBI (New Buildings Institute). 2014. "Getting to Zero 2014 Status Update." http://newbuildings. org/sites/default/files/2014_Getting_to_Zero_Update. pdf.

Schwer, P 2013. PV and the Electrical Grid: The Bullit Center Getting to Net Zero. http://annualmeeting2013.naseo.org/Data/Sites/2/presentations/PAE-Schwer-Bevan.pdf National Association of State Energy Offices 2013 Annual Meeting and Getting to Zero National Forum. September 17, 2013.

World Business Council for Sustainable Development, 2013. The Business Case for Green Building pp. 36.