A SUPPLEMENT TO BUILDING DESIGN+CONSTRUCTION

MARCH 2011

BUILDING DESIGN+CONSTRUCTION
INSPIRING THE BUILDING TEAM

Zero and Net-Zero Energy Buildings + Homes

Eighth in a Series of White Papers on the Green Building Movement

Net-Zero Energy: The Next Frontier in Green Building

Ready or not, the U.S. design and construction industry is about to embark on an exciting journey: the development of net-zero energy buildings and homes.

The past decade gave the AEC industry the green building movement, inspired by the U.S. Green Building Council's Leadership in Energy and Environmental Design rating system. Now the U.S. design and construction industry is about to set forth on an uncharted and perhaps even more adventuresome path.

The stakes are high. Executive Order 13514 of October 2009 directs federal agencies, beginning in 2020, to achieve net-zero energy use in new construction and renovations by 2030. At least 15% of existing federal buildings need to meet the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings by 2015.

The Energy Independence and Security Act of 2007 set a goal of net-zero energy use for all commercial buildings by 2030. EISA 2007 further specified a net-zero energy target of 50% of U.S. commercial buildings by 2040 and a net-zero standard for 100% of new and existing commercial buildings by 2050.

The U.S. General Services Administration has commissioned a number of net-zero energy buildings. The U.S. Department of Energy is developing measures that are designed to lead to cost-effective "NZEBs" by 2025.

In his 2011 State of the Union Address, President Obama proposed a Better Buildings Initiative whose goal is to make all commercial buildings 20% more energy efficient by the end of the decade.

We submit our eighth White Paper on Sustainability in the hope that it will inspire architects, engineers, contractors, building owners, developers, building product manufacturers, environmentalists, policymakers, government officials, corporate executives, officeholders, and the public to foster the development of net-zero energy buildings and homes.

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A Note on Terminology: For the sake of stylistic uniformity, the editors have used the terms "net-zero energy buildings" and "NZEBs" throughout this report. Readers are referred to Chapter 1 for further discussion of terms and definitions. At the author's discretion, Chapter 4 also uses unique terms.

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1. Defining Net-Zero Energy Buildings

By Paul Torcellini, PhD, PE, and Shanti Pless, LEED AP

Paul Torcellini is Group Manager for Commercial Buildings Research and Shanti Pless is a Senior Research Engineer at the National Renewable Energy Laboratory, Golden, Colo.

Net-zero energy buildings (NZEB) have been the subject of research initiatives at the National Renewable Energy Laboratory and in the Department of Energy in recent years. In 2006, we and our NREL colleague Michael Deru and our DOE colleague Drury Crawley published "Zero Energy Buildings: A Critical Look at the Definition," an early attempt to reach a common definition, or even a common understanding, of what the term "zero energy building" means.[1]

With the passage of the Energy Independence and Security Act of 2007, the pace of activity surrounding net-zero energy buildings quickened. EISA 2007 authorized the Department of Energy to host industry-led Commercial Building Energy Alliances and to establish the Net-Zero Energy Commercial Building Initiative, whose mandate is to support the goal of net-zero energy for all new commercial buildings by 2030.[2] EISA 2007 further specifies a net-zero energy target of 50% of all U.S. commercial buildings by 2040 and a net-zero standard for *all* commercial buildings, new and existing, by 2050. Toward this end, the Department of Energy has set a goal of creating the technology and knowledge base for cost-effective net-zero energy commercial buildings (NZEBs) by 2025.

In response to this aggressive agenda, in 2009 we, along with Dru Crawley, took the next step in our discussion of net-zero energy buildings with the publication, in ASHRAE Journal, of "Getting to Net Zero."[3] Last year, we added another dimension to the definitions based on a hierarchy of possible renewable energy supply options for NZEBs, in "Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options."[4]

This chapter summarizes the key points in our effort to create a workable set of definitions for NZEBs, based on these three documents. The formulation of the definitions was guided by two basic principles: 1) energy efficiency and demand-side technologies need to be optimized first, before renewable energy supply is considered; it is almost always easier to save energy than to produce it; and 2) the fewer the number of energy transfers, the better. Readers of this White Paper who wish to follow our discussion more closely are invited to access the original articles online.

SEEKING A WORKABLE CONSENSUS

The quest for ever greater precision in measuring energy performance has uncovered the need for greater precision in the definition of "net-zero energy performance." What do design and construction professionals, building owners, energy experts, government officials, and others involved in the built environment mean by this term?

In concept, an NZEB is a building with greatly reduced operational energy needs. In such a building, sufficient efficiency gains will have been made such that the remaining portion of the building's energy needs could be offset by renewable technologies. An NZEB should have no adverse energy or environmental impacts associated with its operation. In other words, an NZEB should be highly energy efficient and capable of producing at least as much energy over the course of a year as it draws from the utility grid.

To arrive at a consensus definition, Building Teams involved in an NZEB project must evaluate two interrelated concerns:

• How will the team account for energy use? Some projects may target net-zero energy at the site. Others might allow purchased renewable energy to supplement

The San Ysidro Land Port of Entry, on the border with Mexico, is the busiest such facility in the world. PVs and a closed-loop geo-exchange system contribute to its efficient energy use.

RENDERING: MILLER HULL PARTNERSHIP

1 Paul Torcellini, Shanti Pless, Michael Deru, Drury Crawley, "Zero Energy Buildings: A Critical Look at the Definition" (2006), NREL Report No. CP-550-39833, presented at 2006 ACEEE Summer Study, 14-18 August 2006, Pacific Grove, Calif. At: www.nrel.gov/docs/fy06osti/39833.pdf.

2 See Chapter8 for more on these and other NZEB-related programs.

3 Drury Crawley, Shanti Pless, Paul Torcellini, "Getting to Net Zero," ASHRAE Journal, September 2009. NREL Report No. JA-550-46382. At: www.nrel.gov/docs/fy09osti/46382.pdf.

4 Shanti Pless, Paul Torcellini, "Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options" (2010). NREL Report No. TP-550-44586. At: http://www.nrel.gov/docs/fy10osti/44586.pdf

5 See Chapter 6 for an example of a prototype zero emissions project.

on-site renewables, with that energy accounted for at the source. Still others might put primary emphasis on energy cost, with the goal being to offset any purchased energy with the sale of revenues from on-site renewable energy. Lastly, some might target net-zero emissions of greenhouse gases.[5]

• What are the physical boundaries for choosing among renewable energy options? If a project targets net-zero energy use at the site, that limits the choice of renewables to sources and technologies available within the building footprint or at the site. Other projects might use renewable energy sources from beyond the site (e.g., biomass) to produce power at the site, while others might incorporate purchased renewables, such as renewable energy certificates (RECs).

Agreeing on energy-use accounting and the choice of renewables is pivotal to determining the design goals and strategies of NZEBs.

These factors guided us in formulating the following definitions for various types of net-zero energy buildings (note: NZEBs are assumed to be grid-connected):

Net Zero Site Energy: A site NZEB produces at least as much energy as it uses in a year, when accounted for at the site.

Net Zero Source Energy: A source NZEB produces (or purchases) at least as much renewable energy as it uses in a year, when accounted for at the sources. Source energy refers to the primary energy used to extract, process, generate, and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers, based on the utility's source energy type.

Net Zero Energy Costs: In a cost NZEB, the amount of money the utility pays the building owner for the renewable energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.

Net Zero Emissions: A net-zero emissions building produces (or purchases) enough emissions-free renewable energy to offset emissions from all energy used in the building annually. Carbon, nitrogen oxides, and sulfur oxides are common emissions that NZEBs offset. To calculate a building's total emissions, imported and exported energy is multiplied by the appropriate emissions multiplier, based on the utility's emission and on-site generation emissions (if any).

CLASSIFICATION SYSTEM BASED ON RENEWABLES

More recently, we have added to our definitions by developing a classification system based on the renewable energy sources used in the four types of NZEBs. This classification system starts with the premise that all NZEBs must first reduce site energy use through energy efficiency and demand-side renewable building technologies, including such strategies as daylighting, insulation, passive solar heating, high-efficiency HVAC equipment, natural ventilation, evaporative cooling, and ground-source heat pumps.

As shown in Table 1-1, the classification system breaks down NZEBs into two groups, one that uses on-site supply options, another that uses off-site renewables. At the highest level of the classification system is NZEB:A, a building that offsets all its energy use from renewable sources within its footprint. Next in rank is NZEB:B, which obtains some or all of its renewable energy from the project site—for example, photovoltaics that are mounted on the ground.

NZEB:C buildings use renewables from off the site, such as biomass or wood pellets. At the lowest end is NZEB:D, which uses a combination of on-site renewables and off-site purchases of renewable energy credits.

There is no "best" definition of net-zero energy buildings, nor is there a "best" method for accounting for energy use. Each has its merits and drawback, and Building Teams should select the appropriate approach for each project to align with the client's goals.

However, across all NZEB definitions and classifications, one design rule remains constant: reduce energy demand to the lowest possible level first, then address energy supply. NZEB teams should use all possible cost-effective energy-efficiency strategies first before incorporating renewables. Preference should be given to sources available within the footprint, such as solar hot water. Using on-site renewables minimizes the NZEB's overall environmental impact by reducing losses incurred from transportation, transmission, and conversion losses of off-site renewable energy sources.

OFF-GRID NET-ZERO ENERGY BUILDINGS

Achieving an NZEB without the grid is very difficult, largely because the current generation of energy storage technologies is limited. Most off-grid buildings rely on outside energy sources such as propane for space heating, water heating, and backup generators. Off-grid buildings cannot feed their excess energy production back onto the grid to offset other energy uses. As a result, the energy production from renewable resources must be oversized. In many cases (especially during the summer), excess generated energy cannot be used.

It is possible, though, to have a grid-independent NZEB. To do this, any backup energy needs would have to be supplied from renewable resources such as wood pellets or biodiesel. An off-grid building that uses no fossil fuels could be considered a pure NZEB, as no fossil fuels or net annual energy balances would be needed or used.

NET-ZERO ENERGY BEYOND SINGLE BUILDINGS

As NZEBs become technically and economically feasible, extending their boundaries to groups of buildings—net-zero energy campuses, communities, towns, bases, and cities—may become more and more realistic. Extending the net-zero energy boundary beyond a single building addresses the emergence of communities, neighborhoods, and campuses that would generate renewable energy for a certain group of buildings; however, the energy would not necessarily connect directly to a specific building's utility meter. This would be considered a community-based renewable energy system that would be connected to the grid or to a district heating or cooling system.

For a large organization or neighborhood, it is often more cost-effective and efficient to generate renewable energy in a central location on campus or in the community, rather than on (or in addition to) individual buildings. Community-scale systems allow for a single point for all maintenance and offer economies of scale—larger, central systems can be better optimized and cost less per kilowatt of generation capacity.

Community-based renewable energy systems, however, have some transmission and distribution losses when providing energy directly to a building. Inefficiencies

Table 1-1.
CLASSIFYING NZEBS BY RENEWABLE ENERGY SUPPLY

NZEB Classification		NZEB Supply-side Options	NZEB Definitions
ON-SITE SUPPLY OPTIONS	A	Use renewable energy sources available within the building's footprint and directly connected to the building's electrical system or hot chilled water distribution system. Examples: PVs, solar hot water, building-integrated wind systems.	Feasible for: Site, Source, and Emissions NZEBs Less feasible for: Cost NZEBs • If the source and emissions multipliers for an NZEB:A are high during times of utility energy use but low during times the NZEB is exporting to the grid, reaching a source or emissions NZEB position may be difficult. • Qualifying as a cost NZEB may be difficult depending on the net metering policies in the area.
	B	Use renewable energy sources as described in NZEB:A and Use renewable energy sources available at the building site and directly connected to the building's electrical or hot/chilled water distribution system. Examples: PVs, solar hot water, low-impact hydroelectric, and wind located on parking lots or djacent open space, but not physically mounted on the building.	Feasible for: Site, Source, Cost, and Emissions NZEBs Less feasible for: Cost NZEBs • If the source and emissions multipliers for an NZEB:B are high during times of utility energy use but low during times the NZEB is exporting to the grid, reaching a source or emissions NZEB position may be difficult. • Qualifying as a cost NZEB may be difficult depending on the net-metering policies in the area.
OFF-SITE SUPPLY OPTIONS	C	Use renewable energy sources as described in NZEB:A, NZEB:B, and NZEB:C and Use renewable energy sources available off site to generate energy on site and directly connected to the building's electrical or hot/chilled water distribution system. Examples: biomass, wood pellets, ethanol, or biodiesel that can be imported from off-site, or collected from waste streams from on-site processes that can be used on-site to generate electricity and heat.	Feasible for: Site NZEBs Less feasible for: Source, Cost, and Emissions NZEBs An NZEB:C source and emission position may be difficult if carbon-neutral renewables such as wood chips are used or if the NZEB has an unfavorable source and carbon multipliers. This can occur if an NZEB exports energy during times that the utility has low source and carbon impacts, but imports energy when the utility has high source and carbon impacts. NZEB:C buildings typically do not reach a cost NZEB position because renewable materials are purchased to bring on-site—it would be very difficult to recoup these expenses by any compensation received from the utility for renewable energy generation.
	D	Use renewable energy sources as described in NZEB:A, NZEB:B, and NZEB:C and Purchase recently added off-site renewable energy sources, as certified from Green-E (2009) or other equivalent renewable-energy certification programs. Continue to purchase the generation from this new resource to maintain NZEB status. Examples: Utility-based wind, photovoltaic, emissions credits, or other "green" purchasing options. All off-site purchases must be certified as recently added renewable energy (Green-E 2009). A building could also negotiate with its power provider to install dedicated wind turbines or PV panels at a site with good solar or wind resources off-site. In this approach, the building might own the hardware and receive credits for the power. The power company or a contractor would maintain the hardware.	Feasible for: Source NZEBs, Emissions NZEBs Less feasible for: Site NZEBs, Cost NZEBs NZEB:D buildings may qualify as source and emissions if they purchase enough renewable energy and have favorable source and emissions factors. They will not qualify as Site or Cost NZEBs.

Source: "Getting to Net Zero," ASHRAE Journal, September 2009. NREL Report No. JA-550-46382.

and costs such as distribution piping and wiring, pumping losses, distribution transformers, and thermal losses are often associated with district distribution systems, whereas this is generally not the case with a building-based renewable energy generation systems.

The energy use accounting methods and renewable energy supply hierarchy concepts we have developed for standalone NZEBs still apply to net-zero energy communities. A parallel definition system further defines net-zero energy communities and extends the single-building net-zero concepts to multiple buildings with districtwide renewable energy systems.[6]

ENCOURAGING BUILDING TEAMS TO ACT

This classification system begins ranking energy supply options in the NZEB context. As Building Teams and property owners look to design NZEBs, they must begin a discussion of which classification to seek in order to set workable goals for their projects. Since the publication of the initial NZEB definition paper we have applied these definitions to multiple real-world NZEB examples with various renewable energy options. Some of the buildings used to evaluate these definitions can be found in the Zero Energy Buildings Database, which was developed by the U.S. Department of Energy.[7]

In addition to refining the definitions, we felt that it would be beneficial to classify buildings based on how well they achieve NZEB status by considering which renewable energy supply options they use. We have developed a simple flow chart that illustrates how to navigate the prerequisites and classification requirements to classify NZEBs.[8]

This classification system is meant to encourage, when possible, energy-efficiency strategies, followed by the use of footprint and on-site renewable energy to power buildings. The long-term benefits of these options are numerous:

1. Optimized usability of power-generation capacity in the NZEB context
2. Less reliance on the grid (and therefore less need for investment in the grid)
3. Less energy required because energy losses through conversion, transmission, and distribution would be minimized
4. Fewer peak demand problems with utilities

Ultimately, it is our hope that Building Teams will be encouraged to create more energy-efficient, high-performance structures if the buildings must generate their own energy. BD+C

6 Nancy Carlisle, AIA, Otto Van Geet, PE, and Shanti Pless, LEED AP, "Definition of a 'Zero Net Energy' Community," NREL Report No. TP-7A2-46065. At: http://www.nrel.gov/docs/fy10osti/46065.pdf.

7 At: www.eere.energy.gov/buildings/commercial_initiative/zero_energy_projects.html.

8 At: www.BDCnetwork.com/NZEBflowchart.

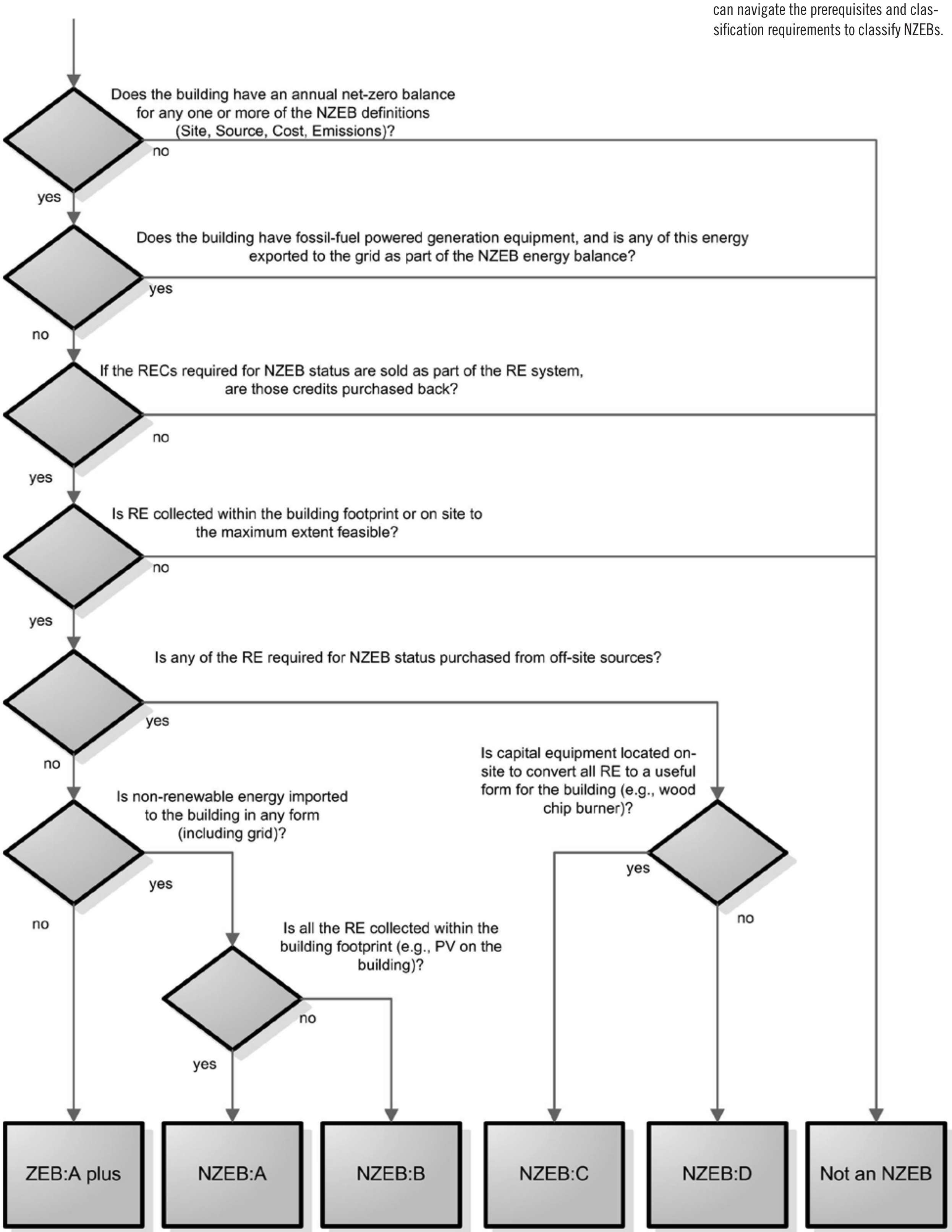
Table 1-2.
PLUSES AND MINUSES OF NZEB DEFINITIONS

Definition	Pluses	Minuses	Other concerns
Site NZEB	• Easy to implement • Verifiable through on-site measurements • Conservative approach to achieving NZEB • No externalities affect performance, can track success over time • Easy for the building community to understand and communicate • Encourages energy-efficient building designs	• Requires more PV export to offset natural gas • Does not consider all utility costs (can have a low load factor) • Not able to equate fuel types • Does not account for non-energy differences between fuel types (availability of supply, pollution)	
Source NZEB	• Able to equate energy value of fuel types used at the site • Better model for impact on national energy system • Easier NZEB to reach	• Does not account for non-energy differences between fuel types (availability of supply, pollution) • Source calculations too broad (does not account for regional or daily variations in electricity-generation heat rates) • Source energy use accounting and fuel switching can have a larger impact than efficiency technologies • Does not consider all utility costs (can have a low load factor)	• Need to develop site-to-source conversion factors, which require significant amounts of information to define
Cost NZEB	• Easy to implement and measure • Market forces result in a good balance between fuel types • Allows for demand-responsive control • Verifiable from utility bills	• May not reflect impact to national grid for demand, as extra PV generation could be more valuable for reducing demand with on-site storage than exporting to the grid • Requires net-metering agreements such that exported electricity an offset energy and non-energy charges • Highly volatile energy rates make for difficult tracking over time	• Offsetting monthly service and infrastructure charges requires going beyond NZEB • Net metering is not well established, often with capacity limits and at buyback rates lower than retail rates
Emissions NZEB	• Better model for green power • Accounts for non-energy differences between fuel types (pollution, GHGs) • Easier NZEB to reach		• Need appropriate emissions factors

Source: "Zero Energy Buildings: A Critical Look at the Definition" (June 2006). NREL Report No. CP-550-39833.

FIGURE 1-1.
NZEB FLOW CHART

Flow chart illustrates how Building Teams can navigate the prerequisites and classification requirements to classify NZEBs.



2. Net-Zero Energy Buildings: What the Case Studies Teach Us

By Barbara Horwitz-Bennett, Contributing Editor

An analysis of several noteworthy case studies reveals a number of prerequisites that are essential to make net-zero energy building projects feasible. "Delivering a net-zero energy project requires an engaged client, an experienced design team and contractor, and a commitment to best practices and innovation," states William D. Brooks, AIA, LEED AP, a principal with Ferraro Choi & Associates (www.ferrarochoi.com), whose Honolulu-based firm designed the LEED Platinum, net-zero Hawaii Gateway Energy Center in Kailua-Kona.

Because NZEB design is a significant departure from traditional design and project delivery, Building Teams must be on board with four essentials:

1. Owner buy-in and the associated cultural change required of the organization.
2. Absolute resolve by all members of the Building Team to achieve zero energy.
3. A highly collaborative, integrated, and clearly focused project process, with the energy consultant/modeler playing a key role.
4. Priority given to the building's energy use and an understanding that this factor will largely dictate the architectural design.

Marin Country Day School, Corte Madera, Calif., a 23,094-sf NZEB powered by a 95.5 kW PV array. Natural ventilation, cold water storage, solar shading, daylighting, and occupancy sensors were used to keep energy consumption to a minimum.

Gaining owner buy-in. Because net-zero energy buildings are dependent on passive design strategies and minimized energy loads, they ultimately require some compromise—for example, smaller offices and fewer copy machines per floor.

"A low-energy building relies first on the architecture—a narrow footprint, daylighting, thermal mass, passive and free energy solutions—but these can all be short-circuited by some traditional workplace solutions like private offices along the exterior walls and high partitions between workstations," says Tom Hootman, AIA, LEED AP, director of sustainability, RNL Design (www.rnldesign.com), Denver, whose firm headed the design-build team for the 222,000-sf National Renewable Energy Lab's new Research Support Facility (RSF) in Golden, Colo., currently the largest completed net-zero energy building in the United States.

In the case of the RSF project, the organizational leadership at the Department of Energy understood the need to forgo traditional perks and conveniences. "I was pleased that our leadership was willing to back the cultural implications of a zero-energy building, for example, going with laptops instead of desktop computers and reducing the number of copy machines," said Ron Judkoff, NREL's Principal Buildings Program Manager. "These kinds of cultural changes can only happen if supported from above."

To get that kind of cooperation on the part of the owner, Building Teams must be very active—almost to the point of being forceful—in explaining the ins and outs of net-zero to the client, and the types of decisions the client will be called upon to make as the project progresses.

"The need for ongoing communication and re-education of a very supportive and collaborative client can be a challenge," according to Drew Gangnes, director of civil engineering, Magnusson Klemencic Associates (www.mka.com). The Seattle-based structural engineering firm is working on the General Services Administration's San Ysidro U.S. Land Port of Entry, located in the busy corridor between San Diego and Tijuana, and tracking net-zero for the occupied buildings. "Each energy system piggybacks on the other, so it's vital to look at it as a collective entity and very clearly explain the process every step of the way."

Complete commitment by the Building Team. Having a dedicated client is not enough to guarantee success with NZEBs. The Building Team members themselves must be committed to investing the extra time, energy, and resources to achieve net-zero.

Take the case of the GSA's Otay Mesa Land Port of Entry, on the California/Baja border. "Most people would consider the design to be straightforward, employing tried-and-true strategies," says David E. Leites, LEED AP, a project manager with the design and construction division of GSA's Pacific Rim region. The innovative part, he says, is in "the intention and determination of the project team."

Furthermore, the initial project objectives must clearly put the goal of achieving net-zero in the forefront. "The most important piece of planning for a net-zero project is setting metrics for energy conservation levels at the beginning of the process," says William Maclay, AIA, a principal with Maclay Architects (www.maclayarchitects.com), Waitsfield, Vt., whose firm has delivered several net-zero energy building projects. "This ensures that all members of the team are on the same page and working toward the same measurable goals."

In the case of the $64 million Research Support Facility, the National Renewable Energy Lab prioritized its goals for the project and spelled them out in the RFP's project objective checklist. The project would be certified at LEED Platinum, with energy performance at least 50% better than ASHRAE 90.1-2004, and, of course, net-zero energy use. These and many other details were spelled out in a 500-page design-build document. This clear delineation of objectives gave the Building Team "a real sense of mission, which was incredibly mobilizing," according to Philip Macey, AIA, director of engineering and sustainability for the general contractor, Haselden Construction (www.haselden.com), Centennial, Colo.

Collaborative design, led by the energy experts. In less complex projects where net-zero energy is not the overriding goal, Building Teams may be able to "get away with letting the goals sort themselves out as you move along in the project," states David Okada, an associate based in Stantec Engineering's (www.stantec.com) San Francisco office, whose firm did the energy modeling and mechanical/electrical design for the NREL project. For a project with aggressive goals like those of the Research Support Facility, goals and priorities "won't just fall in place by themselves," says Okada. The design team must be given clear direction from the client and must fully embrace that directive.

Yet another crucial component of the RSF planning effort was the use of an integrated delivery model to capitalize on the talents and resources of all members of the Building Team. The group kicked off RSF with an interdisciplinary charrette to brainstorm ideas; then, as the project proceeded, key decisions were made via an

PHOTO: GEORGE HEINRICH

The 1,700-sf Science House (at center in photo) features an 8.8 kW photovoltaic array and ground-source heat pumps. The Building Team consisted of Barbour LaDouceur Design Group (architect), Vareberg Engineering (EE), Martin Mechanical Design (ME), The Weidt Group (environmental consultant), and LS Black Constructors.

CHART 2-1.
TOP 10 ENERGY-CONSERVING STRATEGIES USED IN THE SCIENCE MUSEUM OF MINNESOTA'S SCIENCE HOUSE

		Percent of PV capacity
1	Dimming daylight controls with high-performance glazing	54%
2	Heat pump-improved efficiency	44%
3	Heat pump-assisted hot water	25%
4	Classroom direct system at 50 foot-candles	24%
5	Occupancy sensor control of all lights	24%
6	R-28 wall insulation	12%
7	Unoccupied temperature setback/setup	11%
8	Total ventilation recovery	7%
9	R-40 roof insulation	4%
10	Private office task/ambient lighting design	4%

Source: The Weidt Group

The "percent of PV capacity" is the percentage by which each strategy hypothetically reduced the amount of photovoltaics in the Science House project. The calculation in the chart is: kWh savings for a strategy / kWh generation of the PV system = strategy savings as a % of PV capacity. According to David Eijadi, FAIA, LEED AP, BD+C, a principal with The Weidt Group, the chart was created during the design stage to see how to balance energy efficiency against energy generation. Energy generation via PV was governed both by cost and by the limitation of the roof area. The PV capacity assumed was 10,000 kWh/year (which, according to Eijadi, is what the system currently generates when operating at 100%) and was based on budgeted cost, roof area, and PV efficiency. The chart was used to communicate to the owner and architect the additional size and cost of the PV array if any of the given strategies was omitted. Thus, a daylighting strategy that saves 5,400 kWh would have a % PV capacity of 54% (5,400 kWh/10,000 kWh). In other words, without the daylighting strategy, 54% more PV capacity would have to be added in order for the building to remain at net-zero.

interdisciplinary decision-making process, with energy use at the forefront of the group's thinking, according to RNL Design's Hootman. It is likely that the use of some form of integrated project delivery (IPD) will be assumed, if not required, in future NZEB projects.

Energy modeling as the chief design component. The U.S. Department of Energy has played a major role in the development of energy modeling going back to the mid-1970s, with the development of its DOE-1 and DOE-2 energy simulation software. It is not surprising, therefore, that energy modeling was used extensively in the Research Support Facility project as a design tool in and of itself, as opposed to merely as a design verification tool. This raises another important distinction between NZEBs and more conventional projects: the fact that the energy profile ultimately determines the building's form and structure.

"We took a much deeper dive into the energy modeling in terms of the level of detail," says Stantec's David Okada. "Many aspects of the building could not be simulated with standard software, so we had to put a lot of work into building calculation methodologies from scratch."

"Our first model was an energy model, and our first drawing of the main building section fixed the main energy strategies into place," says RNL's Hootman. "The energy drove the architecture, which meant, in this case, a building form with narrow, long wings." Based on Stantec's energy simulations, the RSF team was able to determine how to orient the building, how deep to set the floor plates, and how much glazing to put on the façade.

For example, the designers had to compromise on the amount of glass on the facades to keep the energy loads under control, bringing the window-to-wall ratio on the north and south façades to an average of 25%. "Many architects would have been outraged to have been limited to that amount of glass," says NREL's Judkoff. "I have to give the architectural team an awful lot of credit for being willing to go along with it." Through the use of electrochromic glass and unique window shading devices, the designers were still able to provide more than 600 windows, thus opening up the walls to allow daylighting to penetrate to the interior workspace (see "Windows Keep Green Goals in View," *Building Design+Construction*, October 2010, at: http://www.bdcnetwork.com/article/windows-keep-green-goals-view).

Window design was also crucial to the design of the net-zero energy Science Museum of Minnesota's Science House, in St. Paul. "Window placement, rather than being based exclusively on views and facade composition, was based almost entirely on its impact on the building's energy efficiency through passive solar and daylighting strategies," says David Eijadi, FAIA, LEED AP BD+C, a principal with The Weidt Group (www.twgi.com), Minnetonka, Minn., which served as the environmental building consultant on the project. Science House is currently producing about 30% more energy than it consumes.

Since every watt counts in net-zero energy projects, the energy modeling simulations must be extremely detailed. Shoehorning the energy analysis into the fast-tracked design-build process for the NREL project was extremely demanding of the Building Team and provides an important lesson for others. "It's really important to make sure that the energy accounting/modeling work is factored into the design and construction schedule," says Stantec's Okada, who acknowledges that the design process "could have gone a lot smoother if the timeframes for modeling were incorporated into the project schedule."

MANAGING MULTIPLE DESIGN FACTORS

Plug load: The hidden energy sinkhole. Even though energy modeling and innovative energy-efficient designs will certainly go a long way toward achieving net-zero, the shocking fact is that in terms of a building's

RENDERING: TATE SNYDER KIMSEY ARCHITECTS

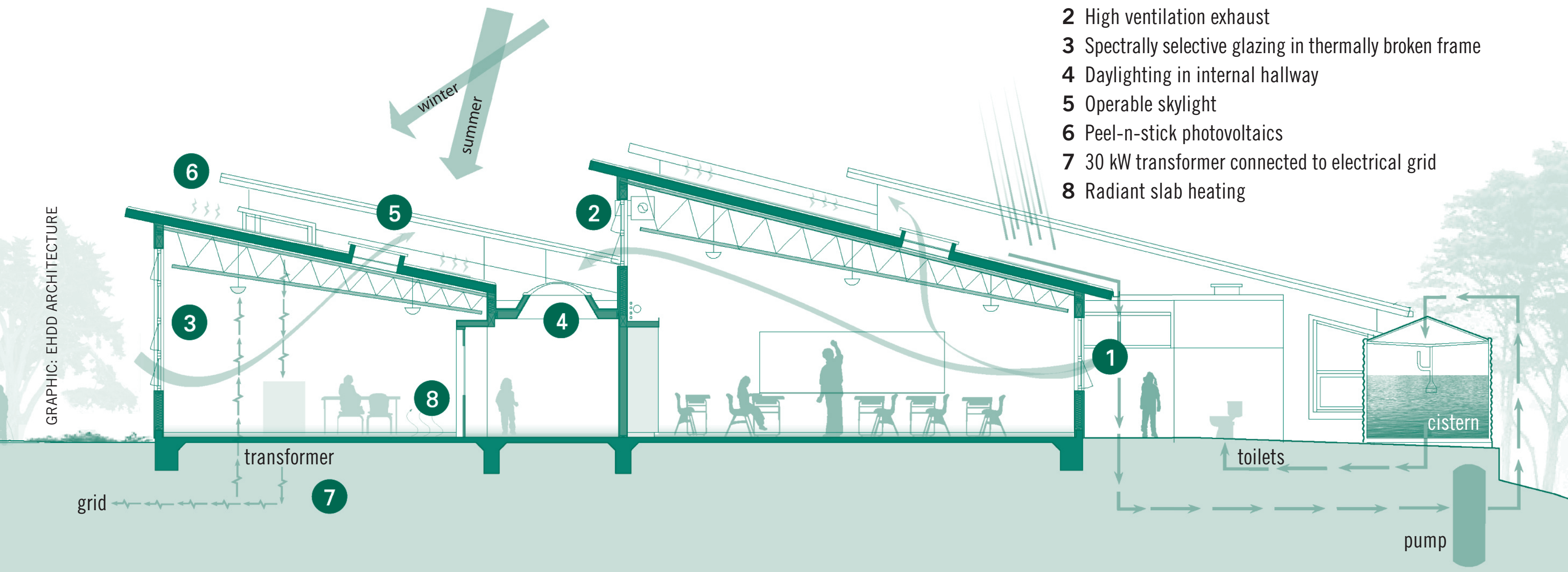
The Otay Mesa (Calif.) Land Port of Entry, one of a number of net-zero energy projects commissioned by the U.S. General Services Administration, will be powered by a 280 kW photovoltaic system. The GSA is also testing more than a dozen "proving ground technologies," such as kinetic energy machines. Tate Snyder Kimsey Architects and IBE Consulting Engineers are the design team, with Lam Parters (lighting) and Greg Gordon & Associates (SE).

Step-by-step Design Map to Net-Zero Energy

William Maclay, AIA, a principal with Maclay Architects, Waitsfield, Vt., offers this step-by-step guide to net-zero energy building design:

1. Employ a highly collaborative, integrated design process.
2. Elongate the building along the east-west axis to maximize daylight.
3. Shoot for envelope criteria of R-60 for the roof, R-40 for the walls, and R-20 for the below-grade foundation.
4. Identify the optimal energy-generation system for the site and climate.
5. Specify mechanical systems that support the net-zero goal, such as air-source or ground-source heat pumps.
6. Set up a monitoring system to ensure that all building systems are operating properly.
7. Provide for periodical review of energy-performance data to identify any problems and better educate the building owner in how to monitor and run the facility.

Chartwell School NZEB Strategies



Design innovations for the net-zero (electricity) Chartwell School, a 21,227-sf facility in Seaside, Calif. The Building Team of EHDD Architecture (architect), Taylor Engineering (ME), The Engineering Enterprise (electrical engineer), Tipping Mar + Associates (SE), and Benya Lighting Design (lighting) first reduced energy consumption with spectrally selective glazing, operable skylights, daylighting, and radiant slab heating before adding the 30 kW PV setup. The project won an AIA/COTE Top 10 Award.

total energy profile, it's only half the equation. "For the RSF project, the façade design, daylighting, natural ventilation, etc., only accounted for half of the energy use in the building," states Okada.

The other half is devoted to *plug load*. Computers, copiers, electronic devices, appliances, and the like account for an average 50% of a commercial building's total electricity use. And because Building Teams are rarely involved in office equipment procurement decisions, the responsibility to keep these plug loads in check falls on the owner/facility manager.

"A lot of attention must be given to the plug loads, and this is typically left out of the formula," says Chuck M. Davis, FAIA, founding partner and senior principal with EHDD Architecture (www.ehdd.com), San Francisco, whose firm has designed five net-zero energy projects.

For example, in performing the energy analysis for the NREL Research Support Facility, the Building Team discovered that the workstation phones, which had to be plugged in 24/7 as part of the intercom/life safety system, were drawing between 10 and 15 watts. By switching to low-energy phones, this cut the plug loads by 8%, amounting to a 2% reduction in the building's total energy load.

The building's operating schedule—the total number of hours the building is occupied, the hours of heaviest use, whether it is used on weekends, etc.—and the behavior of its occupants can have a huge impact on the plug load and must be factored into the plug load analysis, says Brad Jacobson, AIA, LEED AP BD+C, a senior associate with EHDD Architecture. "If you're doing net-zero, you really have to care about those factors, because plug loads really determine how much energy the building is going to use. It really has to be thought through."

One of EHDD's net-zero (for electricity) projects, Chartwell School, in Seaside, Calif., which won an AIA/COTE Top Ten award, provides an example of how occupant behavior can skew plug load consumption. After the building was operational, the actual energy load turned out to be significantly greater than anticipated in the model. Upon further analysis, the team discovered that a security consultant had recommended leaving the site lighting on all night. Even an old refrigerator, donated by well-meaning parents of a student at the school, was found to be using more than its proper share of electricity. Fortunately, these problems were easy to address and the energy profile of the building was able to be straightened out. But the case illustrates the need to keep plug load clearly in mind—a caution that should apply to all building projects, not just NZEBs.

Monitoring: More than a necessary evil. The Chartwell School experience brings up another vexing issue: the importance of ongoing energy management and monitoring. "With every project, much is learned during the submetering phase, when building performance is confirmed and systems can be tweaked to ensure that high-performance standards are being met," says Maclay. Metering and monitoring educate the Building Team, the owner, and the facility staff in how the building is performing as an integrated system.

Because net-zero energy use is measured by the actual building operation over the course of a year, monitoring is essential to uncover and correct any inefficiencies or irregularities to ensure that energy performance is on track.

NREL has already made several operational adjustments in response to energy monitoring on the Research Support Facility project. In one instance, analysis of the lighting energy data revealed a significant bump in the lighting load in the late evening. Further investigation led to the discovery that the cleaning crew was responsible, according to RNL's Hootman. It was decided to reschedule the cleaning crew to a daytime shift, when they could work under daylight conditions.

Minnesota's Science House experienced a couple of significant operations failures that, because they did not directly cause occupant discomfort, would have been difficult to diagnose had it not been for the building's monitoring system. On one occasion, the building's ground-source

Table 2-1.
NZEB CASE STUDIES

PROJECT	NZEB FEATURES	BUILDING TEAM
Hawaii Gateway Energy Center Kailua-Kona, Hawaii 3,600 sf	20-kw PV system, extensive daylighting, passive thermal chimney, cooling system utilizing 45°F seawater	Architect: Ferraro Choi & Associates MEP, lighting, energy consultant: WSP Lincolne Scott Structural engineer: Libbey Heywood Contractor: Bolton
Audubon Center at Debs Park Los Angeles, Calif. 5,020 sf	25-kW PV system, on-site wastewater treatment, daylighting, thermal mass	Architect: EHDD Architecture Mechanical engineer: IBE Consulting Engineers Electrical engineer: Kanwar & Associates Structural engineer: Parker – Resnick Lighting designer: Clanton & Associates Energy analysis: CTG Energetics Contractor: TG Construction
Aldo Leopold Legacy Center Baraboo, Wis. 11,900 sf	39.6-kW PV system, daylighting, ground-source heat pumps, low-flow plumbing fixtures	Architect: The Kubala Washatko Architects Structural engineer: KompGilomen Engineering Contractor: The Boldt Company Mechanical engineer: Matrix Mechanical Systems Electrical engineer: Powrtek Engineering
Science House Science Museum of Minnesota St. Paul, Minn. 1,700 sf	8.8-kW PV, daylighting, ground-source heat pumps, passive solar design, multimodal natural ventilation	Architect: Barbour LaDouceur Design Group Electrical engineer: Vareberg Engineering Mechanical engineer: Martin Mechanical Design Structural engineer: Mattson Macdonald Young Structural Engineers Environmental building consultant: The Weidt Group Contractor: LS Black Constructors
San Ysidro U.S. Land Port of Entry San Ysidro, Calif.	PV, rainwater reclamation, geoexchange system, radiant heating/cooling, low-flow fixtures	Architect: Miller Hull Partnership MEP engineer: Interface Engineering Structural engineer: Magnusson Klemencic Associates
National Renewable Energy Lab Research Support Facility Golden, Colo. 220,000 sf	2,500 kW PV, natural ventilation, daylighting, passive solar design, integrated solar collecting + underground thermal storage system, radiant heating/cooling	Architect: RNL Design MEP engineer, energy consultant: Stantec Contractor: Haselden Construction
Dockside Green (net-zero carbon) Victoria, B.C.	2MW waste wood biomass plant, daylighting, high building envelope thermal resistance, smart controls	Architect: Busby Perkins + Will MEP, lighting engineer: Stantec Structural engineer: RJC General contractor: Farmer Construction
Putney School Fieldhouse Putney, Vt. 16,800 sf	36.8 kW PV, high-performance insulation, air-source heat pumps, composting toilets	Architect: Maclay Architects Mechanical engineer: Kohler & Lewis Electrical engineer: William Bissell Structural cngineer: Engineering Ventures Energy consultant: Energy Balance Lighting: Naomi Miller Lighting Design General contractor: DEW Corp.
Otay Mesa Land Port of Entry Otay Mesa, Calif.	280+ kW PV, geothermal, rainwater and treated water underground cistern storage system, active beams, radiant panels	Architect: Tate Snyder Kimsey Architects MEP engineer: IBE Consulting Engineers Lighting designer: Lam Partners Structural engineer: Greg Gordon & Associates

heat pump failed and the electrical backup heating system kicked in; needless to say, the electrical system operated much less efficiently than the heat pump. Another time, an electrical connection from one of the PV arrays was damaged and energy production took a dip. "Had these issues not been detected and fixed, Science House would not have been net-zero for the year," says Eijadi.

Building Teams should also be advising clients to take monitoring to the next level, says Glennis Briggs, AIA, LEED AP, an associate principal at EHDD. The firm encourages clients to use these analyses to actively reduce energy loads in striving for net-zero usage. EHDD's Davis says his firm is focusing on outliers: "We're pushing hard to have metering of the PV output, as well as usage, so we can track down who are the high consumers and figure out why they're the high consumers."

Photovoltaics: Ready or not, here they come. Photovoltaics have come to be the most common renewable strategy available to designers of zero energy buildings. However, a number of technical, economic, and logistical hurdles must be overcome to make PVs work for specific NZEB projects.

PROJECT	NZEB FEATURES	BUILDING TEAM
Chartwell School Seaside, Calif. 21,227 sf Zero electricity only	30 kW PV, daylighting, radiant heat	Architect: EHDD Architecture Mechanical engineer: Taylor Engineering Electrical engineer: The Engineering Enterprise Structural engineer: Tipping Mar + Associates Lighting designer: Benya Lighting Design
Exploratorium San Francisco, Calif. 210,000 sf In construction	Bay heating/cooling, adaptive reuse, 1.54 MW PV system	Architect: EHDD Architecture Structural engineer: Rutherford & Chekene Mechanical/plumbing engineer: Rumsey Engineers Electrical engineer: Cammisa and Wipf Civil engineer: Kennedy Jenks Acoustical: Charles M. Salter Associates Landscape: GLS Lighting: David Nelson & Associates, LLC Contractor: Nibbi Brothers Contractors
Packard Foundation Los Altos, Calif. 49,000 sf In construction	Daylighting, chilled beams, high-performance envelope, plug load reductions, 285 kW PV system	Architect: EHDD Architecture Structural: Tipping Mar & Associates Mechanical/plumbing engineer: Rumsey Engineers Electrical engineer: IDeAs Acoustical consultant: Charles M. Salter Associates Landscape architect: Joni L. Janecki & Associates Lighting designer: Janet Nolan & Associates Daylighting: Loisos Ubbelohde Contractor: DPR Construction
Aquarium of the Pacific Watershed Classroom Long Beach, Calif. 2,600 sf	2.8 kW PV system, living roof, thermal mass, passive heating and cooling	Architect: EHDD Architecture Structural engineer: Rutherford & Chekene Mechanical/plumbing engineer: Rumsey Engineers Civil: Moffatt & Nichol Engineers Acoustical: Charles M. Salter Associates Landscape: Nuvis Landscape Architecture and Planning
IDeAs San Jose, Calif 6,560 sf	Net-zero energy, net-zero carbon, 30 kW BIPV, adaptive reuse, daylighting, occupancy and daylight controls, minimized plug loads, radiant heating and cooling, ground-source heat pump, building monitoring	Architect: EHDD Architecture Mechanical/plumbing engineer: Rumsey Engineers Structural engineer: Tipping Mar & Associates Civil engineer: Carroll Engineering Electrical/Lighting: Integrated Design Associates Landscape architect: MPA Design Contractor: Hillhouse Construction Co.
Marin Country Day School, Step 2 Corte Madera, Calif. 23,094 sf	Cold water storage, radiant heating/cooling, daylighting, natural ventilation, solar shading, daylight and occupancy sensors, 95.5 kW array	Architect: EHDD Architecture MEP engineer: Stantec Structural engineer: Tipping Mar & Associates Civil engineer: Sherwood Design Engineers Acoustical consultant: Salter & Associates Landscape architect: CMG Lighting designer: TMT Associates Contractor: Oliver & Co.

RENDERING: COURTESY MILLER HULL PARTNERSHIP

The San Ysidro (Calif.) Land Port of Entry at the U.S.-Mexico border handles more than 100,000 crossings a day. The three-phase project, designed by The Miller Hull Partnership, is targeting LEED Platinum status as well as net-zero energy use.

For example, Building Teams need to be on top of the latest products and technologies, as newer, more advanced offerings are constantly arriving on the market. This was particularly relevant for the LEED Platinum Aldo Leopold Legacy Center, Baraboo, Wis. "By the time we ordered the PV panels, the manufacturer had produced better panels with higher output," recalls Joel Krueger, AIA, a project manager with The Kubala Washatko Architects (www.tkwa.com), Cedarburg, Wis. Thanks in part to this improvement in efficiency, the building produces about 10% more energy per year than it consumes.

Although it paid off to specify the newer, more efficient panels for the Leopold project, in some cases PV panels with the highest efficiency rating may not necessarily be the most cost-effective option. Therefore, choosing the right PV system requires a complicated calculation that takes into account numerous variables, including the availability of rebates and incentives, the amount of roof area, the optimal siting for the PV system, the type of roofing system, and the building's required energy load.

PV technology is developing so quickly that specifications can change in the middle of a project. For the first phase of NREL's Research Support Facility, the Building Team specified panels with 13% efficiency to be the most cost-effective option at the time. When a second wing was designed, however, the Building Team was able to specify new high-efficiency panels capable of generating efficiencies of 19%.

To reiterate, it is important for Building Teams to carefully weigh all the costs and benefits between energy-conservation measures and the use of renewables. In some cases, the extra investment in photovoltaics may be better spent on making the building more energy efficient. The Weidt Group's David Eijadi states that, in general, conservation and efficiency measures can often prove to be 7-10 times less expensive—that is, more cost-effective—than applying power-generation technologies.

For example, in the design of the Putney (Vt.) School Fieldhouse, Maclay Architects specified air-source heat pumps over more efficient ground-source heat pumps and saved about $100,000 in upfront costs, while the cost of adding PVs to make up the net energy difference between using air-source and ground-source pumps was only $35,000, a savings of $65,000—not quite the 7-10 factor posited by Eijadi, but nothing to be sneezed at either.

Even when a whole building approach is employed to make the PV system work for the building, technical issues can still arise after the installation has been completed.

Take the Aldo Leopold Legacy Center, for example. After carefully considering how to maximize daylighting, provide natural ventilation with clerestory windows, create comfortably sized spaces, and support the building's passive and active solar systems, the design team established what it believed to be the optimal roof pitch—which, as it turned out, was less than optimal. "We started having problems with snow buildup on the PV panels," says Krueger. A more steeply pitched roof would have shed snow more readily and increased annual energy production from the PVs. This case illustrates the on-going learning process that Building Teams are encountering as they ramp up their use of photovoltaics and other more "exotic" technologies in an effort to achieve net-zero.

Even social conditions can impact the use of renewables. For the net-zero Audubon Center in Los Angeles, the owner was concerned about vandalism in Debs Park as the project was being designed; as a result, it was determined that all PVs had to be installed on the roof, with none at ground level, which severely limited the size of the array and led to power shortfalls in the wintertime. "Now that it's a more supervised area, if we were to do it again, we would be able to install more PVs to provide more power in the winter," says Briggs.

Another hurdle for NZEB projects employing photovoltaics and other renewables is the fact that approvals for off-the-grid systems can be complex, making the permitting process longer and more involved. For the Audubon Center, the EHDD-led team had to negotiate with the Los Angeles fire department over fire personnel's ability to move around on the roof. "Ultimately, we had to leave accessible aisles, which restricted the amount of area we had for PVs," recalls Briggs.[1]

1 The California Fire Marshal's Solar Photovoltaic Installation Guidelines, available free at http://osfm.fire.ca.gov/pdf/reports/solarphotovoltaicguideline.pdf, is a widely referenced standard.

2 B. Griffith, N. Long, P. Torcellini, and R. Judkoff (NREL), and D. Crawley and J. Ryan (USDOE), "Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector," NREL/TP-550-41957, December 2007, at: http://www.google.com/search?q=62%25+of+commercial+buildings+net-zero+NREL&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a

3 Documentation for the Research Support Facility is available on NREL's website at: http://www.nrel.gov/sustainable_nrel/rsf.html

In sum, although photovoltaics are the flavor of the month for renewables, Building Teams involved in NZEB projects are obligated to at least explore other options, such as biomass, geothermal, wind, or even small-scale hydroelectric power.

For the Dockside Green mixed-housing project now being designed in Victoria, B.C., photovoltaics simply didn't make economic or engineering sense. However, due to the project's location in a heavily forested area, waste wood biomass could become a viable option. "The amount of biomass energy sold offsite to a nearby hotel makes the project net-zero carbon, and time will tell whether or not the balance will show net-zero energy for the development," reports Michael Driedger, LEED AP BD+C, a sustainable building advisor in the Vancouver office of designer Busby Perkins+Will (www.busby.ca).

The lesson, of course, is that Building Teams should not always grasp at PVs as the solution. Other forms of renewable energy—not to mention additional improvements in more conventional energy-saving strategies—could prove to be more cost-effective and appropriate for certain NZEB projects.

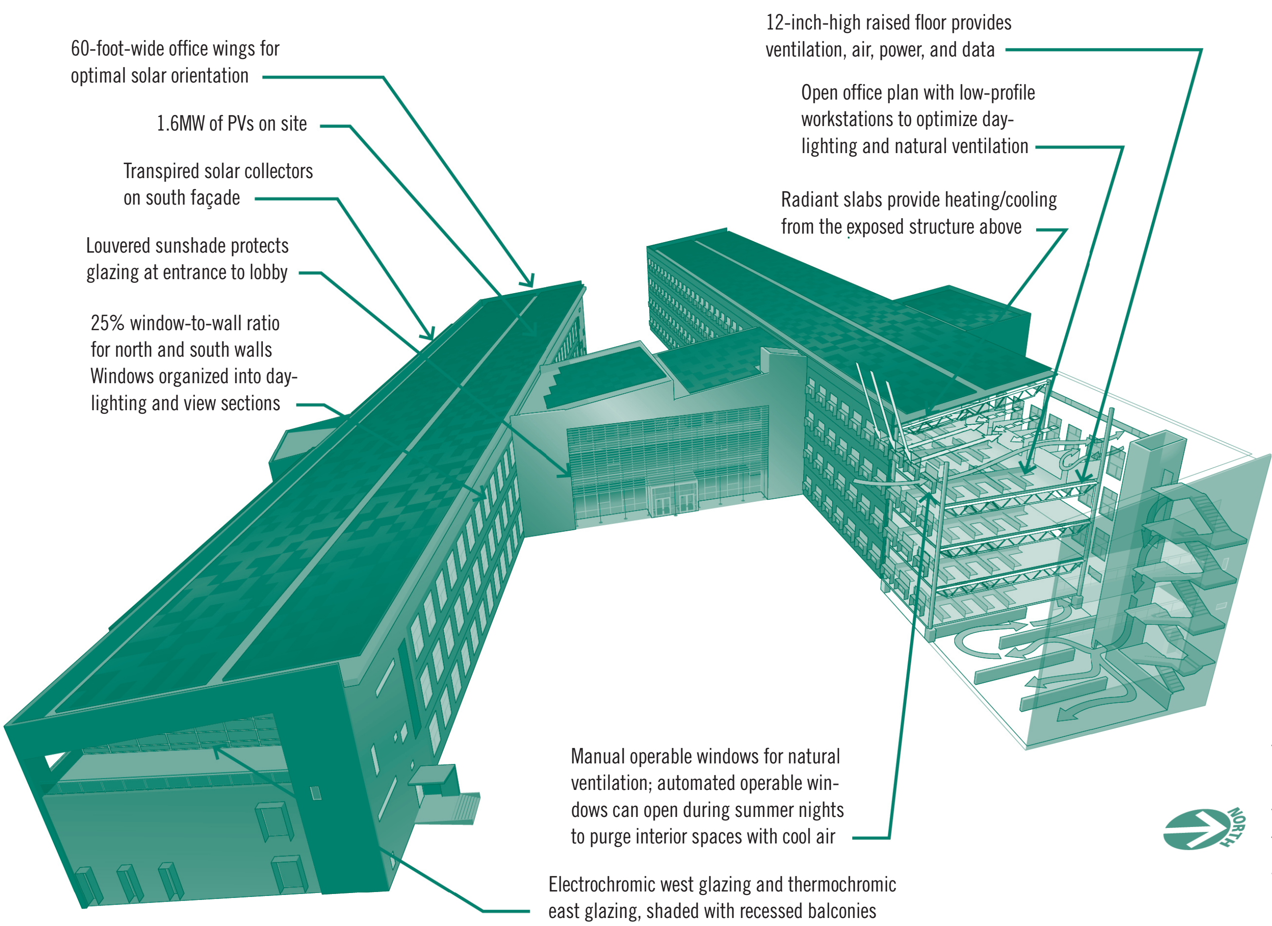
WHAT ABOUT ECONOMIC FEASIBILITY?

Although zero energy buildings are certainly not for the weak of heart, some experts feel they are more achievable than is commonly believed. "There's a huge opportunity out there for moving to net-zero," says RNL Design's Hootman. He points to a 2007 U.S. Department of Energy and NREL study, which concluded that 62% of commercial buildings (representing 47% of commercial floor area) had the potential to achieve net-zero (defined as net site energy use of zero or less) through the use of known technologies and practices with projected performance levels for 2025.[2]

"These results indicate that the [NZEB] goal is not too aggressive and can be achieved for large segments of the commercial sector," the report concluded. Building types with the best NZEB prospects: K-12 schools, university classroom buildings, residential projects, low-rise hotel facilities, and office buildings.

"Life cycle cost analyses of net-zero energy projects in comparison to grid-based energy projects often favor the net-zero approach due to the substantial savings in energy costs over the life of the facility," says Scott

NREL Research Support Facility



Source: National Renewable Energy Laboratory

Schematic illustrates the numerous energy-conservation strategies used by the Building Team for the 220,000-sf NREL Research Support Facility before the 2,500 kW PV system was added. The slanted H-shaped building takes full advantage of solar orientation and optimized window-to-wall ratio.

Inatsuka, PE, president of WSP Lincolne Scott (www.wspgroup.com), Honolulu, whose firm did the M/E work for the Hawaii Gateway Center project.

Although the high cost of utility-provided energy in Hawaii makes net-zero attractive there, Inatsuka believes that as building owners focus more on life cycle savings, net-zero projects will gain in popularity, thereby creating an incentive and demand for growth in architectural and engineering expertise in this realm.

Assuming utility rates keep going up and PV costs keep coming down, at some point those lines will cross, says EHDD's Jacobson. He notes that energy codes, notably California's bellwether Title 24, are becoming more and more stringent, which means that at some point the jump to net-zero will be more economically justifiable.

"While a fuel cost increase of 1% won't make net-zero feasible economically, if we look at the past 10 years where we have seen fuel escalation rates of 10-14%, these rates do make net-zero economically feasible," adds Maclay.

Maclay and other experts consulted for this White Paper agree that Building Teams can make significant strides toward net-zero energy buildings with currently available off-the-shelf products and solutions. RNL Design's Hootman says, "I believe more buildings can reach very high levels of energy efficiency through innovative and integrated design using simple strategies rather than relying on an innovative technology application."

Jacobson echoes Hootman's assessment. "You can get 40-50% baseline energy savings with the basics such as shading, daylighting, good orientation, and insulation. Then you really have to look at the plug load, but that's where you can jump up to 60%."

Paul Torcellini, NREL's group manager for commercial buildings research (and one of the authors of the NREL/DOE study cited above), claims that many buildings can be cost neutral up to about 50% energy savings, a goal that is achievable with available designs features, not "advanced widgets."

Beyond that 50% mark, however, is where the added expense comes in. According to EHDD's Davis, that tipping point is somewhere north of 60%. "Going significantly beyond 60% can start costing real money," says Davis.

At the same time, the cost-neutral equation has to be looked at from a long-term life cycle perspective. While federal agencies like the GSA and DOE can absorb the extra costs associated with net-zero energy buildings (and are under mandate to do so), for the private sector a seven-year payback is the outer limit of financial feasibility, according to MKA's Gangnes. He sees utility company incentives as making the difference in the net-zero equation for the commercial sector. "We're just begging for a new paradigm as to how energy and water utilities help with the construction cost of net-zero energy and water projects," he says.

One other technical roadblock: the absence of a smart grid. GSA's Leites believes that this gap in the system is holding back net-zero projects by lengthening the payback period for owners who want to install on-site renewable systems. Needless to say, building such a smart grid—assuming approval and funding were forthcoming—could take years.

CHANGING THE DESIGN CULTURE

Another obstacle to achieving net-zero energy buildings is that they are still considered something of a novelty among architects, engineers, contractors, and building owners. NZEBs account for only a minute percentage of total construction, and many of the completed projects are on the small side. Speaking for one segment of the industry, Magnuson Klemencic's Gangnes says, "There's this problem among the engineering community that if they haven't done it before, they can't or won't do it." Similarly, Davis states, "I think there's a lot of unleashed creatively out there in the industry, but people are afraid to move out of the box. It's the people who experiment and take risks that create change."

Despite the small number of operating net-zero energy facilities, Busby Perkins+Will's Blair T. McCarry, PEng, PE, LEED AP, believes that change is coming. He notes that General Electric has announced net-zero energy packages for homes starting in 2015, the state of California is discussing regulations for net-zero energy projects by 2020, and ASHRAE has committed to making net-zero energy projects financially viable by 2030. "To build the road to net-zero energy projects, owners and designers should be targeting low energy use in their projects to develop their skill sets," says McCarry.

Building product technology continues to advance, with new developments in photovoltaic glazing, window frame technology, and geothermal systems. (See Chapter 3 for more on NZEB technology developments.) "This next generation of energy technology will really help us get even better performance out of buildings," says Haselden Construction's Philip Macey.

NREL's Paul Torcellini says he hopes the Research Support Facility will serve as an inspiring example to the design and construction community of the feasibility of large-scale net-zero energy projects. "This building really shows that this can be done," he says. "It portrays people who are actually doing and practicing what they are preaching."[3]

But even when there is a committed owner and a talented group of designers, engineers, and contractors in place, Building Teams must still be realistic. "Zero is a real number—it can be measured, and it can't be faked," warns The Weidt Group's Eijadi. "You can't guess your way to zero. It requires a plan, desire, and diligence." BD+C

3. How Building Technologies Contribute To Net-Zero Energy Design

By Chris Sullivan, Contributing Editor

Increased interest in and public awareness of environmentally preferable approaches to living and working—spurred in great part by the U.S. Green Building Council and its LEED (Leadership in Energy and Environmental Design) green building rating program—has, over the last decade or so, ignited a renaissance in high-performance building technology. Whereas in the past the public at large viewed the transportation sector—especially automobiles—as the chief culprit in terms of energy usage and greenhouse gas emissions, in more recent times the building and construction sector has been tagged as responsible for nearly two-fifths (39%) of energy use and a commensurate amount of GHGs. As a result, the market for green building has improved dramatically, leading to greater investment in high-performance building science.

Approaching new construction or renovation with the goal of attaining a net-zero energy balance calls for a combination of design strategies, products, materials, and whole systems that require Building Teams to be familiar with the wide spectrum of available technologies. To reach the goal of net-zero energy use, building owners and developers are going to have to take calculated risks, at times investing in newer products and systems that may not yet have an established track record of proven lifetime performance.[1]

In this chapter, a broad range of technologies is discussed, from those with very long horizons to a number of proven, widely accepted materials and systems with shorter and more reliable payback scenarios. On the one hand are renewable energy systems, which produce their own energy and can quickly bring buildings nearer to a net-zero energy profile. On the other are materials and systems that reduce energy use, making the site or facilities in question more energy efficient from the start—the first step in achieving NZEB goals.

The chapter presents a raft of solutions for renewable energy, technologies that have shown proven life cycle performance and reasonable payback. Following that discussion, energy-efficiency measures, ranging from enclosure assemblies to electrical products, are compared in two general groups: basic, commonly used technology; and newer products and systems requiring some additional cost but promising advanced performance when applied successfully.

LONG-HORIZON TECHNOLOGIES: RENEWABLE ENERGY AND MORE

A leading strategy for planning a net-zero facility is to include one or more on-site systems that allow the building to produce some or all of the energy needed for operation. Optimization of renewable energy is a relatively recent area of development, however, and the ability to fully exploit sources of energy such as solar, wind, geothermal, and hydroelectric will be a learning process for Building Teams and the AEC industry at large for years to come.

Typically, there are two major reasons for the difficulty with adopting renewable sources: first, the **location**; and, second, the potentially lopsided **cost-benefit ratio**. Let's see how these factors play out with specific technologies.

> Attaining a net-zero energy balance will require Building Teams to be familiar with a broad range of technologies.

Geothermal energy can be an appealing choice in many cases because, under the right conditions, it can work as well for small-scale, remote projects as for urban high-rise buildings. A geothermal heat pump attached to a ground loop provides clean, free heating and cooling for as long as it operates. But the building must be in a location where drilling at depths of 100-300 feet (for vertical loops) is feasible and permitted, and where drilling to those depths would successfully reach a suitable thermal source.

In terms of cost, the typical geothermal heat pump system comes in at nearly twice that of a conventional HVAC system: a small, three-ton-capacity geothermal HVAC unit averages $7,500, compared with $4,000 for a standard HVAC system, according to the California Energy Commission (www.consumerenergycenter.org). Moreover, depending on location, owners can expect an outlay beginning at $10,000 and running to $30,000 or more for drilling.

First-cost numbers like these put geothermal squarely into the long-payback category of renewable solutions for many clients and real estate investors. However, certain owner-occupied client groups with long timelines for their properties, notably in higher education and government, would be more amenable to making a long-term investment in geothermal.

Wind power: Also requiring a sizable initial outlay, wind-powered technologies generally cannot offer a performance guarantee as established as that for geothermal. Investors relay stories of windmill and turbine installations that have suffered from a lack of wind. Complaints of noise associated with turbines have made applications difficult in some residential or environmentally sensitive areas. The most successful application for wind power continues to be industrial wind farming; use of this renewable for building-specific energy is challenging at best.

A recent example involved 12 West, a mixed-use project by owner Gerding Edlen Development in Portland, Ore., where the Building Team applied four small turbines to a 23-story building's "eco-roof" to provide about 1% of the facility's required electric power. Observers of this and similar applications have criticized their use of wind power as too minor. In some cases, however, wind turbines can be symbolically important to a project to raise awareness of its high-performance and NZEB design. Based on cost-benefit analysis, however, wind turbines may not contribute enough for many net-zero energy building projects, unless the location is very favorable to wind production.

That explains why other observers see a future in the use of building-integrated wind turbines, pointing to such success stories as the Bahrain World Trade Center. Three massive turbines, each supported by a bridge between the complex's aerodynamically designed twin towers, supply up to 1,300 megawatt-hours per year—between 11% and 15% of the facility's power requirements. The Bahrain towers are unique in their location, with its steady wind; most building-integrated wind projects encounter far more turbulent wind patterns, making the turbines much less effective.[2]

Moreover, turbines can create significant noise and vibration problems for the occupants of buildings to which they are attached. There are safety issues as well: If a turbine blade should come loose on a distant wind farm, people are unlikely to be injured, whereas a 50-foot blade falling in an urban area could wreak havoc.

As an alternative to building-integrated wind power, one prevailing environmental and economic strategy among facility occupants and managers is the purchase of power through community- and utility-based programs aggregating power from renewable sources. Wind and solar farms are the most common sources. In the future there may be opportunities for communities to purchase tidal energy, although recent investment levels in this area suggest that the wait may be very long, especially for U.S. energy users. Except in unusual situations, Building Teams should not expect to find relief for their net-zero energy problems from these kinds of technologies.

NEARER-TERM BENEFITS OF BIPV'S

Though it tends to work best in sun-drenched locations, solar harvesting technology is seen as the renewable energy source with the most promise for designing net-zero energy buildings, now and for the near future. It is also the most frequently incorporated into economically viable high-performance and net-zero projects. The consensus within the growing photovoltaics industry is that **distributed PV systems**, those which provide electricity at the point of use, are the simplest and most economical—and for that reason, the most commercially beneficial. Building-mounted and building-integrated PV (BIPV) power systems for individual buildings are the primary types of distributed systems.

Research into solar photovoltaic technology for buildings has typically focused on 1) increasing the cost-benefit ratio of PV employment and 2) increasing the available surface area for solar collection on a given project. The first goal is important for projects in areas with less sun or low sun angles. Argonne (Ill.) National Laboratory, a major U.S. Department of Energy research facility near Chicago, is currently developing two such improvements to PV collection materials. The first is the use of atomic-layer deposition, or ALD, to create thin-film PV material that can be used to coat structures. The very thin coatings reduce the distance that charges within the device have to travel, which translates directly into higher efficiencies, according to Seth B. Darling, PhD, an Argonne scientist.

Though thin-film PV has largely supplanted older crystalline PV types, new approaches incorporating nanotechnology into first-generation PV materials may ultimately yield the highest-performing results. Research at Argonne includes the use of "quantum dots"—nanometric semiconducting crystals—in a technology called "advanced luminescence concentrators." These crystals operate efficiently under diffuse light, ideal for low-sun areas, and allow for "tuning" the amount of energy they absorb or using a specific band gap of the light spectrum. This means that energy could be collected even from the near-infrared part of the spectrum, says Darling. Current solar technologies cannot capture light in this portion of the spectrum.

Other R&D efforts are also tackling the applied

1 The Whole Building Design Guide (www.wbdg.org), produced by the National Institute of Building Sciences, is an excellent online free technical resource for those seeking solutions to many building technology problems.

2 No less a figure than Alex Wilson, the respected editor of Environmental Building News, has taken the technology to task (see "The Folly of Building-Integrated Wind," EBN, 18:5, 2009, at: http://www.buildinggreen.com/auth/article.cfm/2009/4/29/The-Folly-of-Building-Integrated-Wind), citing problems related to turbulent air flow, noise and vibration, safety, poor measured performance, and cost-effectiveness. See also "Wind Power, Windy City-style," Jeff Yoders, Building Design+Construction, November 2010, for a case study of a wind turbine in a commercial parking garage, at: http://www.bdcnetwork.com/article/wind-power-windy-city-style.

technologies. Novel manufacturing techniques are lowering the cost of solar materials or helping to guarantee the effectiveness of those materials across different applications. For example, BioSolar, based in Santa Clarita, Calif. (www.biosolar.com), is developing green solar collectors whose white "BioBacksheets" are composed of cotton and a nylon resin made from castor bean oil. No petroleum-based products are used.[3]

For the development of net-zero energy buildings, Building Teams are well advised to consider the growing variety of building-integrated photovoltaic (BIPV) elements available commercially. While rooftop arrays are still the most common solar-energy solution—the simplest to install, and generally the least expensive—manufacturers are creating products that take advantage of other building surfaces, not just the roof.

Photovoltaic glazing is a prime example. PV glass is semi-transparent and therefore not ideal for all window applications, though it may be appropriate for non-view glazing applications, such as skylights, greenhouses, clerestory settings, or overhangs intended to provide shade. The technology typically involves applying thin-film photovoltaic materials to an inner surface of double- or triple-paned glass. PV glazing is rapidly becoming more commercial as the technology continues to improve, with many large manufacturers making forays into the market.

Still, the product is considered expensive and is not used very widely, especially since other PV products are less expensive and generate more power. The product is generally applied in a vertical plane, which in most cases is not the optimal angle for the sun's ray to hit the glazing, thereby reducing its efficiency.

Shading systems are often apt locations for PV collection. These may be panels secured to the facade, often adjustable so that their angle can be optimized for both shade and PV efficacy, or they may also be shading structures attached to or near the main facility. PV materials are commonly used to make shaded parking areas, with the power generated often used to run the parking area's lighting or to contribute to the facility's power demands.

For **roofing** and other building products, manufacturers are applying PV collection even in traditional slate and clay tiles. **PV siding** products are being used for solar heat collection on south-facing walls. One such system, manufactured under the brand name SolarWall PV/T, by Conserval Engineering's SolarWall, Buffalo, N.Y., and Toronto (http://solarwall.com), is a hybrid system that combines PVs with transpired solar panels. The system was used in the Beijing Olympic Village and at Montreal's Concordia University, where a 100 kW system is producing 24.5 kW of electricity and 75 kW of thermal heating. Many manufacturers are stocking the shelves of hardware stores with solar-panel kits for do-it-yourselfers, possibly ushering in a new era of solar power acceptance at the homeowner level.

CURRENT LEADING-EDGE NZEB TECHNOLOGY

The early adoption of newer NZEB technologies like building integrated PVs follows closely upon the trend toward high-performance building design. **Smart glass** is a prime example. Although currently higher in cost compared to glazing with low-e coatings, the potential benefits of smart glazing elements—which change light-diffusion properties based on environmental and building conditions—have made them an increasingly popular choice for achieving net-zero energy goals.

Though there are several subcategories, in general smart-glass technologies have adjustable or "tunable" emissivity, which can be controlled by building occupants or with sensors. The reduction in energy costs for facility operation makes the payback period for large buildings far shorter than that associated with photovoltaics—5-8 years, as opposed to 25 or more years for unsubsidized PVs—even though the glass itself requires electricity to perform its "smart" function.

Electrochromic glass has dominated the growing smart glass market. Voltage applied either manually or automatically to electrochromic glazing alters its color and transparency; normally this results in a change from colorless transparency to blue translucency, although recent developments in the technology using reflective hydrides as the electrochromic agent offer a switch to mirroring and reflectivity rather than darkening and altered color.

Last year, one manufacturer, SAGE Electrochromics, Faribault, Minn. (www.sage-ec.com), received $100 million in DOE funding plus another $80 million from French building products giant Saint-Gobain to build a new manufacturing facility in Minnesota. This level of investment could be a sign that the use of electrochromic glass may increase in coming years. The product, which won a BuildingGreen Top 10 Green Building Product Award and a prestigious R&D 100 Award, was used in the National Renewable Energy Lab's Research Support Facility, Golden, Colo., and is being installed in the Community and Student Services Center at Chabot College, Hayward, Calif.

Alternatives to electrochromic technology are less likely to capture the smart-glass market, however, in spite of their possibly lower initial costs (not counting installation). **Suspended particle devices** (SPDs), which are applied to glazing using thin-film laminate, and **polymer-dispersed liquid crystal devices** share similar weaknesses. Both are translucent and often

3 For an excellent review of current experimental research in PVs, including the work at Argonne and BioSolar, see: "Solar PV innovation on the leading edge for 2010," Joyce Laird, RenewableEnergyFocus.com, at: http://www.renewableenergyfocus.com/view/7350/solar-pv-innovations-on-the-leading-edge-for-2010-/.

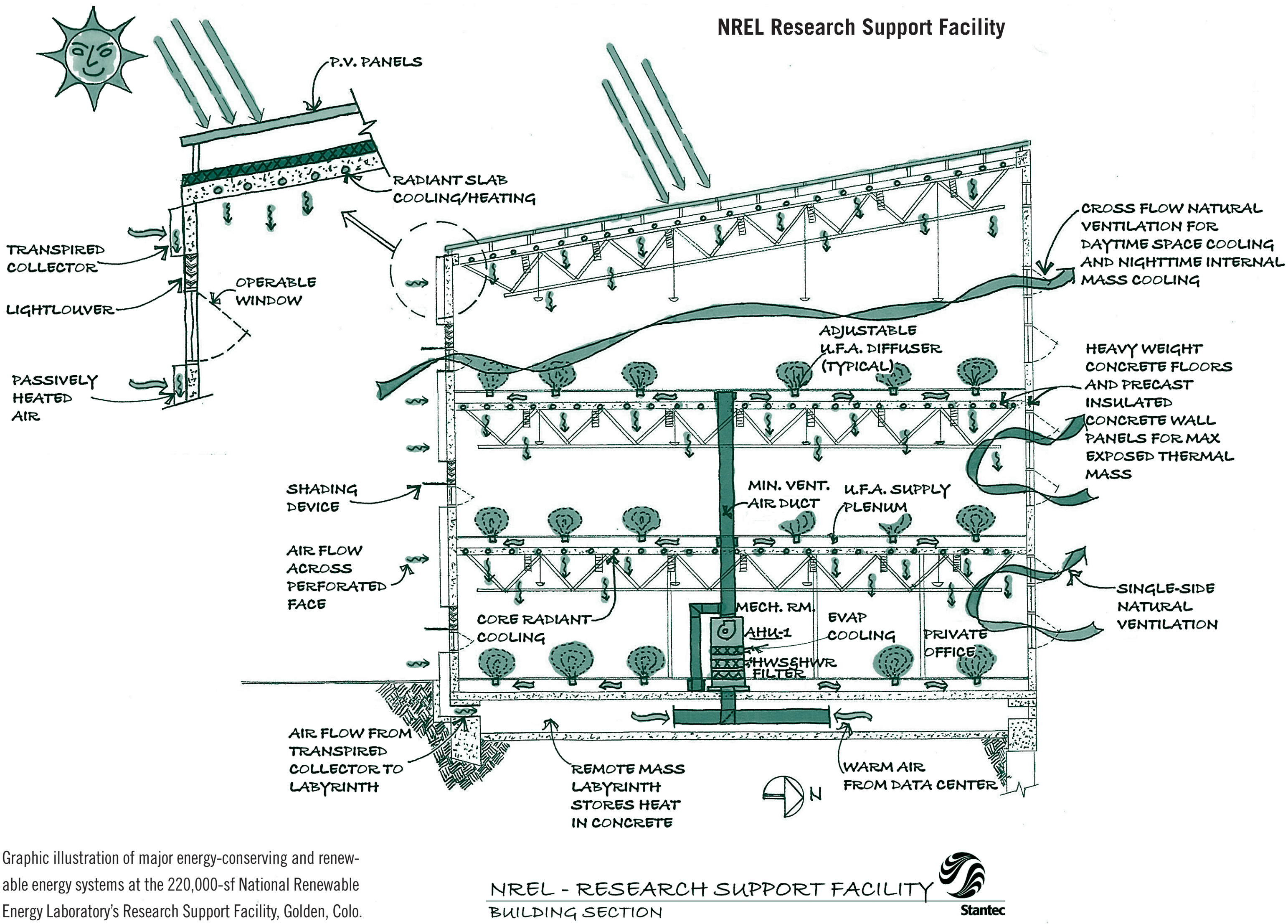


ILLUSTRATION: COURTESY STANTEC

Graphic illustration of major energy-conserving and renewable energy systems at the 220,000-sf National Renewable Energy Laboratory's Research Support Facility, Golden, Colo.

milky in their power-off state; both require a steady current to achieve transparency, whereas electrochromic devices require only an initial burst to change the state of the glass.

Over prolonged periods, this means electrochromics have lower energy needs and operating costs. SPD and LCD devices may find their way in smaller applications and in interiors, where flexibility of privacy requirements is beneficial.

Micro-blinds offer some advantages as an alternative to SPDs and LCDs, not least of which is a simplified and cost-efficient fabrication method that is easily customizable. Composed of rolled thin metal blinds that are invisible to the naked eye, micro-blinds offer transparency in the power-off state—the reverse of how SPDs and LCDs work—as well as improved UV durability and very fast switching speed, measured in milliseconds. Currently, the National Research Council of Canada (www.nrc-cnrc.gc.ca) conducts the bulk of research and development focusing on micro-blinds.

For residential and other projects, **heated glass** provides what is arguably the most cost-effective smart glazing solution. Using a conductive coating whose previous applications addressed issues of condensation on refrigerator doors, heated glass uses low voltage to eliminate drafts caused by convection cooling, making the areas near windows warmer and interiors more comfortable.

In general, while NZEB projects also require careful consideration of passive solar design techniques and elements, smart glass technologies such as heated glass can dramatically improve the results.

COMMON NZEB CONSTRUCTION SYSTEMS

Certain technologies, while still not yet entirely mainstream, have already contributed to the success of many NZEB projects. Stakeholders who intend to build a net-net-zero energy facility will find that there are a number of sustainable building elements that have already become indispensable to this area of building design.

Structural insulated panels (SIPs) and **insulating concrete forms** (ICFs) both contribute to the success of many high-performing structures and are considered to be reliable if somewhat pricey (on a first-cost basis) options for building well-insulated, energy-efficient buildings. The relative benefits and drawbacks of each should be considered carefully for each individual project, but both create insulated walls that reduce energy costs and often help meet LEED standards.[4]

SIPs, composed of rigid foam insulation between two layers of structural board, tend to be less expensive than ICFs but offer less thermal mass. The cast-in-place concrete walls formed by ICFs generally have lower R-values than SIPs, requiring that they be thicker; thicker walls tend to be more expensive because of the amount of product required, but the added thermal mass often improves the cost-benefit analysis over the building's lifetime. Depending on the type of ICF chosen, the form (which becomes part of the structure) may provide other benefits, such as acoustical or thermal insulation. Some ICFs also serve as substrates for interior and exterior finishing products, adding to their economic benefit.[5]

Highly efficient cladding solutions often provide insulation adequate to achieve net-zero energy status when SIPs and ICFs cannot be used. Exterior insulation and finish systems (**EIFS**), sometimes called synthetic stucco, are an example. Two DOE studies conducted by Oak Ridge National Laboratory (ORNL) beginning in 2005 showed that EIFS performed exceptionally well when compared to a range of conventional cladding systems, both in terms of thermal insulation and moisture control for buildings in the DOE Zone 3 coastal climate region.[6]

When EIFS systems are installed properly, they create a nearly unbroken envelope that acts as an air and vapor barrier as well as insulation. **Insulated metal panels**, which have a foam core sandwiched between metal panels, offer similar benefits. Insulated metal panel systems and their newer cohort, **insulated composite backup panels** (ICBPs) used behind rainscreens of various materials, tend to be more expensive per square foot as cladding than EIFS. All of these cladding systems can be used on new construction, but also provide an ideal way to retrofit existing structures for high performance and efficiency—and potentially for net-zero energy operation.[7]

New roofing technologies must also be considered in net-zero energy design. **Cool roofing** materials, usually composed of white, light-colored, or otherwise reflective or low-emissivity materials, consistently demonstrate the ability to significantly reduce unwanted heat gain and the associated costs of energy for cooling; electric bills are frequently reduced by 10-20%. The federal government offers tax credits for implementing cool roofs on both residential and commercial projects.

DOE Secretary Steven Chu is a cool roofing enthusiast, touting its success at reducing costs for individual facilities and for reducing the urban heat-island effect in densely populated areas, and he has mandated their use in future new and reconstructed DOE building projects.[8] In hot and humid climes, cool roofing can go a long way toward achieving net-zero energy design, though complaints of glare in some areas may have slowed their progress in that market.

Vegetated or planted roof type **green roofs** bring flora and landscaping to rooftop areas while also offering

4 See: "ICF vs. SIP: The Debate Continues," Dean Dalvit, EVStudio, Denver, 31 October 2008, at: http://evstudio.info/2008/10/31/icf-vs-sipthe-debate-continues/.

5 For a case study of ICFs in residential projects, see: "Zero Energy Homes," ICF Builder Magazine, at: http://www.icfmag.com/articles/green_building/zero_energy_homes.html.

6 See Achilles N. Karagiozis, Roland Serino, and Mikael Slanovaar, "Development of Wall Assembly System Properties Used to Model Performance of Various Wall Claddings," at: www. ornl.gov/sci/roofs+walls/staff/papers/EIFS.pdf.

See also "The Hygrothermal Performance of Exterior Wall Systems: Key Points of the Oak Ridge National Laboratory NET Facilities Research Project," Building Envelope Group, Oak Ridge (Tenn.) National Laboratory, 1 January 2005 through 30 March 2006, at: http://www.google.com/search?q=Hygrothermal+Performance+of+Exterior+Wall+Systems%3A+Key+Points+of+the+Oak+Ridge+National+Laboratory+NET+Facilities+Research+Project%E2%80%9D+&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client.

See also: "Government Study: EIFS Is Best-performing Wall System," EIMA (EIFS Industry Members Association), Falls Church, Va., at: http://www.eima.com/buildingenvelopere-searchtesting/governmentstudyeif-sisbestperformingwallsystem/.

7 For additional information on EIFS, see Kristina Koepke, "Energy-efficient Cladding Can Reduce Heating, Cooling Loads," Building Operating Management, May 2010, at: http://www.facilitiesnet.com/hvac/article/EnergyEfficient-Cladding-Can-Reduce-Heating-Cooling-Loads--11711.

LEDs: Durable, sustainable, low energy use

Artificial lighting is responsible for 20-50% of energy consumed in U.S. residences and offices.[1] Fluorescent and mercury-based lamps offer a low-power-consumption alternative, but with drawbacks for the environment and building occupants. The newest option: light-emitting diode (LED) fixtures.

LED lamps offer a durable, sustainable, low-energy choice. LED lamps are more expensive than many alternatives, but they are becoming more and more affordable. And with some LEDs providing up to 50,000 hours of use, the life cycle cost is quite favorable.[2]

LED manufacturers are also creating screw-in lamps, which make them easy to use in net-zero energy retrofits. White LEDs that compare favorably with warm-white-light halogen lamps are now available for general illumination or overhead wash. Last year, Osram Opto Semiconductors announced a prototype single-chip LED with an efficiency rated at 104 lumens/watt and a light color of 3000 K; Philips is offering a similar product.

1. Hawken, Paul; Lovins, Amory; Lovins, L. Hunter. Natural Capitalism (2000).

2. http://buildaroo.com/news/article/net-zero-energy-buildings-achievable/

benefits of reduced heat gain, water filtration and catchment, direct carbon reduction (photosynthesis consumes carbon dioxide and produces oxygen), and enhanced aesthetics. Though vegetated roofing is somewhat costly to purchase, install, and maintain, it is fast gaining popularity and can be effective for NZEB projects because of the improvements to building thermal performance. Gaining enthusiasm less quickly are technologies that create **vegetated walls**; the systems required to keep vertical landscapes watered often use more energy than the technique saves.

The net-zero energy Audubon Center at Debs Park, Los Angeles, Calif., designed by EHDD Architecture (architect), IBE Consulting Engineers (ME), CTG Energetics (energy analysis), Kanwar & Associates (electrical engineering), and Clanton & Associates (lighting), with TG Construction (GC). PV panels on the roof of the 5,020-sf facility provide 25 kW of power.

The desire to reduce unwanted solar heat gain has led to a number of developments in **fenestration, glazing, and façade technology**, many of which dovetail with a desire to maximize natural light and reduce costs associated with artificial lighting. A recent showplace of how effective novel glass technologies can be, IDeAs Z^2 Design Facility, the new headquarters of Integrated Design Associates, focused on the retrofit of a "concrete box" to create a net-zero energy building. The south-facing wall was replaced with low-emissivity glazing and an exterior shading overhang. While the exterior shading helps control heat gain, the copious glazing, combined with skylights and highly reflective white paint on the interior walls, provides enough natural daylight to obviate the need for artificial light year-round. In the summer, lights are only required after 7:30 p.m.[9]

Among these glazing technologies, it should be noted that **low-e glass** is now abundantly available at a variety of price points, and is considered essential for high-efficiency commercial projects.

Exterior and interior shading strategies, crucial in sunny climes, also continue to benefit from technological advancement. **Motorized shades**, whether manually operated or driven by sensors, can pay for themselves in just a few years by reducing cooling costs; many new interior shade systems boast almost completely silent operation, while others use "cellular" shading material to provide filtered light even as they add a layer of insulation that may reduce heating costs as well.

The recently completed net-zero energy Richardsville Elementary School, in Warren County, Ky., demonstrates the usefulness of two other fenestration technologies: **light shelves** and **tubular skylighting**.[10] Light shelves, generally made from extruded aluminum, are typically fixed horizontally above eye level inside or outside the façade to reflect daylight up to the ceiling and deep into a facility interior where daylight might not otherwise reach. Tubular skylighting has a similar goal, to have daylight penetrate deep into the facility, and does so by channeling sunlight entering via a dome- or sphere-shaped glass receptor ends on the roof, through tubes and into the interior where the light can be made diffuse, useful, and pleasant.[11]

IMPROVING MECHANICAL/ELECTRICAL SYSTEMS

Building mechanical and electrical systems present a huge opportunity for net-zero energy design. HVAC systems alone can account for up to 40% of a commercial building's energy use, and high-performing HVAC systems can reduce the energy used and the associated costs by anywhere from 10% to more than 70%. Though there are not many radically new developments in HVAC technology, achieving high performance depends upon successful design strategies coupled with building commissioning before occupancy, according to experts in NZEB systems approaches. Where possible, the incorporation of power from renewable energy sources also adds efficiencies to HVAC and electrical systems.

According to Building Teams involved with NZEB projects, HVAC zoning is essential: dividing commercial and institutional spaces into discrete areas that can be climate-controlled separately based on the needs

8 See Erin Pierce, "Cool Roofs: An Introduction," at: http://www.eereblogs.energy.gov/energysavers/post/Cool-Roofs-An-Introduction.aspx.

9 See Mignon O'Young, "Transforming a Concrete Box into a Net-Zero-Energy Building," Green Architecture and Building Report, 11 June 2009, at: http://www.gabreport.com/gabreport/2009/06/transforming-a-concrete-box-into-a-net-zero-energy-building.html.

10 See "Schools go net-zero and win national award," KABC-TV, Los Angeles, at: http://www.greenrightnow.com/kabc/2009/06/22/schools-go-net-zero-in-kentucky-and-win-national-award/. See also: "First Net-Zero Energy Public School Set to Open This Year," Biofriendly Blog, at: http://biofriendly.com/blog/energy/first-net-zero-energy-public-school-set-to-open-this-year/.

11 Lighting Design Basics (2002), by Mark Karlen and James Benya (available for purchase online), remains an excellent handbook on lighting basics and energy efficiency in lighting.

of each space's unique set of occupants. With HVAC zones successfully integrated into the facility—usually via flexible building automation system (BAS) applications—**sensor and actuator technologies** should be installed to achieve maximum performance for flexible occupancies and varying environmental and climate conditions. Recently, actuators have been fitted to façade openings, such as hoppers and operable windows, for better control of ventilation.

Though the cost-benefit ratio of BAS is typically better for large-scale facilities, freestanding smaller facilities (and even single-family homes) can derive valuable energy savings from its implementation. The most effective BAS schemes use the most information available, from internal and external temperature sensors, flow sensors, thermostats, and the like.[12] Automation should also apply to lighting and other electric systems (lighting zones are as useful as HVAC zones), which calls for **motion sensors** or other occupancy detectors to be most efficacious. Automation tied to electrochromic glass, interior and exterior shades, or other such high-performance building elements can deliver a significant portion of the energy savings needed to achieve net-zero energy. As BAS development progresses, the systems are becoming user-friendly enough to be controlled manually through software on a personal computer or even a Web browser; future developments include interaction between BAS and even MEP system components with utilities, also known as "smart grid" technologies.[13]

Stakeholders in planned net-zero energy projects should invest in **energy modeling and analysis software**, whether in planning stages or for operations.[14] According to Ron Judkoff, principal architectural engineer and program manager for the National Renewable Energy Laboratory, in Golden, Colo., most modeling software tools use algorithms developed by NREL for the software EnergyPlus. (It should be noted, however, that in planning NREL's recently completed Research Support Facility, the project engineering team also consulted IES Virtual Environment as well as eQuest, largely because these two modeling programs are considered ideal for studying daylighting and lighting scenarios.)

Judkoff notes that energy modeling contributes crucial information in the planning stages, while data from energy analysis can help to optimize efficiency during the operation and occupancy stage. "NREL and some of the other national labs have a whole team of people who currently work together on EnergyPlus development," he says. "The national lab work is foundational in that we create the simulation tools and algorithms many others use."[15]

Even vertical transport—elevators and escalators, typically heavy energy-using components of commercial

Overhang moderates sunlight penetration into the interior office space at the corporate headquarters of Integrated Design Associates, San Jose, Calif. Natural ventilation through operable windows, plus electrochromic window glazing, were also used in the project, which is "double zero" for energy and GHG emissions.

and large-scale facilities—has seen recent successes in efficiency-oriented improvements.[16] A demonstration net-net-zero energy elevator designed by Matthew Lloyd Architects, London, was constructed for the 2010 London Festival of Architecture, yet it is too expensive (about $65,000) to be considered for commercial applications.[17] Other improvements to electrical motor efficiency hold promise. **Variable-voltage, variable-frequency (VVVF) technology**, currently used globally in elevators and already quite efficient, continues to improve. Several elevator manufacturers offer **VVVF with regenerative drives**, meaning the braking energy of the lift is captured by the drive and reused as lifting energy.[18]

Regenerative VVVF elevators typically provide the greatest cost-benefit ratio in high-rise, high-volume applications. Recent developments in efficiency, however, are more broadly applicable. Testing performed in 2009

12 For an example of such integration, see "Another Take at Zero-Energy Buildings: Optimum Energy's Nathan Rothman (Part 4)," at: http://www.sramanamitra.com/2010/01/09/another-take-at-zero-energy-buildings-optimum-energy%E2%80%99s-nathan-rothman-part-4/.

13 For a review of the status of the Smart Grid, see "Integrating Building Automation Systems with a Smart Utility Grid Project," at: http://www.nist.gov/el/highperformance_buildings/intelligence/smartgrid.cfm.

14 For insight on energy modeling and analysis software, see Jeff Yoders, "Energy Analysis No Longer a Luxury," at: http://www.bdcnetwork.com/article/energy-analysis-no-longer-luxury, and "2009: The Year of Energy Analysis," at: http://www.bdcnetwork.com/article/2009-year-energy-analysis?page=show

15 See "BIM and energy software analysis: net-zero energy buildings expert roundtable II," Environmental Design & Construction, 1 October 1, 2010, at: http://www.edcmag.com/Articles/Leed/BNP_GUID_9-5-2006_A_10000000000-000905410. See also http://www.edcmag.com/Articles/Web_Exclusive/BNP_GUID_9-5-2006_A_1000000000-0000917830.

16 For an exhaustive review, see "Energy-Efficient Elevators and Escalators," at: www.e4project.eu/documenti/wp6/E4-WP6-Brochure.pdf.

17 See Bonnie Alter, "Revolutionary Elevator Uses Zero Energy," at: http://www.treehugger.com/files/2010/06/elevator-uses-zero-energy.php.

by Nevada Power on 60 hp elevators and 40 hp escalators at Caesar's Palace in Las Vegas demonstrated the potential of Power Efficiency Corp.'s proprietary E-Save technology to reduce power consumption by 15-40%, depending on the application. The firm's new motors accomplish this by creating "cruise control" for electrical motors: motor speed remains constant, but energy requirements change based on load.[19]

BASIC INGREDIENTS OF NZEB PROJECTS

While exciting new technologies are pushing us toward a future of net-zero energy buildings, Building Teams for today's NZEBs will spend the most time specifying and integrating efficiency elements that have been around for decades. Most of these tried-and-true building elements save energy by increasing the building envelope's overall R-value, while others will reduce the amount of electricity, energy, and water consumed.

Using elements that carry thermal mass is arguably the most venerable insulating technique. Properly applied, **brick and masonry systems** offer qualities ideally suited to passive heating and cooling design. Greg Schwietz, CSI, CDT, and Paul Nutcher, CSI, CDT, in conducting research for an article on net-zero energy design, found that many net-zero designs incorporated either concrete masonry units (CMUs) or polished concrete floors, or both, and that they were particularly effective in applications such as commercial and educational projects where occupancy rates are significantly higher during the day.[20]

Brick construction has served as the primary material for net-zero energy building designs in Germany and elsewhere in Europe, including the high-efficiency Passivhaus projects. One net-zero energy residential project by solar architect Clemens Dahl and built in Eltville-Rauenthal/Rhine, Germany, in early 2009 combined a first-story envelope entirely of brick with a wood-frame attic supporting a solar roof array.[21] In 2009, Potomac Valley Brick, a clay brick manufacturer in Rockville, Md., sponsored a competition for architecture students

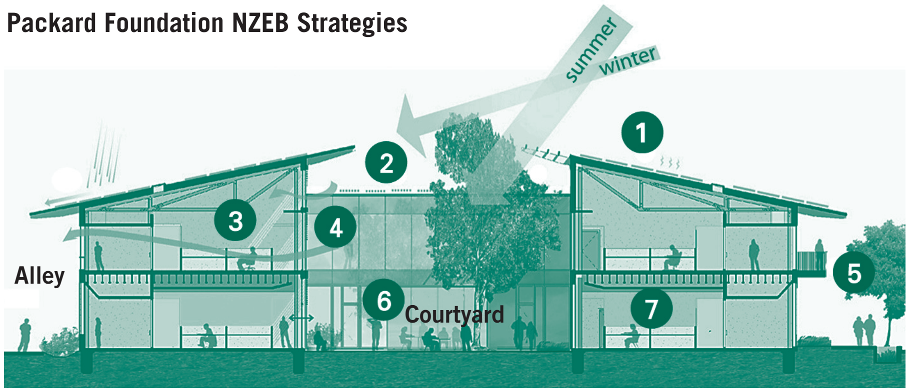
18 ThyssenKrupp Synergy system provides gearless machines that transfer unused power that would normally be dissipated via heat into the machine room. "With the regenerative drive the excess energy is captured and reused and the system eliminates costly traditional cooling of the elevator machine room," according to the manufacturer. See: http://www.thyssenkruppelevator.com/sustainabilityproducts.asp Otis offers the Gen2 regenerative drive system. See Loren Snyder, "Elevators Moving Up on Energy Efficiency" (October 2007), at: http://www.facilitiesnet.com/elevators/article/Elevators-Moving-Up-On-Energy-Efficiency--7549. KONE claims its regenerative drive can save up to 25% of the energy consumed by a typical 14-person elevator; see: http://www.kone.com/countries/en_GB/Products/Elevators/konemonospaceplatform/Energyefficiency/Pages/default.aspx.

19 See "Elevator, Escalator 'Cruise Control' Can Save 34% in Power," Environmental Leader Insights, at: http://www.environmentalleader.com/2009/10/02/elevator-escalator-cruise-control-can-save-34-in-power/. More information at: http://www.powerefficiencycorp.com/Esave.

20 "Zero-energy Buildings," Construction Specifier, October 2010, at: http://www.kenilworth.com/publications/cs/de/201010/48.html.

21 See: http://www.solarserver.com/solarmagazin/anlage_0209_e.html.

Packard Foundation NZEB Strategies



GRAPHIC: EHDD ARCHITECTURE

1. PV panels supply 100% of renewable energy
2. Solar hot water panels
3. 40-foot width maximizes daylighting and natural ventilation
4. Dynamic exterior blinds lower with direct sun
5. Layered shading strategies
6. Triple-glazed, highly insulating windows
7. Chilled beams with 100% fresh air

Section of a new office building, now under construction, for the David and Lucile Packard Foundation, Los Altos, Calif. The 49,000-sf facility, which will house 120 employees, will use chilled beams, a high-performance envelope, plug load reductions, and a 285 kW photovoltaic system to achieve net-zero energy status and LEED Platinum certification.

from around the world to design with brick. The 2010 competition challenges students to design a 10,000-sf net-zero energy office building (theoretically located in Baltimore, Md.) with brick as a primary material; winners will be announced in March 2011. The goal of the competition is to reintroduce brick, a 4,000-year-old architectural material, into the discussion of sustainable design.[22]

Whatever the material, the building envelope systems specified will largely determine the success of a net-zero energy project. According to the DOE 2008 Buildings Energy Data Book (http://buildingsdatabook.eren.doe.gov/), heating and cooling of buildings accounts for 32% of energy consumed in the commercial building sector and 35% on the residential side. Since the building envelope includes glazing and fenestration, high-performance envelope design must also incorporate strategies to reduce the consumption of energy for artificial lighting, which annually amounts to 7% of all energy consumed in the United States.

Resources abound for the design team striving for net-zero energy, and the vast majority of research available discusses existing technology. Furthermore, tax credits of 30% of cost are available for many of those who apply simple components for optimizing the envelope, including elements as basic as weather stripping and insulation.

Approaching the design from a more holistic viewpoint, Building Teams must consider the use of effective **moisture and air barriers.** In many buildings, air leakage can account for 50% of heat loss, with a typical small building containing as much as 2,000 linear feet of cracks and gaps. Whether applied toward the interior or the exterior of the envelope assembly, a well-designed air barrier is crucial to NZEB success. Exterior air barrier solutions include **high-performance curtain wall systems** of all kinds, **panelized wall sheathing**, **spray or fluid-applied liquid membranes,** and **synthetic wraps**.

If the team chooses to make the air barrier part of the envelope interior, they have three choices: a sheeting product, a liquid membrane, or an airtight drywall assembly, which when used in the proper climate and wall type can simplify the creation of an air barrier by making it part of a traditional gypsum interior assembly. Care must be taken to address the issue of openings in the envelope for windows and doors; specification of highly insulating glazing can be entirely undermined by an inadequate fenestration assembly, which can create air leakage, heat loss, moisture intrusion, and condensation. Poor window and door assemblies threaten not only the building's energy efficiency, but also the life span of the building itself, according to building enclosure specialists.[23] Window placement is also crucial, and is almost always linked most closely to south-facing elevations.

Finally, Building Teams must consider all that modern sustainable design has to offer, carefully specifying the best, most cost-effective technology that will produce the lowest energy consumption. **Low-flow plumbing**, for instance, saves both water and energy use while the price difference versus a standard-flow fixture is negligible. The use of **solar hot-water collection** adds another way to capture energy with very fast payback. Spending slightly more to upgrade electrical and lighting systems to even moderately more efficient models will create short-term payback for the client and take the design a major step toward net-zero energy status.

Existing technologies, even those as traditional as brick and insulation, must be considered for all net-zero energy buildings, whether residential or commercial. As in the case of reducing greenhouse gas emissions, the most cost-effective measures for reducing energy costs in structures are building insulation, lighting systems, air-conditioning (HVAC), and water heating.[24] When it comes to technology, going to the extreme of net-zero energy really starts with the basics.[25] BD+C

22 More info at: http://www.brickstainable.com/awards-event-info.html; 2009 winners came from Cyprus, Mexico, Qatar, and the U.S. See: http://www.brickstainable.com/competition/previous-winners.html. See also Derrick Taruc, "Project 'Brickstainable,'" The Poly Post (29 November 2010), at: http://www.thepolypost.com/lifestyle/project-brickstainable-1.2417025.

23 The Building Enclosure Council (BEC-National, at http://www.bec-national.org), a national organization with 23 state and local branches in the U.S., and the Building Enclosure Technology and Environment Council (BETEC, at: http://www.bec-national.org/index.php/betec/), are authorities on building enclosure technology. The Journal of Building Enclosure Design, published by the National Institute of Building Sciences, is an excellent resource. Free subscription at: http://www.wbdg.org/references/jbed.php.

See also "Energy Efficiency and Durability of Buildings at the Crossroads," a joint report of NIBS, BETEC, and BEC, 2 September 2008, at: nibs.org/client/assets/files/betec/03BEST1WhitePaper.pdf.

24 See "The McKinsey Cost Curve," in Building Design+Construction, "Green Buildings + Climate Change" (November 2008), pp. 51ff, at: http://www.bdcnetwork.com/article/bdcs-2008-white-paper-green-buildings-climate-change.

25 A valuable primer and energy data resource is the Buildings Energy Data Book, prepared for the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy by D&R International, Ltd. Silver Spring, MD. September 2008. Access at: http://buildingsdatabook.eren.doe.gov/.

For more than 50 years, Sto Corp. has been committed to the concept of sustainability. Our mission statement, summarized by the three words "Building with conscience," focuses on this commitment to environmental, economic and social sustainability. Simply put, it means doing the right thing for our customers, our community and the environment.

Sto Corp., based in Atlanta, Georgia, is an innovative leader and producer of a broad range of versatile cladding and coating systems for building construction, maintenance and restoration. Sto Corp. is ISO 14001:2004 as well as ISO 9001:2008 certified and operates production plants strategically located to serve more than 200 distributor shipping locations across North and South America. At research and development laboratories in the U.S. and Europe, Sto continues to revolutionize the industry with the highest quality products and application technology. Sto is also the world's largest manufacturer of exterior thermal insulation systems with 27 subsidiaries operating at 21 factories worldwide.

Sto recognizes the impact that buildings can have on the environment and on their occupants. That is why our mission is to maintain the value of old and new buildings for their owners, investors and users, by researching, developing, producing and marketing product systems and services that improve a building's energy efficiency, durability and aesthetic appeal. Through collaboration with like-minded customers and partners, we want to act as a pacesetter and play a leading role in helping to ensure that the world in which we live is designed in line with environmental requirements and our needs as human beings.

Sto products are designed to support sustainable building practices. We produce products that protect the building from degradation, are long lasting and energy efficient. We use low-VOC materials that are environmentally friendly and safe for the workers that apply them. We constantly look for innovative solutions to building issues and ways to improve our products' effectiveness and value. Sto Corp. manufactures insulated wall claddings, fluid-applied waterproof air barriers, and even coatings that have pronounced self-cleaning properties. These products are key components in sustainable construction today.

Sto supports sustainability throughout our operations. Sto Corp. manufactures our products in factories that are located strategically throughout the U.S. to best serve our markets. As of 2009, all of our North American facilities have implemented an ISO 14001 certified Environmental Management System, which we use to guide our efforts toward continual improvement of our environmental footprint. Sto Corp. has achieved a huge reduction in materials sent to landfill through company-wide recycling programs including paper products and electronics recycling. Other areas of improvement include: reduction of electricity use in all facilities; waste water reduction and recycling in our manufacturing processes; and a program for airborne particulate capture and exposure reduction. These efforts all help Sto minimize our carbon footprint, and we continually look for new ways to reduce the impact that our operations have on the environment.

Sto Corp. is committed to energy conservation, environmental protection and sustainability. Sto Corp. continues to demonstrate environmental consciousness in the three key dimensions of our business: our products, our processes, and environmental benefits to our customers. For more information on Sto Corp., please visit www.stocorp.com.

Sincerely,

David Boivin
President and CEO

4. Analyzing the Business Case

By Jerry Yudelson, PE, MBA, LEED AP BD+C/O&M

Jerry Yudelson is the author of 12 books on green building, green homes, green marketing, and water policy. His forthcoming book, The World's Greenest Buildings (Routledge, London, 2012), will focus on performance data from 60 of the world's highest-rated green buildings. He heads the Yudelson Associates consultancy in Tucson, Ariz., providing green building and sustainability consulting to a wide range of corporate and institutional clients.

Within a relatively short period of time, less than a decade, the business case for attaining a LEED rating for new green buildings has become the "Next Normal." Many major national property development, real estate management, and ownership interests, both public and private, now consider a LEED rating to be an important element of business as usual. For these executives, those with direct responsibility for managing economic assets to achieve a specified return, making the business case is vital, whereas saving the world is generally not their top priority (unless they are part of an organization that strongly seeks to meet triple-bottom-line considerations.)

In the new world of sustainable business, running a successful business and promoting a healthy environment are not seen as mutually exclusive. Still, profitability, both short- and long-term, is the key yardstick in business; a business that cannot maintain profitability cannot be considered sustainable. The time is fast approaching when the business case for greening *existing* buildings will also be considered as the Next Normal. That time is not quite here, but the experience and viewpoints of some of the leading practitioners of energy-efficient and green building operations are helping to usher in this new era.

What's the next frontier for business? I think it is Zero Net Energy (ZONE) buildings. (I have coined the term ZONE, for ZerO Net Energy, and find it more useful than the terms ZNE or ZEB now in use.) How do they fit into this green building world? What is the business case for ZONE buildings? Here, I will focus only on those buildings that meet the ZONE definition of the Living Building Challenge,[1] i.e., they have no net annual energy use and provide their annual net energy use with on-site renewable energy. In my opinion, calling a building "net-zero energy" that makes up for energy shortfalls by purchasing green power directly from off-site sources (or by purchasing renewable energy credits, or RECs) is a bit like the groom hiring a stand-in for his own wedding because he'd rather be golfing.

In addition, new energy standards such as ASHRAE 2011, Standard 189P, CALGREEN (the new State of California building code), and the like that reduce the maximum site energy use of a conventional building will make it ever easier to achieve ZONE standards, in combination with the likelihood of falling prices for on-site solar and wind energy systems.

TABLE 4-1. ASSUMPTIONS FOR A ZONE BUILDING WITH PV POWER

Required maximum energy demand (source)	100 kWh/sm/year (EUI = 31)
Required maximum energy demand (site)	40 kWh/sm/year (EUI = 12)
Annual PV system output	1500 kWh/kW (peak), AC output
PV system efficiency	15 kW/1000 sf
PV system cost	$5000/kW (peak), installed
Value of solar PV incentives (tax credits, utility rebates, depreciation)	$2000/kW (peak)

Source: Yudelson Associates, 2011

HOW MUCH EXTRA WOULD A ZONE BUILDING COST?

The key in developing ZONE buildings is to reduce their energy demand. An emerging standard for good building performance is a source (or primary) energy use of 100kWh per square meter per year.[2] This translates to a site energy use intensity (EUI) goal of about 12 (thousand Btu/sf/year).[3] (See Table 4-1.) Reducing the energy demand of a building to this low level will be a great challenge for Building Teams, but many buildings, primarily in Europe, have shown this can be done.[4]

To this must be added the cost of solar to make up the difference. For example, on a 110,000-sf (~10,000 sm), low-rise office building, solar photovoltaics would need to supply one million kWh of electricity (100 x 10,000) to offset the primary energy use of the building. At 1,500 kWh/kW (peak) of annual electricity production (in a sunny climate), the system would need to have a power output of 667 kW (peak). At 15 watts/sf of areal efficiency, the required extent of panels would be about 44,000 sf. On a two-story building, this would just about work. (Of course, adding solar thermal panels to meet the hot water and heating needs of the building—almost always a good idea, in my opinion—would reduce the required PV system size.) With an installed cost at about $5,000 per kW (peak) of PV, that would add about $3.3 million to the cost of the project, or about $30/sf of building area. Assuming federal and local incentives could contribute up to 60% of the initial cost, the net cost of the PVs would be about $12/sf, about 5% on a $240/sf conventional office building.

To the anticipated objection from building owners—"We can't pay 5% more for a ZONE building!"—consider the capital cost reduction that can be achieved by pursuing an integrated project design strategy aimed at cutting overall systems and envelope costs, using integrated project delivery (IPD) and the latest in BIM design technology. For example, the conceptual design study by HOK and The Weidt Group described elsewhere in this White Paper (see Chapter 6) posits that "integrated design on steroids" could produce a 170,000-sf (16,000-sm), four-story office building in St. Louis, Mo., with a site EUI of 22 that would require a 52,000-sf photovoltaic array and 15,000 sf of solar thermal panels. (Note: Some of the PV array is located on top of an adjacent parking structure—an appropriate design solution, in my opinion.) According to the authors, this approach would produce a net-zero-carbon building with a 12-year payback for features going beyond those of a conventional LEED-certified project.[5]

THE MULTIFOLD DIMENSIONS OF THE BUSINESS CASE

The business case for greening existing buildings is based on a framework of benefits: economic, financial, risk management, public relations and marketing, and project funding.[6] Table 4-2 lists the wide-ranging benefits of ZONE buildings. Some benefits accrue directly to the building occupants, some to the current property owner or manager, and some to the building's future financial and economic performance. However, some key benefits of certified green buildings, specifically those related to improvements in occupant productivity and health (notably daylighting and indoor air quality), will not necessarily be enhanced in a ZONE building. The business case benefits cited for ZONE buildings must necessarily relate specifically to the net-zero energy or net-zero carbon performance.

BENEFITS THAT ACCRUE DIRECTLY TO THE BUILDING OWNER

Let's start with the easiest justification for ZONE buildings: direct economic benefits to the building owner through reduced operating costs, induced higher rents, higher occupancy, or greater resale value.

Economic and financial benefits. For energy-efficient and green buildings, enhanced economic benefits can take a variety of forms, starting with lower operating costs.

Reduced operating costs. With electricity prices rising steadily in many metropolitan areas, making buildings energy efficient makes good business sense. Even in the case of "triple-net" leases, in which the tenant pays all operating costs, landlords may still want to offer tenants the most economical space for their money. For a small investment in capital cost, green buildings can save on energy operating costs for the lifetime of the building. In an 80,000-sf building, for example, using $3.00/sf per year in energy costs, an owner's savings of 100% for a ZONE building would translate to a reduction of $240,000 in annual operating costs that could be passed on, in whole or in part, to the tenants, thereby providing considerable marketing value as well as a potential increase in rent over time.[8]

Lower maintenance costs. More than 120 studies reviewed by Lawrence Berkeley National Laboratory have documented that energy-saving new buildings, if properly commissioned, will show additional savings of 10-15% in energy costs.[9] Retro-commissioning alone will typically yield 5-10% annual energy savings, according to a 2008 survey. Commissioned buildings also tend to be much easier to operate and maintain, with marked improvements in building equipment life, thermal comfort, and indoor air quality. By conducting comprehensive functional testing of all energy-using systems in normal operations, it is often possible to have a smoother-running building because potential problems are identified on a regular basis. Retro-commissioning of commercial buildings is a formal way to examine potential energy-saving improvements and to upgrade a building's Energy Star rating prior to trying other retrofits and adding renewables to achieve ZONE status.

Tax benefits and other financial incentives. Many states offer tax benefits for green buildings, including tax credits or deductions, property tax abatement, and sales tax relief. For example, New York State allows builders who meet energy goals and use environmentally preferable materials to claim up to $3.75/sf for interior work and $7.50/sf for exterior work in credits against their state tax bills.[10]

The 2005 federal Energy Policy Act (EPAct) and subsequent amending legislation offer two major tax incentives for greening existing buildings: 1) *a tax credit* of 30% on the installed cost of solar thermal (water heating) and solar electric (photovoltaic) systems, good through the end of 2016; and 2) *a tax deduction* (good through 2013) of up to $1.80/sf for projects that reduce energy use for lighting, HVAC, building envelope measures, and water heating systems by 50% compared

TABLE 4-2.
POTENTIAL BUSINESS-CASE BENEFITS OF ZONE BUILDINGS

1. Utility cost savings for energy and water, typically $3.00-4.00/sf, along with reducing the building's carbon footprint due to zero-net-energy use.
2. Maintenance cost reductions from commissioning, monitoring, metering, and other measures to assure proper HVAC system performance.
3. In commercial buildings, increased value from higher net operating income (NOI) and better public relations, owing to higher rents and greater occupancy in LEED-certified buildings.[7]
4. Tax benefits for specific investments in renewable energy and other sustainable technologies, such as those specified in state and federal legislation since 2005.
5. More competitive real estate holdings for private-sector owners over the long run, especially in comparison with LEED-certified new buildings and others that offer lower energy costs.
6. Risk mitigation, especially against future increases in electricity prices (electricity use comprises 70% or more of building energy use).
7. Marketing benefits, especially for developers and building owners.
8. Public relations benefits, especially for developers, building owners, and building management firms.
9. Improved recruitment and retention of key employees.
10. Higher morale for tenants and building owners and managers.
11. Greater availability of equity funding (such as from institutions engaged in so-called "responsible property investing"), including funding for building sales and for upgrading existing building performance to ZONE standards.
12. Demonstration of commitment to sustainability and environmental stewardship, as well as enhancing shared values with key stakeholders.

Source: Yudelson Associates, 2011

1 http://ilbi.org/lbc/v2-0, accessed 2 January 2011.

2 Personal communication, Thomas Auer, Transsolar, December 2010, based on Transsolar's experience with several buildings in Germany. See also Jerry Yudelson, "If It Doesn't Perform, It Can't Be Green," Building Design+Construction, November 2010, at: http://www.bdcnetwork.com/ifitdoesntperformitcantbegreen.

3 100 kWh/sm/yr @ 3414 Btu/kWh and 1 sm/10.89 sf, giving a total source EUI of about 30. Ratio of site to source energy use is about 2.5 kWh/kWh for fossil-fuel-fired U.S. electric power, resulting in a site EUI goal of 12. This will vary by region, of course, with those areas having more hydroelectric power having a lower site-to-source ratio.

4 See Jerry Yudelson, Green Building Trends: Europe (Island Press, 2009).

5 "The Path to Net Zero Co$_2$urt: Where Form Follows Performance," HOK and The Weidt Group, 2010, at: www.netzerocourt.com, accessed 2 January 2011.

with a 2001 baseline standard.[11]

These incentives could be readily applied to ZONE buildings. For example, on the retrofit of a 300,000-sf commercial office building, a tax deduction of up to $540,000 would be available, netting a potential tax savings of $135,000 at a 25% marginal federal tax rate. In addition, solar incentives to offset remaining building loads would receive federal tax credits, and possibly local utility rebates and state tax benefits as well.

Additional financial incentives. Depending on location, a number of other financial and project incentives may be available for green building investments, including:

• State tax credits and sales tax exemptions on material purchases

• Property tax exemptions

• Utility cash rebates, grants, and subsidies (typically based on energy savings or the use of renewable energy systems)

•Permit assistance, including faster permitting or priority processing for new buildings

•Greater opportunity for financing from socially responsible investors, such as pension funds, REITs, and private investment groups that focus on green buildings

The Database of State Incentives for Renewable Energy and Energy Efficiency (www.dsireusa.org), available from the North Carolina Solar Energy Center, is a reliable and fairly complete source of current information on all types of incentives.[12]

Risk mitigation. Risk in building operations has multiple dimensions: financial, market, and legal, not to mention the risk to the owner's reputation. Since it's often hard to increase net operating income from building operations in the short run, especially in today's economic climate, mitigating risk exposure also has positive economic benefits.

Meeting pro forma projections. There is growing evidence of considerably greater resale value for LEED and Energy Star buildings. Buildings with lower energy costs tend to be easier to rent and sell, because sophisticated tenants can understand and directly experience their benefits. Obtaining higher rents and greater occupancy for such buildings compared to similar projects in the same real estate market could become an increasingly important risk management benefit of ZONE buildings in the private sector.

More competitive product. It should not require too great a stretch of the imagination to see that buildings with net-zero operating costs for energy are likely to be more attractive to a growing group of corporate, public, and individual private tenants who value sustainability, making ZONE buildings more competitive in high-profile real estate markets. Greenness per se will not soon replace traditional real estate attributes—notably price, amenities, and the all-important location, location, location—but it is likely, in my opinion, that ZONE features will soon be entering into tenants' rental decisions and buyers' purchasing decisions.

BENEFITS TO BOTH OWNER AND TENANTS

Many building owners in both the public and private sectors are finding considerable benefits from green buildings, particularly in the form of positive marketing and public relations with their stakeholders.

Public relations and marketing benefits. Marketing is an essential component of all building operations, even in the public and quasi-public sector. Publicly traded corporations, privately held companies, public agencies, universities, hospitals, school districts, and many nonprofit social and environmental organizations seeking to maximize their brand equity are capitalizing on the marketing and public relations benefits of green buildings—benefits that likely will accrue to ZONE buildings in the future.

Stakeholder relations and occupant satisfaction. Tenants and employees want to see a demonstrated concern for their personal well-being and that of the planet. Progressive building owners are wise to market these benefits to discerning and skeptical clients and stakeholders, using the advantages of LEED and Energy Star, including support from local utility and industry programs. This is not "greenwashing"—making unsubstantiated green claims—

How to Refinance a Green Portfolio

Based on recent experience with LEED-certified buildings, it is possible that future portfolios of ZONE buildings could benefit from favorable refinancing terms.

Take the case of Melaver, Inc., a sustainably minded commercial real estate development company based in Savannah, Ga. According to Melaver chief financial officer Denis Blackburne, LEED certification proved to be the difference in enabling the company to refinance some of the firm's properties in the last decade. "We went to New York City and met with the top financial institutions and said, 'We have a portfolio of six green properties for you,'" Blackburne recalled. "They thought we were tree huggers and we were sent off to the 'community grants' floor. We went back home, did our homework, and presented our case to the financial community the second time around by saying, 'We have six properties that have quality tenants, are in the right location, look great, are well-managed, have high occupancy, and by the way are high-performing, energy efficient, and environmentally friendly.' All of a sudden the doors opened and we were able to refinance this portfolio and exceed our objective by far. When we looked at the future cash flow projections, we were given full credit for the future benefits that were included in the LEED certification."[13]

6 *"Making the Case for Green Building," Environmental Building News, 14, No. 4, 34-35 (April 2005), http://www.buildinggreen.com/articles/IssueTOC.cfm?Volume=14&Issue=4 (fee), accessed 2 January 2011.*

7 *See for example, Sofia Dermisi, "Effect of LEED Ratings and Levels on Office Property Assessed and Market Values," Journal of Sustainable Real Estate (JOSRE), 1, 1, 2009, 23-47; Franz Fuerst and Patrick McAllister, "An Investigation of the Effect of Eco-Labeling on Office Occupancy Rates," JOSRE, 1, 1, 2009, 49-64. See also Norman Miller, "Does Green Still Pay Off?" CoStar Group, http://www.costar.com/JOSRE/doesGreenPayOff.aspx, accessed 2 January 2011.*

8 *Peter Belisle, "Tips from the Trenches," Commercial Property Executive, December 2010, at: http://digital.cpexecutive.com/publication/?i=53725, accessed 2 January 2011.*

9 *Lawrence Berkeley National Laboratory, "The Cost-Effectiveness of Commercial-Buildings Commissioning," 2004, at: http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html. This research reviewed 224 studies of the benefits of building commissioning and concluded that based on energy savings alone, such investments have a payback within five years.*

10 *Natural Resources Defense Council, at: www.nrdc.org/cities/building/nnytax.asp, accessed 6 March 2007.*

11 *U.S. Department of Energy, at: www.energy.gov/taxbreaks.htm, accessed 2 January 2011.*

but rather a positive response to a growing public concern for the long-term health of people and the environment.

Would ZONE buildings with green building certifications actually help building owners reduce tenant turnover through greater satisfaction? Most commercial real estate leases are of the "triple net" variety, whereby the owner passes through all operating expenses to the tenant; therefore, any savings in energy costs directly benefit the tenant, not the owner. If operating costs for energy were reduced to zero, would that be a sufficient incentive to encourage tenants to renew their leases? It probably depends on many factors beyond just energy cost.

It should be noted, however, that one of the ongoing costs in operating buildings is paying for leasing commissions and tenant improvements to meet the needs of new tenants, so any factor that enhances tenant retention will save the owner at least some costs. Thus, if a ZONE building eliminates energy costs, it would have to be penciled out as to whether the costs of the energy improvements versus the benefits of tenant retention would work in the owner's favor over the long run.[14]

Environmental stewardship. Being a good neighbor is appropriate not just for building owners and users, but also for the larger community, and it is a key component

The Z^2—for "net-zero energy, net-zero emissions"—IDeAs office building in San Jose, Calif., uses high-efficiency electrochromic windows and skylights to take advantage of daylight and operable windows to permit natural ventilation. Photovoltaic panels, part of the single-ply roof, provide the facility's energy source. A Johnson Controls Metasys building management system controls the geothermal heat pump and radiant floor system.

Converted Bank Becomes First Commercial Net-Zero Energy, Net-Zero Emissions Building

In 2005, when Integrated Design Associates (IDeAs), an electrical engineering and lighting design services firm, bought a 7,200-sf, '60s-era bank branch in San Jose, Calif., the firm's principals had a clear intent: to turn the windowless concrete structure into a unique headquarters building.

After consulting with the Building Team—EHDD Architecture, Rumsey Engineers, and Hillhouse Construction—the firm's principals, David and Stephania Kaneda, charged the team with turning this ordinary structure into a net-zero energy, net-zero emissions "Z^2" showcase. This was accomplished using a full complement of sustainable design techniques and renewable energy from building-integrated PVs to meet 100% of the facility's energy requirements, with no use of fossil fuels and no greenhouse gas emissions.

Johnson Controls designed the HVAC system to maximize performance, energy efficiency, and indoor air quality. The energy efficiency of the HVAC system and building envelope delivers a building that uses less than 25% of the energy consumed by the average commercial buildings of similar size.

The design incorporates a geothermal heat pump, which takes advantage of the constant year-round below-ground temperature (10ºC), as well as a radiant floor system with cross-linked counterflow tubing that uses water to convey heating and cooling to the space.

The system uses less energy to provide the same level of comfort as traditional systems, due to the temperature variance between the occupants and the floor itself. "Since the system has been operating [the building was completed in 2007] it has already provided a very cool and comfortable environment during some very hot weather," said David Kaneda. "It is a very efficient system that [is helping] us meet our net-zero energy target."

A Johnson Controls Metasys building management system controls the flow rates and slab temperature to optimize performance while using the least amount of energy. Pump speeds are kept at their lowest demand speed using power inverter technology that responds to actual demand. Floor condensation is prevented by the system, which compares the floor temperature to the room air dew point temperature. Dehumidification is provided, if needed, by the air handler using chilled water and concurrent condenser water for temperature control via a pair of dual coils in the air handler. The Metasys system monitors air quality sensors and automatically operates the air handler when carbon dioxide levels rise above a preset point.

of triple-bottom-line management. Developers, Fortune 1000 corporations, colleges and universities, school districts, healthcare systems, state and local governments, federal agencies, and progressive building owners and real estate developers have long recognized the marketing and public relations benefits of a demonstrated concern for the environment.

Green buildings fit right in with that message, which is why I expect to see in the very near future major commitments to ZONE buildings by corporate real estate executives. One example of the potential benefit of such an approach is Adobe Systems, a major software maker based in San Jose, Calif. In 2006, Adobe received LEED-EB Platinum awards for its three headquarters towers. Not only did this announcement yield waves of adulatory publicity for Adobe, but the firm was also able to demonstrate that the capital investment had returned a net present value almost 20 times the initial cost.[15]

A growing number of public and private entities are committing their organizations to well-articulated sustainability mission statements and are including their real estate choices as a factor that can both reflect and advance the larger sustainability mission. ZONE buildings will become a key item on these checklists.

Institutional brand image. Consumer-oriented companies like Walmart, Kohl's, Best Buy, and PNC Bank have delicately exploited their association with green, solar, and energy-efficient buildings to improve their brand image, and many more enterprises, both public and private, are following suit.[16] Fortune 1000 corporations, particularly those issuing sustainability reports, are beginning to see how building green demonstrates to their employees, shareholders, and other stakeholders that they are walking the walk. This trend will only accelerate as these entities engage in building ZONE headquarters, office buildings, and other facilities.

Branding and positioning of commercial properties. Speculative developers with a growing portfolio of green projects might generate a greater ability to win business from major corporate tenants with a strong commitment to sustainability as evidenced by ZONE buildings. This could be particularly true for ZONE retrofits, which could represent a golden opportunity to reposition older office and industrial properties as more upscale or trendy.

For example, warehouses have extensive roof areas and relatively low energy-use intensities; thus, a commitment to ZONE buildings could be easily realized for many warehouses. Such branding might help to make older properties more competitive with new LEED-certified buildings coming on line in major real estate markets. Alternatively, forward-thinking developers could apply a ZONE branding concept to entire office parks, using large-scale photovoltaic solar energy systems or tall wind turbines that would be architecturally iconic and highly visible to the public. Establishing and improving the environmental performance of older properties could be an essential element in rebranding and repositioning them to be more attractive to tenants looking for green office space, as evidenced by a ZONE designation.

Recruiting for top revenue producers. Over the past 15 years, corporate America has grown profits largely by squeezing operating costs through downsizing, rightsizing, outsourcing, logistics and information technology improvements, and other well-established management techniques. Having done all that, many companies may be reaching the limits of what they can do to trim costs and boost efficiency. To grow profits in today's economy, companies need to grow top-line revenue. In the U.S. economy, which has largely shifted toward providing services, top-line revenue growth comes from recruiting and retaining best-and-brightest performers. For service-providing companies in particular, the 80/20 rule holds true: in most cases, 80% of revenues will be derived from the efforts of the top 20% of employees. High-profile companies in ultra-competitive industries like electronics, pharmaceuticals, and healthcare must focus a good part of their marketing and business development strategies on making their companies attractive to a relatively small pool of the most highly qualified people.

Add to this the coming scarcity of Gen X'ers—the population born between 1965 and 1978—who are needed to fill the key management and leadership positions in private businesses and the public sector. By 2014, there will be 7% fewer 35- to 44-year-olds in the U.S. than in 2005, a shortfall of 2.6 million in this crucial demographic cohort.[17] If it is true that "demographics is destiny," it is easy to see why businesses and organizations seeking to get and keep good people, especially those who drive top-line revenue growth, will be looking to ZONE buildings and workplaces to provide tangible evidence of their commitment to sustainability to this key demographic segment. High-level recruitment may soon emerge as a key driver for forward-thinking corporations and organizations to consider making their green buildings into ZONE buildings.

The next step: Employee retention. One often-overlooked aspect of green buildings is their potential effect on people's desire to stay with an organization. It can cost $50,000-150,000 to replace a valued employee, and most organizations experience 10-20% turnover per year. Of course, employees leave their jobs for many different reasons, but in some cases at least it is due to a poor physical conditions in the working environment. What if that brain drain could be stemmed through green building?

Take a hypothetical example: In a company with a

12 For a list of state tax incentives for renewable energy, see the Directory of State Incentives for Renewable Energy, www.dsireusa.org. Other local government incentive programs can be found at https://www.usgbc.org/ShowFile.aspx?DocumentID=691, accessed 2 January 2011.

13 Jerry Yudelson, Greening Existing Buildings, 2009, New York: McGraw-Hill, p. 81.

14 Peter Belisle, "Tips from the Trenches," Commercial Property Executive, December 2010.

15 U.S. Green Building Council, at: www.usgbc.org/News/PressReleaseDetails.aspx?ID=2783, accessed 2 January 2011.

16 For example, a few years ago PNC Bank committed to making all of its new branches at least LEED Certified: http://www.prweb.com/releases/2010/05/prweb3972764.htm, accessed 2 January 2011.

17 See Jerry Yudelson, The Green Building Revolution, 2007, Washington, DC: Island Press, p. 41.

18 During a 2008 tour of the Genzyme headquarters in Cambridge, Mass., the first large corporate LEED Platinum building (completed in 2004), I was told that employee turnover in this beautifully daylit building had been reduced by 5%, representing 45 fewer people leaving the company each year. At $50,000 per loss, this represented an annual profit gain of $2.25 million, about $6.00/sf. If the LEED Platinum had cost an extra $12.00/sf (about 5% of capital cost), the reduction in turnover alone would represent a two-year payback on the incremental investment, not counting energy savings or other benefits.

workforce of 900, turnover at the low end (10%) would mean 90 employees leaving every year. If building green could reduce gross turnover by 10%, the cost of replacing those nine employees would be obviated, resulting in a first-year savings to the company of $450,000 in turnover costs (at the low end), and as much as $1.35 million over a very reasonable three-year "payback" period.[18] Taken alone, the value of that $1.35 million might easily be enough to justify spending the extra funds to help achieve a ZONE building.

BENEFITS TO FUTURE FINANCIAL PERFORMANCE

Most private organizations have short-term planning horizons. But many large property owners have been in business for decades and plan to stay in business, so they must balance the short-term costs and benefits of greening their buildings with the longer-term positive outlook for sustainable buildings. In this context, the long-term reduction in operating costs for ZONE buildings must count as a major benefit, provided that the incremental costs can be financed in a way that is not detrimental to the owner's cash flow. Let's look at some ways this objective can be achieved.

Picking up the PACE. The growth of commercial PACE (Property Assessed Clean Energy) financing is one way this is happening. Already, half the states in the U.S. have adopted PACE programs, mostly for existing buildings.[19] In PACE financing, the building, not the owner, carries the incremental cost of energy-saving investments, through a loan that is recovered from future property tax assessments, typically over a 20-year period. My own analysis shows that investment portfolios with payback periods greater than seven years are unlikely to show positive cash flows, since interest rates on the loans are typically greater than 7%. This need not be a problem, however, if the longer-term paybacks of solar systems, for example, were to be bundled with the shorter-term paybacks from efficient lighting, variable frequency drives, high-efficiency HVAC systems, and similar active systems. In fact, it's quite possible to retrofit an existing building to be a ZONE building, even in the humid tropics, as was done in a 2009 retrofit in Singapore by the Building and Construction Authority.[20]

'Future-proofing' energy costs. Energy represents 30-35% of a typical building's operating costs and is among the more nettlesome costs for owners to control. In major cities, commercial buildings already are paying very high electricity rates for peak-period electricity. As electricity supply continues to lag behind demand, it is not unreasonable to expect utilities to try to reduce the growth in demand by bumping up peak-period rates even more. As with older buildings, demand reduction is a key strategy in reaching ZONE goals and improving user comfort. Anything that can be done to reduce thermal loads in a building, such as installing low-wattage lamps and using occupancy daylight sensors, will also reduce peak-period electrical demand and the resulting charges an owner has to pass through to tenants.

BARRIERS TO REALIZING ZONE BUILDING BENEFITS

While there are a number of factors promoting ZONE buildings, there are also several critical inhibiting factors that deserve further attention.

Split incentives. One of the biggest barriers to greening existing buildings is that the benefits of energy savings are often unequally distributed between those who pay for the work and those who benefit from it. In the world of commercial multi-tenanted buildings, this issue is often called the "split incentive," where owners incur the costs and tenants reap the benefits.

In the case of a corporate or government owner/operator, however, the split often comes because of the difference in how capital expenditures and operating costs are treated in the organization's budget process. Thus, even when it can be proven mathematically that spending money on energy-saving improvements today will save money in the long run, the budget process will disallow the extra "first costs" as exceeding the current budget allocation for the project.

Benefits vary by owner type. Table 4-3 shows the distribution of green building benefits. When seeking to build or upgrade to ZONE buildings, property owners, facility managers, building operators, and developers should consider these distinctions in tailoring their case to decision makers. In the future, public policy for promoting ZONE buildings will take this unequal distribution of benefits into account by creating incentives to overcome gaps in the marketplace, such as the "split incentive" issue referenced earlier. Cities and states committed to reducing overall carbon emissions are likely to institute mandates for commercial building owners that would require them 1) to disclose energy use prior to leasing or selling the building, as is the case for the District of Columbia and the state of California; or 2) to obtain LEED-EB or Energy Star certification (as Austin, Texas, is doing) for existing buildings or with any major renovation, similar to what has been required for years on the West Coast for earthquake protection.[21]

Financing ZONE building upgrades. Incremental energy-efficiency and renewable energy investments of as much as $5.00/sf represent a significant capital outlay that may rule out such investments for many building owners. With prevailing interest rates still relatively low, it would seem to be a financially prudent time to borrow for such upgrades. However, the capital available for

19 http://pacenow.org/blog/, accessed 2 January 2011.

20 http://www.greenbusinesstimes.com/2010/09/15/singapores-zero-energy-building-zeb-on-track-to-meet-net-zero-power-consumption/, accessed 22 January 2011.

21 Disclosure is already required in 2011 by California's AB 1103 (2007 law), see: http://www.energy.ca.gov/ab1103/, accessed 22 January 2011; as of 1 June 2011, the city of Austin's Energy Conservation and Disclosure Ordinance will require Energy Star ratings for all commercial buildings (10 years or older) that receive their energy from Austin Energy, at: http://www.austinenergy.com/About%20Us/Environmental%20Initiatives/ordinance/commercial.htm, accessed 22 January 2011. The District of Columbia requires disclosure of energy use data for private-sector buildings exceeding 200,000 sf. ASHRAE has also developed a green building labeling standard; see: http://www.tc76.org/ASHRAEBuildingEnergyLabelingProgramJarnagin.pdf.

financing these upgrades, while currently difficult for many companies to obtain, hopefully will become more accessible as economic conditions improve.

NEEDED: A CONCERTED, 40-YEAR EFFORT

In 2009, the World Business Council for Sustainable Development issued a report specifying how the goal of the U.N. Intergovernmental Panel on Climate Change to reduce world carbon emissions by 77% by 2050 might be met with appropriate contributions from the building sector.[22] The study looked at six building markets that produce half the world's GDP and generate two-thirds of global primary energy: Brazil, China, Europe, India, Japan, and the U.S. Among the principal findings:

• Energy-efficiency projects totaling $150 billion annually could reduce carbon footprints by 40% with five-year (or less) discounted payback periods, assuming energy prices around $60 per barrel of oil.

• A further $150 billion annually in energy-efficiency projects, with paybacks between five and 10 years, could add another 12% in carbon footprint reductions, bringing the total to 52%.

The WBCSD report noted the split incentive dilemma: Building owners would be responsible for putting up the initial capital for these investments, but under generally applicable current lease structures, tenants would be the main beneficiaries. Even these savings make up only one-third of the projected reductions in building energy use necessary to control the growth in carbon emissions. To go beyond only those energy investments with shorter paybacks will require "integrated actions from across the building industry, from developers and building owners to governments and policy-makers," according to the WBCSD.

Among other measures recommended by the WBCSD report:

• Tax incentives and subsidies to spur investments and reduce the payback period to less than 10 years.

• New building codes and inspection procedures focused on energy efficiency.

• Restructuring the goals of new construction projects to include integrated ZONE design and carbon emission reduction as a prime requirement.

Beyond these measures, the study called for major cultural and behavioral shifts that can be the hardest changes to bring about, but are arguably the most effective in the long run. Getting building occupants to take responsibility for energy use will not be easy, but it can, from my experience, be achieved through effective monitoring, metering, and feedback systems. However, it may be harder (legally and professionally) to convince architects, engineers, and contractors to take responsibility for the performance of systems they design and construct, even if they are not legally required to do so.

In conclusion, the business case for net-zero energy buildings is solid and will become more apparent within the next two years. The business case does not rest solely on measurable economic and financial benefits, but on many other tangible and intangible benefits as well, including public relations, marketing, employee relations, access to new forms of financing, and building "reputational capital" as a sustainable enterprise. While it is crucial to be able to justify the economic and financial benefits of ZONE buildings, the prospect of future regulation of carbon emissions, while currently on hold, will eventually drive the business case for net-zero energy building upgrades on the part of leading building owners, operators, and managers.

Such regulation will take place first in states such as California (where public policy, coupled with pressing problems in public finance, will combine to compel all levels of government to find ways to save on energy) and then move to other states and cities with aggressive policies to counter climate change. Even without further regulation, I believe creating net-zero energy buildings will, in the next few years, become a guiding principle of corporate sustainability initiatives. BD+C

22 "Energy Efficiency in Buildings—Transforming the Market," World Business Council for Sustainable Development, http://62.50.73.69/transformingthemarket.pdf accessed 1 May 2009.

TABLE 4-3.
DISTRIBUTION OF ZONE BUILDING BENEFITS

Benefit type /Owner type	Energy savings	Building value	Marketing to tenants	Public relations	Recruitment and retention	Sustainability claims
Private, owner-occupied	Yes	Not typically important	N/A	Very important	For recruiting key people	Yes
Private, speculative, or not owner-managed	No (for a typical "triple net" lease)	Yes	Yes	Very important	Indirect benefit	Yes
Retail	Yes	Yes	Somewhat	Very important	Not yet seen as important	For most, not yet important
Colleges and universities	Yes	N/A	N/A	Very important	Somewhat important	Very important
Federal government	Yes	N/A	N/A	Important for policy	Not too important	Important to the current Administration
State government	Yes	N/A	N/A	Important for policy	Not too important	Important for policy
Local government	Yes	N/A	N/A	Important for policy	Somewhat important	Important for policy

Source: Yudelson Associates, 2011

NAIMA

NORTH AMERICAN INSULATION MANUFACTURERS ASSOCIATION

The idea of a net zero energy building has quickly moved from concept to reality. In fact, it is now a compelling and integral part of the "green construction movement." Tomorrow's net zero energy buildings will improve this country's energy balance and help put the U.S. back on a path toward greater energy security and sustainability.

Energy efficiency is the key to its success. The availability of existing, yet energy and environmentally efficient technologies, such as high-performance insulation systems, is one of the reasons the net zero building concept has advanced so quickly. At the forefront of these discussions is the North American Insulation Manufacturers Association (NAIMA).

The North American Insulation Manufacturers Association is a trade association of North America's leading fiber glass, rock wool and slag wool insulation manufacturers. NAIMA has a 75-plus year history in the energy efficiency arena, and its fundamental objective is to promote energy efficiency, sustainable development, and environmental preservation through the safe use of high-performance fiber glass, rock wool and slag wool insulation.

Insulating the Building Envelope: Maximizing Energy Efficiency on the Road to Net Zero Energy Buildings

NAIMA firmly believes that the first step toward net zero energy buildings must be maximizing energy efficiency in the building envelope. Today's thermal envelope systems are designed specifically to reduce energy consumption and improve occupant comfort. The good news is these insulation technologies are one of the few that can be implemented immediately and installed to meet the energy code requirements of today and energy demands of the future. Unlike many of the other technologies targeted for net zero energy buildings, insulation requires no additional energy such as electricity to function. And, most importantly, these insulation systems will enhance the performance of additional energy efficiency technologies as they are designed into or added to the buildings.

Architects, specifiers, builders, homeowners, and policymakers are all part of the process to building a sustainable future. To help these important audiences in their building and construction decisions, NAIMA maintains a large literature library filled with free (and many downloadable) specification tools, scientific research, installation recommendations, and codes and standards information. In addition, our website (www.naima.org) maintains current information on the status of building energy codes, federal and local tax incentives as well as links to our members, who offer advanced insulation thermal envelope systems.

NAIMA is active in the Commercial Buildings Consortium and other formal and informal dialogues on the topic of net zero energy buildings. As an industry leader in the energy efficiency discussion, NAIMA has always taken an active role in the many leading U.S. and global organizations that are helping to develop policies and implement educational programs that will make their way into the net zero energy building arena.

Insulate today. Save tomorrow.

Kate Offringa
President and CEO
North American Insulation Manufacturers Association (NAIMA)
www.naima.org
703-684-0084

5. Developing Effective Codes and Standards for Net-Zero Energy Buildings

By Ryan M. Colker, JD, Dave Hewitt, and Jessyca Henderson, AIA

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In the past couple of years, policymakers have come around to viewing energy codes as an opportunity to effect wide-ranging changes in energy use. The past two cycles of ANSI/ASHRAE/IES Standard 90.1 and the past and current cycles of the International Energy Conservation Code (IECC) already have resulted in improvements on the order of 30% in energy efficiency, in contrast to the single-digit improvements in prior versions. So-called "stretch codes and standards" designed to reach even further, notably ANSI/ASHRAE/USGBC/IES Standard 189.1 and the International Green Construction Code (IgCC), are also coming to the fore.

Leading organizations within the building community, including the AIA,[1] ASHRAE, the U.S. Green Building Council, and the Illuminating Engineering Society, as well as top design and construction firms and government agencies such as the U.S. Department of Energy and the General Services Administration, have identified net-zero energy buildings as the ultimate goal for cutting energy use in buildings and reducing their greenhouse gas emissions. Achieving widespread net-zero energy buildings through the adoption and enforcement of codes and standards is likely a long way off, but if we are to move an industry that often is slow to change, the discussion must start now.

Understanding how current building energy codes function, their shortcomings, and the possibilities for improvement are essential if we are to achieve cost-effective, technically sound net-zero energy buildings. Currently, there seems to be little attention focused on how energy codes function, whether they are getting us to our energy goals, and what future codes might look like.

Even though "energy" is in their names, current energy codes do not actually regulate energy use. They regulate the thermal envelope and the systems for HVAC and lighting that influence the use of energy but not the building's actual energy use. The codes also are based on utilization in an ideal world where equipment, insulation, ducting, windows, doors, air barriers, lighting systems, equipment, and controls are all installed perfectly, where O&M requirements are followed to the letter, and where building occupants don't override the systems and make educated decisions about their energy use. In practice, the actual performance of buildings is never perfect, no matter how diligent the Building Team, operations staff, building occupants, and owner may be.

Moreover, current codes do not cover all the energy-consuming functions in a building, even though these functions contribute to the overall energy use and influence the energy use of equipment covered under the code. Plug and process loads and elevators and escalators generally are not included. In California, for instance, plug loads account for about 40% of overall energy use in buildings—closer to 65% in hospitals and restaurants.[2]

Finally, annual spending for code development, implementation, training, and enforcement is estimated at around only $200 million dollars, well short of the $810 million needed to ensure a 90% compliance rate.[3] Current compliance rates also are unknown, although some reports indicate levels as low as 40%.[4] This is far from the 90% compliance by 2017 mandated in the American Recovery and Reinvestment Act (Public Law 111-5).

Net-zero energy buildings are just beginning to enter the marketplace. However, to achieve energy independence and reduce greenhouse gas emissions, they and other buildings that are verifiably green throughout their life cycles must gain much wider adoption. The current approach to determining and regulating energy use will not get us there. If we are to get to truly net-zero energy buildings, we'll need codes and standards that measure real (not just modeled) energy performance, account for all energy uses in buildings, and provide for post-occupancy regulatory scrutiny.

THE MANY FLAVORS OF CODES AND STANDARDS

Codes and code-intended standards are specifically written for adoption by jurisdictions to facilitate the achievement of community goals. Minimum codes and standards (such as the IECC and Standard 90.1) provide baseline levels that all buildings should meet. Stretch codes or standards (such as Standard 189.1 and the IgCC) require higher levels of achievement and can be used in a variety of ways by jurisdictions or individual building owners—for example, to apply to all buildings

1 *Architecture 2030, The 2030 Challenge. At: http://architecture2030.org/2030_challenge/the_2030_challenge, accessed 23 September 2010.*

2 *Architectural Energy Corporation, "Rethinking Percent Savings: The Problem with Percent Savings and the New Scale for a Zero Net-Energy Future," 2009. At: http://www.archenergy.com/news/rethinking-percent-savings-the-problem-with-percent-savings-and-the-new-scale-for-a-zero-net-energy-future.*

in a jurisdiction, or to apply only to specific types of buildings as the basis for earning incentives. Stretch codes define a higher level of energy efficiency that may be used as the basis of voluntary programs (such as utility efficiency efforts) or government construction projects, or may be adopted by local jurisdictions to go beyond state-required minimums. Stretch codes are likely to be the first places NZEBs will enter the code world (see Figure 6-1).

Today's energy codes come in two basic formats, *prescriptive* and *performance*, each with its pros and cons. A possible third format, *outcome-based*, has begun to pique the interest of the building community.

PRESCRIPTIVE CODES: EASY TO USE, EASY TO ENFORCE, BUT REACHING THEIR LIMITS

Prescriptive codes provide minimum characteristics for many building components (e.g., R-values for wall and ceiling insulation, U-values for windows, and SEER or EER for unitary air conditioners). Prescriptive codes represent a checklist of requirements and minimally acceptable specifications, making them relatively easy for Building Teams to comply with and code officials to enforce.

However, prescriptive codes have several shortcomings. Since they are based on strict requirements and updated on a fixed cycle (currently three years), they can be slow to incorporate new technologies. Nor do they reward more efficient design decisions that look at the building as a total system. Lastly, prescriptive codes favor projects seeking minimum levels rather than those seeking high performance.[5]

Moreover, criteria in prescriptive codes are based on the ideal, not actual practice. The building's actual total energy use cannot accurately be determined through the codes because the codes do not cover all energy uses (although building energy modeling does allow for determinations based on assumptions associated with unregulated energy uses).

Even though policymakers may believe that prescriptive energy codes will reduce energy used in new construction and renovations, prescriptive codes do not contain a requirement to measure energy use, to see if the desired results are being met. Moreover, the very nature of prescriptive codes and the many aspects of building design that they do not touch (such as window area and building massing, shape, and design) make it difficult to compare actual energy use between buildings even if it was required to be measured.

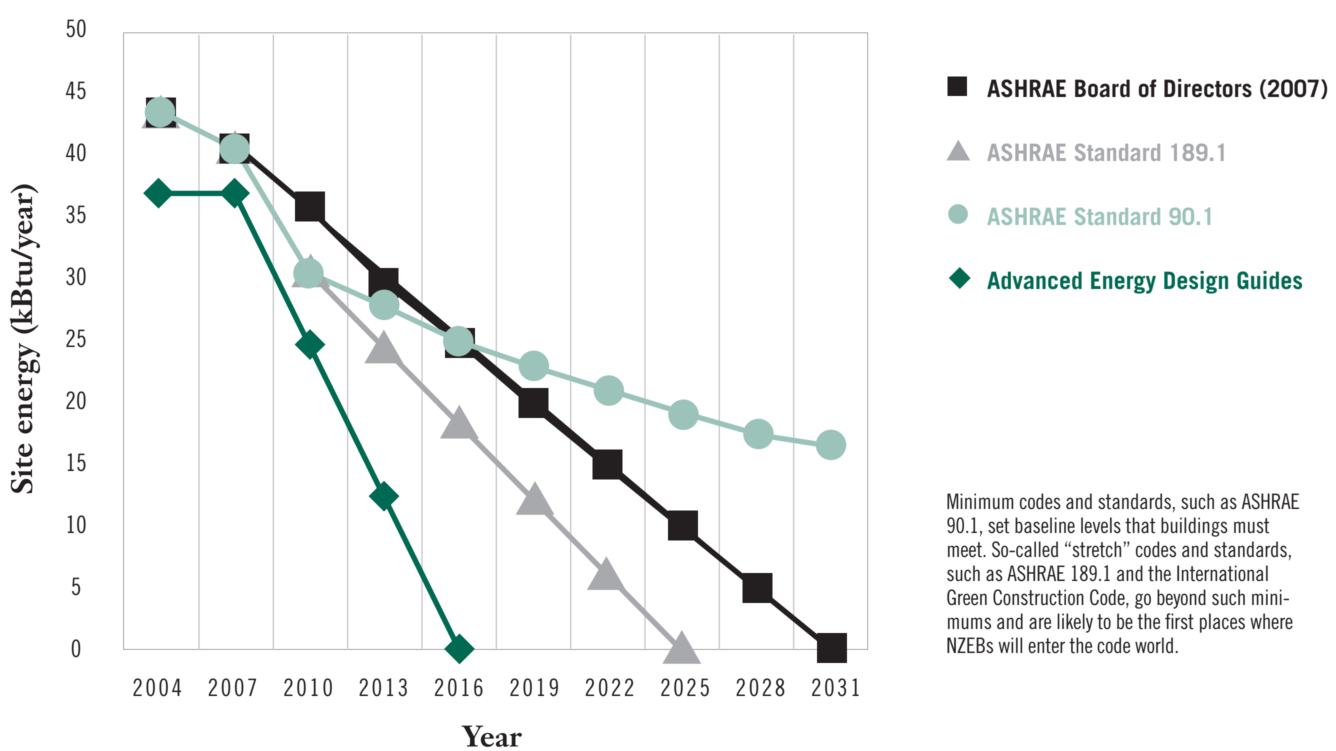
Given the nature of prescriptive codes and their

3 Institute for Market Transformation, "$810 Million Funding Needed to Achieve 90% Compliance with Building Energy Codes," Washington, D.C., 2010. At: http://imt.org/codecompliance.html.

4 Building Codes Assistance Project, "Roundtable Discussion on Energy Code Compliance and Evaluation," Washington, D.C., 2009.

5 Dave Hewitt, Mark Frankel, and David Cohan, "The Future of Energy Codes" in Proceedings: 2010 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, D.C. At: zeroenergycbc.org/.../ACEEE%20Panel%208%20--%20Future%20of%20Energy%20Codes%20v2%20DRAFT.pdf.

FIGURE 6-1.
ENERGY REDUCTION PROJECTIONS FOR ASHRAE STANDARDS & ADVANCED ENERGY DESIGN GUIDES



Minimum codes and standards, such as ASHRAE 90.1, set baseline levels that buildings must meet. So-called "stretch" codes and standards, such as ASHRAE 189.1 and the International Green Construction Code, go beyond such minimums and are likely to be the first places where NZEBs will enter the code world.

development, gains in energy efficiency are predicated on incremental improvements in the efficiencies of individual building components or systems. As these components and systems become more efficient, they will represent a smaller proportion of the building's total energy use, thus making it harder to impact total energy use through prescriptive codes. At some point, the laws of thermodynamics, potential technology improvements, and cost will make increasing the efficiency of existing components and systems prohibitive.

PERFORMANCE CODES: FLEXIBLE, TECHNOLOGY NEUTRAL, BUT STILL NO REQUIRED RESULTS

Performance-based codes set a desired level of energy performance, often based on the anticipated results of parallel prescriptive codes. This gives Building Teams flexibility in selecting how to meet the intent of the prescriptive code without necessarily complying with every prescription. Such an approach is particularly desirable for larger buildings, as it provides opportunities for trade-offs across energy-influencing systems to come up with the most cost-effective means for achieving compliance. Further, performance-based codes are technology neutral, thus enabling quicker incorporation of energy-saving technologies and practices into the marketplace.

However, performance codes still are based on proxies for energy use that are essentially derived from prescriptive code provisions. Designers typically demonstrate compliance through energy modeling of the building, incorporating their selected building specifications, and then doing the same modeling but substituting the minimum prescriptive requirements from the code. Models that fulfill requirements under the code may not include all potential energy-saving opportunities in the calculations, including the orientation, massing, and shape of the building. Energy models also are based on numerous assumptions about how the building will be used—its operating hours, occupant density, plug load, and so on.

While building energy modeling has improved significantly in recent years, energy models often do not correlate to actual building energy use,[6] not least because buildings are complex systems with numerous variables, including the behavior of building occupants themselves. (COMNET, the Commercial Energy Services Network [http://www.comnet.org], is seeking to provide consistency across models through the establishment of modeling rules.) Today, energy models are largely intended to determine relative energy performance based on component and systems choices rather than as predictors of actual energy use.[7]

As with prescriptive codes, performance codes do not necessarily provide any assurance that the completed building actually will perform at the level anticipated by the code. Typically no follow-up of actual results is required, just inspection during construction. However, some jurisdictions, including Baltimore and Seattle, now require post-occupancy evaluations.

While performance codes may be desirable for large buildings, small building owners typically do not have the resources to invest in energy models, nor do most code officials have the expertise to evaluate and verify the accuracy of these models. Certification of the model outputs by the architect or engineer of record, if required at all, typically is deemed sufficient.

OUTCOME-BASED CODES: MEASURE, MONITOR

Recognizing the difficulties in applying current prescriptive and performance equivalence energy codes to achieve defined and measurable levels of energy use, thought leaders in the building community are calling for a transition to outcome-based codes. The IgCC may even include an outcome-based approach to energy use once it is finalized later this year.

Outcome-based codes establish a target energy use level and provide for regular measurement and reporting of energy use to assure that the completed building performs at the established level. Such a code can have significant flexibility to reflect variations across building types and can even cover existing and historic buildings. Most importantly, it can address all energy used in a building and provide a metric to determine the overall energy efficiency of the building's design, construction, and operations.

Despite the potential benefits of outcome-based energy codes, *three major areas of concern* must be addressed before widespread adoption of outcome-based codes is possible:

1. How energy-use targets are to be set
2. Who would be responsible for performance
3. How the code would actually be enforced

Setting energy-use targets. Ideally, in setting energy-use targets, it would make sense to work backwards from the stated goal of net-zero energy. However, what pace is realistic for ultimately achieving net-zero energy? To set a realistic starting point and a schedule for improvement, code developers must understand the current levels of building energy use not only from existing buildings but also from new buildings that are designed to meet current prescriptive energy codes.

One source of data is the Energy Information Administration's Commercial Building Energy Consumption Survey (http://www.eia.doe.gov/emeu/cbecs/). CBECS provides data based on a survey of some 5,000 buildings of different types from across the country. As of February 2011, however, only data from the 2003 survey was available, and some building types do not

6 RK Stewart, "Attention: Performance Marker Ahead," DesignIntelligence, at: http://www.di.net/articles/archive/attention_performance_marker_ahead, accessed 16 September 2010.

7 Sean Denniston, Liz Dunn, Jayson Antonoff, and Ralph DiNola, "Toward a Future Model Energy Code for Existing and Historic Buildings," in Proceedings: 2010 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, D.C. At: eec.ucdavis.edu/ACEEE/2010/data/papers/2188.pdf.

have statistically significant data for certain climate zones. Improvements to CBECS or other sector-wide datasets will be necessary to have a meaningful baseline and to monitor progress toward net-zero energy goals. Reported energy use based on implementation of outcome-based codes or the emerging disclosure requirements can start the development of a meaningful database.

For small, non-complex buildings with tight budgets, however, prescriptive requirements may still be desirable, and could be developed utilizing the outcome-based targets. It is possible to envision multiple parties establishing prescriptive pathways to reach specified energy targets. For example, an HVAC manufacturer or association might develop prescriptive pathways that feature very high-efficiency mechanical equipment, while other interests might develop pathways for daylighting/lighting controls or high-efficiency envelope performance.

The 2,600-sf Aquarium of the Pacific Watershed Classroom, from the Building Team of EHDD Architecture (designer), structural engineer Rutherford & Chekene, and mechanical/plumbing engineer Rumsey Engineers, employs a living roof, thermal mass, passive heating and cooling, and a 2.8 kW photovoltaic system.

Assigning responsibility for achieving performance goals and post-occupancy enforcement for outcome-based codes is a matter that will need to be addressed even at the pilot stage. Initial steps include providing submetering within buildings to better determine how energy is being used, requiring owners to pay for recommissioning major building systems if anticipated performance levels are not achieved, or imposing a surcharge on energy bills or taxes. The starting point for outcome-based codes may simply be setting performance targets that need to be achieved, followed by required monitoring of energy performance. This would at least create awareness of building performance, along with a useful database on actual building energy use. In this way, outcome-based codes would be closely tied to the benchmarking efforts that various cities and states are beginning to require.

Outcome-based codes will likely require a two-stage process for verifying compliance. The first stage would focus on the design and construction of the building, including plan review and on-site inspections. Code officials could continue to use existing methods for verifying building compliance prior to occupancy. Although greater flexibility of code interpretation and enforcement might be granted in this first stage, resources and training for code officials and the building design and construction community will still be required.

The second stage would be based on the measurement and reporting of ongoing building performance. Since the regulation of outcomes is largely outside the current practice of building code enforcement, new mechanisms for ongoing enforcement and addressing noncompliance, both incentive- and penalty-based, would have to be examined. Measurement and reporting tools will be essential for verifying ongoing compliance. ASHRAE's Building Energy Quotient (http://www.buildingEQ.com) and RESNET's HERS rating system (http://www.resnet.us/home-energy-ratings) may provide helpful models.

'Non-Codes': LEED and Energy Star. Some jurisdictions have implemented code-type requirements based on voluntary programs, primarily LEED and the U.S. Environmental Protection Agency's Energy Star program. Due to the voluntary nature of these programs, they do not fit well into the role of a mandatory code. For instance, if a jurisdiction were to require a specific level of LEED certification for certain projects, such levels can be achieved through many different combinations of points that may or may not reflect the community's priorities.[8] Finally, such requirements essentially abdicate code enforcement to a third party that is not beholden to the jurisdiction. In fact, the USGBC recognizes that LEED is not appropriate for wholesale adoption as a code for all buildings within a jurisdiction and cites this as a reason for being a partner in the development of Standard 189.1.[9]

IS 'DESIGNED FOR NET-ZERO' ENOUGH?

Setting a concrete goal like net-zero energy use demands actual results, while current claims of a percentage above code are based on numerous assumptions and

8 Four hundred forty-two localities (384 cities/towns, 58 counties), 34 states, and the Commonwealth of Puerto Rico have adopted LEED initiatives—legislation, executive orders, resolutions, ordinances, policies, and incentives—some of which cover private-sector projects. See http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1852. For a list of state and local government incentive strategies for green building, see http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2078.

9 U.S. Green Building Council, Greening the Codes, Washington, D.C. At: www.usgbc.org/ShowFile.aspx?DocumentID=7403.

variables that may not necessarily produce meaningful results. Eventually, net-zero energy buildings will be codified, and Building Teams, owners, and operations teams will have to be ready to produce net-zero energy use over the life of the building. As targets approach net-zero energy use and ongoing measurement and reporting requirements are implemented, component-by-component and discipline-by-discipline approaches will no longer produce the desired results. Building information modeling (BIM) and integrated project delivery (IPD) will assist Building Teams in understanding the results of decisions made throughout the design process and the synergies across building systems.

Under current contracting processes, Building Teams are not necessarily compelled to address long-term energy use and other performance factors for which they might share risk. (Note: AIA IPD documents do address shared risk and liability.) Barring the discovery of negligence or fraud, building owners and jurisdictions have no assurance that completed buildings will actually perform at the levels anticipated by the energy codes. Furthermore, it is not common practice for Building Teams to follow up to learn whether completed projects are achieving the target energy use. (A notable exception: the 138 architecture firms that have signed the AIA 2030 Commitment, under which they agree to provide detailed energy-use data. See http://www.aia.org/about/initiatives/AIAB079458.)

There are few examples of code language that mandate and enforce activities that can assist in the long-term realization of NZEBs, such as commissioning and operations and maintenance (O&M); however, changes being considered in U.S. model codes and standards could include requirements for pre-occupancy commissioning and the development of O&M plans. Another concern is whether design teams have sufficient interaction with O&M personnel and building occupants to explain the design intent, get feedback on the practicality of proposed solutions, and provide training on the selected systems. (The exception here would be owner-occupied structures, especially for education, healthcare, and corporate real estate clients, where owners and end users often have a significant role in the design.)

Another concern is that buildings are intended to last anywhere from 30 to 100 or more years, yet most of the design and specification of systems is based on returns on investment as short as two to three years. Property owners who focus on such short-term returns have little incentive to invest in long-term energy savings. This also holds true when energy costs are paid by building tenants but the key energy-consuming systems are controlled by the building owner.[10]

Outside the U.S., the European Union's Energy Performance of Buildings Directive requires member countries to establish an energy performance certification for buildings.[11] In the U.S., a few jurisdictions (notably the states of California and Washington, the District of Columbia, and Austin, Texas) have adopted requirements to periodically monitor and report actual building energy use.[12] While attempts are under way to measure actual energy performance in the U.S., there are no requirements to compare actual performance to the anticipated energy use modeled in the design phase.

Programs like LEED and ASHRAE's *Advanced Energy Design Guides* (accessible at: http://www.ashrae.org/publications/page/1604) provide resources and recommendations for the design and construction of 30% more energy-efficient buildings, but continue to rely on proxies for energy use to determine energy efficiency. The relatively new LEED for Existing Buildings Operations & Maintenance (LEED-EBOM) and USGBC's Building Performance Partnership (BPP) are beginning to address post-occupancy energy use and the disconnect between design and operations.

California has set a target of 100% of new commercial buildings and 50% of existing buildings to be net zero by 2030.[13] NZEBs as currently defined in California and other jurisdictions may not be feasible for high-use buildings like hospitals and quick service restaurants or in taller buildings in dense urban environments. Exploring a community-wide approach to NZEBs may produce the desired results but in the most cost-effective manner. Most NZEBs built to date

10 The Model Green Lease Task Force, chaired by B. Alan Whitson, RPA, is attempting to address the first cost vs. long-term rewards issue through the development of the so-called "green lease." See http://www.squarefootage.net/TMGL_task_force.html.

11 European Parliament Directive 2002/91/EC. See http://ec.europa.eu/energy/efficiency/buildings/buildings_en.htm.

RENDERING: EHDD ARCHITECTURE

Interior courtyard of the net-zero energy David & Lucile Packard Foundation building, currently under construction in Los Altos, Calif., by DPR Construction, with occupancy expected in 2013. After reducing energy use as far as possible through such strategies as daylighting, chilled beams, and a high-performance building envelope, a 285 kW PV system will provide the energy needed to enable the project to achieve net-zero status.

The 21,227-sf Chartwell School, in Seaside, Calif., employs a 30 kW photovoltaic array to achieve net-zero electricity use. Experts in the field believe that future building and energy codes and standards are going to have to develop ways to ensure that actual energy use is measured, if net-zero energy buildings are to gain a firm foothold in the U.S.

have been small, owner-occupied buildings, and the definition of renewable energy generated on site will almost certainly need to be modified to apply across a variety of building types and sizes and avoid unintended consequences, such as supporting low-density development.[14] Washington State avoided this quandary in recent legislation by simply requiring energy codes to be 70% more efficient by 2031.[15] This is an efficiency level that would enable many buildings to achieve net-zero energy use on site if they were to use on-site renewables.

Several voluntary programs have also been initiated to begin the drive to NZEBs. California utilities and the Energy Trust of Oregon are implementing commercial new construction programs that provide additional incentives and design assistance for owners and design teams whose buildings approach NZEB efficiency levels (i.e., 40-50% more efficient than current code). The California Public Utilities Commission has developed an Action Plan to support the development of NZEBs in the Golden State. And the Living Building Challenge (http://ilbi.org/lbc), developed by the Cascadia Green Building Council, has certified three NZE buildings, with another 60 or so in the pipeline. Add to these efforts that of the Zero Energy Commercial Buildings Consortium (the authors' organizations—AIA, NBI, and NIBS—are members of the ZECBC Steering Committee; see Chapter 8 for other NZEB initiatives).

There is no doubt that the finance and insurance sectors must also play a key role. Many actors within the energy-efficiency community have raised concerns that the finance, insurance, and appraisal sectors are not including energy-efficient measures as they evaluate risk and determine value. Requirements to demonstrate actual performance may overcome some of these deficiencies.

SETTING A FOUNDATION FOR NET-ZERO ENERGY CODES AND STANDARDS

No matter what code or standard is used to get the building stock to net-zero energy use, important building requirements contained in other codes, including indoor environmental quality, must be maintained. For certain types of buildings, high-performance attributes such as enhanced security or historic preservation may have priority over saving energy.

As the largest energy-using sector, buildings represent arguably the best opportunity to reduce energy consumption.[16] However, today's codes and standards are based on proxies for energy with no requirement to actually measure the end result and leave many building energy uses unaddressed. To reach the goal of net-zero energy buildings, these methods must change. Modeling capabilities must improve, and actual outcomes must be measured.

A recent report on BIM use found that a majority of the companies surveyed attach high importance to verifying that building performance corresponds to the targets identified in design.[17] The World Business Council for Sustainable Development (WBCSD) has developed a roadmap for reducing energy consumption in new and existing buildings that calls for design fees and incentives based on actual energy performance.[18]

Codes and standards can play a significant role in the future of net-zero energy buildings. But the U.S. building community and policymakers must lay a solid foundation through research and changes in practice that will lead to the adoption of energy codes and standards that effectively incorporate advanced building technologies, consider all energy uses in buildings, and account for energy performance after the building is occupied. **BD+C**

12 Dunsky Energy Consulting, Valuing Building Energy Efficiency Through Disclosure and Upgrade Policies: A Roadmap for the Northeast U.S., Northeast Energy Efficiency Partnerships, 2009.

13 California Energy Efficiency Strategic Plan, Zero Net Energy Action Plan: Commercial Building Sector 2010-2012, http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/.

14 David B. Goldstein, Lane Burt, Justin Horner, and Nick Zigelbaum, "Zeroing in on Net-Zero Buildings: Can We Get There? How Will We Know When We Have Arrived?" in Proceedings: 2010 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington, D.C. At: eec.ucdavis.edu/ACEEE/2010/data/papers/2270.pdf.

15 SB 5854 and HB 1747, 2009-2010 Session, Washington State Legislature. At: apps.leg.wa.gov/billinfo/summary.aspx?bill=5854&year=2009.

16 U.S. Department of Energy, Buildings Energy Data Book 2009, Table 1.1.3: Buildings' Share of U.S. Primary Energy Consumption, http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=1.1.3.

17 Harvey M. Bernstein, editor, Green BIM SmartMarket Report, McGraw-Hill Construction, Bedford, Mass., 2010. At: images.autodesk.com/.../mhc_green_bim_smartmarket_report_(2010).pdf.

18 World Business Council for Sustainable Development, Roadmap for a Transformation of Energy Use in Buildings, Geneva, 2009. At: www.wbcsd.org/includes/getTarget.asp?type=d&id=MzQyMTY.

6. Lessons from a Zero Carbon Prototype

By Bill Valentine, FAIA, LEED AP, Mary Ann Lazarus, FAIA, LEED AP BD+C, Gerry A. Faubert, CET, LEED AP, David Eijadi, FAIA, LEED AP BD+C, and Chris Baker, AIA, EIT, BEMP, LEED AP

In 2009, as cap-and-trade legislation and other initiatives to restrict carbon emissions were being discussed at the national level, HOK and The Weidt Group embarked on a study to determine if a reasonably priced, readily constructible and marketable zero carbon emissions commercial office building could be designed. We named the project "The Path to Net Zero Co_2urt."

In terms of our respective roles, HOK provided its expertise as the largest architecture/engineering firm in the U.S. (according to *Building Design+Construction's* 2010 Giants listings), while The Weidt Group contributed its highly specialized capabilities in quantitative comparative analysis and consulting toward evidence-based decision making. We met twice in person and another 15 times via videoconferencing, with many smaller meetings in between scattered over a 10-month period.

We chose to do an office building because office buildings are basic to our industry, the very "stem cells" of construction. We picked a real site in the emerging biotech corridor of downtown St. Louis for three reasons: 1) St. Louis has a four-season climate; 2) its electricity costs are among the lowest in the U.S.; and 3) 81% of the city's electricity is produced from coal. We figured that if we could create a market-rate, carbon-neutral prototype on this difficult site, the design could be replicated in almost any location.

We set an energy-efficiency target of 80% compared to a LEED-certified baseline building in the St. Louis climate region; the remaining 20% would come from renewable sources. Only currently available products and technologies—at real market prices—could be used, and only currently available federal, municipal, and utility incentives would be applied. Our goal was a 10-year payback.

What emerged from our nearly yearlong study was a prototype structure consisting of two four-story, 300-foot-long office "bars" totaling 170,735 sf, with a two-story, 438-space parking garage. While we did not hit our target of 80% energy efficiency, we did come close: 73% energy reduction through energy-efficiency measures, with a 76% reduction in carbon emissions compared to a benchmark LEED building.

Other key findings of the study:

- The building's energy use intensity (EUI) came out to 21.9 (kBtu/sf/yr) before renewable energy was applied.
- Annual energy cost savings through energy-efficiency measures and the solar thermal and PV systems were $184,567, leaving an annual energy cost of $2,418, or $.01/sf at current utility rates.
- The payback period proved to be 12 years, not 10. Applying various scenarios could have reduced the payback period to 10 years—for example, a 7%

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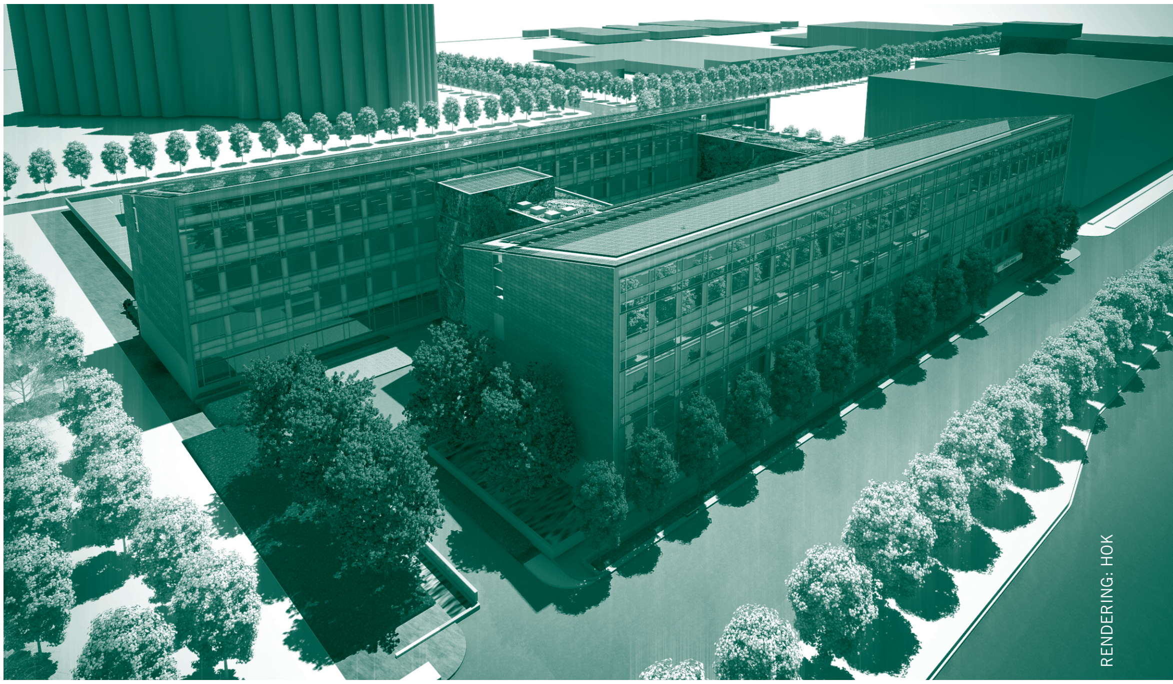


The prototype is organized into two four-story, 300-foot-long office bars oriented east-west and joined by two links that enclose a 60-foot-wide courtyard. Exterior walls consist of R-40 rainscreen construction with tile facades to the east and west. Vision and daylight panels are triple-glazed, double low-e with argon fill.

escalation rate increase in fuel costs, $1.2 million more in one-time incentives, PV costs coming down over time—but these assumptions went beyond our original brief. However, it should be noted that the 12-year payback was based on fuel costs increasing 4% a year over the general rate of inflation; in parts of the U.S. where electricity is more expensive than in St. Louis, the payback would be less than 10 years.

The most important finding, however, had to do with the feasibility of the prototype. Based on detailed cost estimates and leasing data from our research partners, developer Clark Properties/Green Street Properties and contractors Tarlton Construction and Kozeny-Wagner, we were able to show that with an estimated construction cost of $223/sf, our zero-carbon prototype would be marketable and affordable.

All this is described more fully in our report, "ZeroCarbon: Onward to Zero."[1] Here, we would like to discuss what we learned from the study and how Building Teams might apply that knowledge to the design and construction of real net-zero carbon and net-zero energy buildings.

LESSON 1

Get your preconceived notions about what will or won't work out on the table early—and be prepared to change your mind.

Team members should be allowed to "clean out the cobwebs" and get their ideas on the table. At some point, however, we found that you must be willing to explore the limits of what you believe to be true by testing every assumption against alternatives. Net-zero carbon/net-zero energy Building Teams must be open to new ideas and processes, even if they conflict with long-held beliefs or ways of working.

Every idea needs to be run through a rigorous data analysis. The Net Zero Co_2urt team used The Weidt Group's Energy Predesign Scoping Tool (EPST) to do comparative modeling of the performance variables and evaluated more than 90 strategies during the predesign process. The EPST and intensive follow-up analysis allowed us to select the best "bundle" of strategies with which to analyze the carbon emissions and cost implications of hundreds of specific energy-saving opportunities—insulation, white roofs, window design, glazing, lighting design and control, cooling and heating efficiency, alternative HVAC systems, fans, pumps, conditioning of outside air, mechanical solutions, service hot water, and plug loads, to name a few.

In sum, Building Teams must balance their instincts with rigorous data analysis and be willing to be guided by the laws of physics.

1 Free download and videos at: http://www.netzerocourt.com and at http://hok.com (under "HOK Publications" tab).

LESSON 2

Form follows performance.

"Form follows function" must yield to this new mantra when designing a net-zero carbon building. We created a model of a prototype building, measured its performance at every step of the design, and managed expectations through to final design of a building that works. This process ensured that every design decision contributed to the net-zero carbon goal. For that reason, aesthetic considerations must be carefully weighed so as not to compromise building performance by even a small amount, as failures tend to be multiplicative in their impact.

LESSON 3

Make sure to bring the contractor and developer into the discussion early to provide real-world experience and market data.

One thing we could have done better was to integrate cost factors into the model earlier in the game. We had highly reliable emissions data from The Weidt Group but were guessing at key factors like the retail cost of materials and systems, or the market acceptance of proposed leasing structures. Bringing in construction cost estimators Tarlton Construction and Kozeny-Wagner and developer Clark Properties/Green Street Properties helped us enormously to ground our spreadsheets in data from the real world.

It goes without saying that other key consultants—MEP engineers, energy and daylighting analysts, urban designers, and landscape architects—need to be at the table from the start, too.

LESSON 4

Think through the business and marketing side of the equation carefully.

In designing net-zero carbon/net-zero energy projects, Building Teams cannot make unreasonable business assumptions or ignore economic realities. Raising rents beyond what the local market will bear, or assuming 100% occupancy with no contingency, are not viable options. The team must understand the owner's economic requirements, including first cost and cash flow expectations. Based on these calculations and what sound business judgment says is reasonable, Building Teams can set target ranges for energy consumption, generation, and costs.

One wild card in this calculus is the availability of energy-conservation incentives—grants, tax credits and deductions, equipment rebates, tax increment financing, etc.—from state and local governments and utility companies. We were able to identify nearly $575,000 in state and local incentives, on top of a $1.5 million federal

RENDERING: HOK

The west building entry of the 170,735-sf net-zero carbon prototype building conceived by HOK and The Weidt Group, with the assistance of developer Clark Properties/Green Street Properties and cost estimators from Tarlton Construction and Kozeny-Wagner. One of many lessons learned by the team was that getting the trees to work with the daylighting scheme proved more difficult than anticipated. The solution: shorter trees, espaliered in daylight-coordinated orientions to regulate shade and shadow.

solar rebate and a $108,000 EPAct tax deduction. The Directory of State Incentives for Renewables & Efficiency (http://www.dsireusa.org/) is an excellent starting point for researching such incentive programs.

LESSON 5

Balancing daylighting with energy use is more complicated than it appears to be.

Though daylighting is usually the single most effective way to reduce electricity use and carbon emissions, carbon-neutral design requires a precise balance of light and heat. To determine the right combination of energy-efficient glazing and insulated wall panels, our team modeled the daylighting savings offset by the energy penalty of increased floor-to-floor and glass area. These calculations led not only to the optimal window-to-wall ratio, but also to the optimal types of glazing to be used: vision glass at height for building occupants and daylight glazing above that for maximum reflectance into the space.

The analysis demonstrated the falsity of the belief that all-glass buildings, with their presumed ability to maximize daylighting, are the future of low-energy/low-emissions design. Careful analysis of the data enabled us to conclude that there's little point in having glass where it does no good; that, in fact, adding glass above a certain percentage of the floor area or below a specific height would actually increase the building's carbon footprint. The best use of glass is from the waist up and as high up on the wall as possible, to get the right amount of light into the interior space and thereby reduce the need for artificial lighting.

Moreover, the analysis revealed the considerable impact and extensiveness of daylighting design decisions on a successful net-zero solution. Lighting energy is more carbon intensive than heating and cooling energy. The success of daylighting, this powerful carbon-reducing design concept, is dependent on many interacting factors—from choosing the right floor-to-floor height, window height, and bay depth, to selecting the right glass type and surface reflectances. To truly succeed, the final net-zero design solution must be faithful to this all-important design consideration.

LESSON 6

Appreciate the importance of the site, especially the landscaping.

We learned a lot about the appropriate role of trees in net-zero emissions projects. Like most designers, we assumed trees would be a good thing for our project, shading the building against St. Louis's sometimes harsh sun conditions and helping to cool it in the summer. All that is true enough, but we quickly discovered that having too many trees or placing trees in the wrong locations would impede the daylighting and scuttle the overall design. For our prototype, we chose trees of somewhat lower height and espaliered them in daylight-driven orientations to regulate shade and shadow.

Landscaping for a net-zero emissions project, particularly one where tall trees might be present, must preserve access to natural light while at the same time being completely integrated with the total building design. For that reason, Building Teams for net-zero carbon/net-zero energy projects must be willing to attain a new and higher level of integration on site planning.

LESSON 7

Don't assume photovoltaics are effective only in places like Tucson and Abu Dhabi.

PVs actually work quite well in places like St. Louis, which, although it has 150-180 cloudy days a year, has more than enough sun to generate the required on-site solar power for our project. Furthermore, it turns out that solar panels are actually more efficient in cooler climates than in burning-hot ones: excessive heat actually diminishes their ability to generate power. Photovoltaics can be surprisingly effective at atmospheric temperatures from 30-90ºF, which makes them suitable for use in many regions of the U.S. and Canada.

LESSON 8

Don't put too much faith in wind as a source of renewable energy.

We originally hoped that wind would provide some of the needed renewable energy, but detailed analysis of prevailing winds for our site showed them to be inadequate to support the use of building-integrated turbines in the project.

Of course, you should not rule out wind as a possible source of renewable energy, but don't get your hopes up: for most locations in the United States, solar PVs will beat wind every time, not only on cost but also on reliability: winds are usually strongest at night, when they are least needed to generate electricity.

LESSON 9

Don't underestimate the profound impact of building operations on total energy use.

Buildings don't use energy, people do. It is estimated that tenants can consume 50-75% of energy use, so it is important for Building Teams to understand how the owner intends to deploy facility staff and operate the building. The facility staff's behavior can make or break a net-zero emissions design.

Understanding the lines of responsibility and accountability will allow Building Teams to provide technology and services that allow for clear monitoring, measurement, and management—the three M's of building performance—and provide occupants with the tools and knowledge to fully participate in energy conservation.

Building Teams must develop secondary systems and operational expectations. This includes controls and control scenarios for lighting, comfort and security settings, and occupancy and plug loads (see Lesson 10). Developing a plan and installing technologies for maintaining carbon-neutral operations is as important as designing the potential to do so.

LESSON 10

Giving short shrift to plug load volume and management can short-circuit your entire scheme.

Plug load can be a huge variable in a net-zero emissions, multi-tenant speculative office building. As energy codes have become more stringent, plug loads have grown to about 15% of a building's total energy use. In our prototype, we proposeded that the plug load would be enforced at a 30% lower annual base than in a typical office building. Based on input from our real estate partner Clark Properties/Green Street Properties, we set the maximum annual base plug load at 0.5 kW/sf in the lease; tenants would pay a premium for anything over that baseline. We felt that this formula would give tenants an incentive to control their own electricity usage.

Study Sees Net-ZEB Potential in 'Hot and Humid' Climates

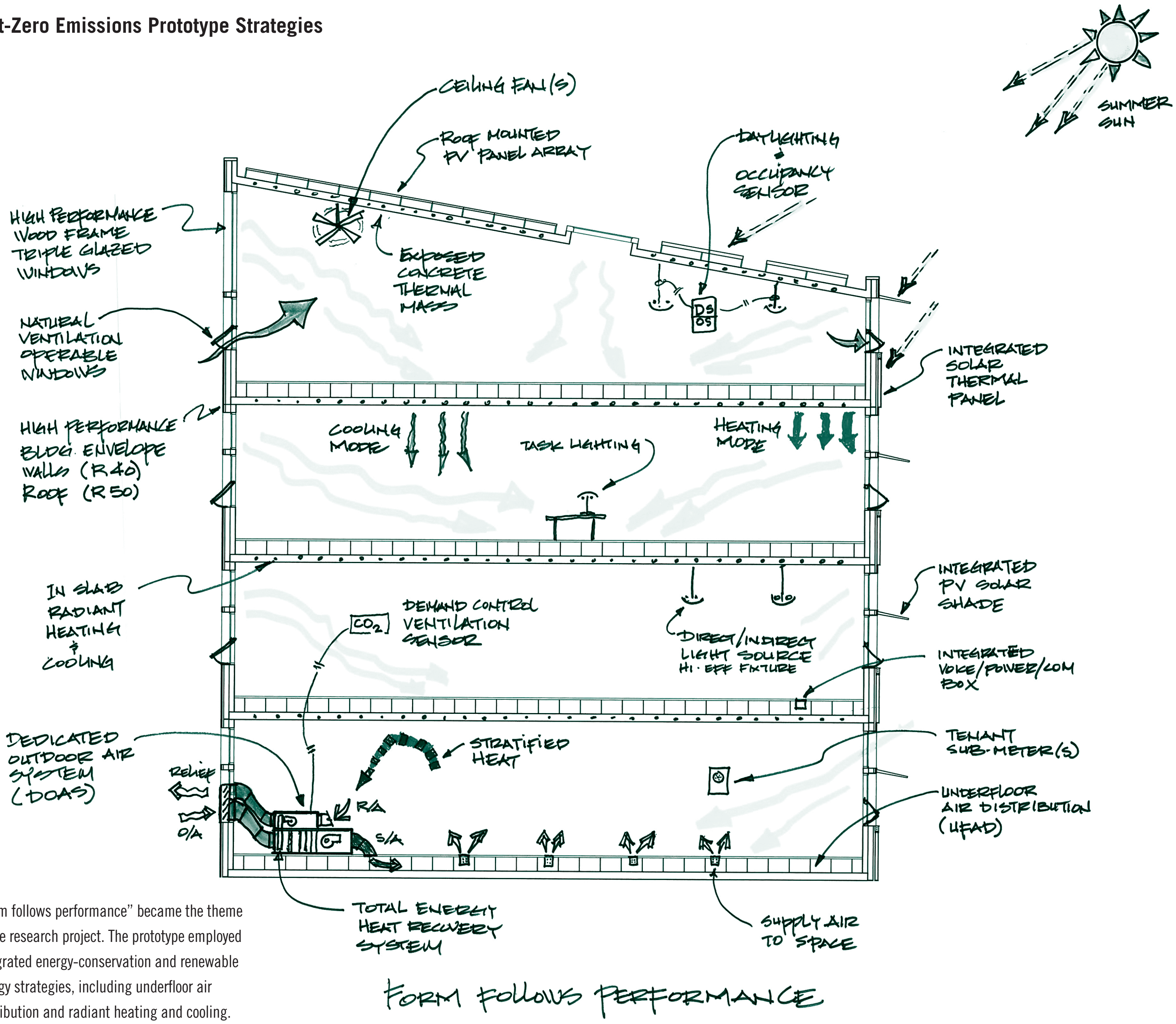
For further insight into the feasibility of net-zero energy buildings—in this case, six different building types, located in hot and humid Houston—see "Zero Energy Buildings: When Do They Pay Off in a Hot and Humid Climate?" Building Design+Construction (February 2011), by Julie Hendricks, AIA, LEED AP, a senior associate, and Kapil Upadhyaya, LEED AP, an energy analyst, with Kirksey EcoServices, a division of Houston-based architecture firm Kirksey.

Major findings of the "Hot and Humid" net-ZEB study:

- Designing buildings for net-zero energy use in hot and humid climates like that of the Gulf Coast of Texas can be a good investment in the context of a 25-year lifetime of the building.
- Investing in energy-efficiency measures, even extreme energy-efficiency measures required to make a building "net-zero energy ready," can become profitable within 9-13 years for a broad selection of building types, making this a potentially attractive investment for a wide range of building owners and developers, especially for owner-occupied properties.
- The net present value (NPV) for larger buildings at 25 years was significantly higher than for smaller ones. Large buildings apparently benefit from economies of scale in the purchase of solar panels and less commonly specified HVAC system components.
- The greater upfront investment required for larger buildings also tends to result in much higher rates of return than for smaller buildings.

Get the complete report at:
http://www.bdcnetwork.com/hotandhumid.

Net-Zero Emissions Prototype Strategies



"Form follows performance" became the theme of the research project. The prototype employed integrated energy-conservation and renewable energy strategies, including underfloor air distribution and radiant heating and cooling.

GRAPHIC: HOK

The takeaway here is that plug loads represent a hidden energy tax on your project. Don't assume that there's nothing you can do to influence building occupant behavior. Ignore the plug load drain at your peril.

LESSON 11

Make sure the end result doesn't scare off potential clients and tenants.

In the early days of the green building movement, Rick Fedrizzi, co-founder, founding chair, and now CEO of the U.S. Green Building Council, would take his slide show around the country to educate audiences about this radically new concept, "green building." His first slide showed a yurt, the circular tent used by Mongol and Turkic nomads. After the laughter settled down, Fedrizzi would exclaim, "That is *not* what we mean by a green building!"

More than a decade later, we must educate our clients, government officials, the public, and even other AEC professionals that net-zero emission and net-zero energy buildings need not be weird-looking or impractical from either a business or design perspective. Most clients, building users, and tenants are, we believe, willing to push the envelope quite a bit to embrace the environmental promise inherent in a net-zero emission building, but not at the expense of marketability or the loss of well-accepted amenities.

The question of amenities came up over the issue of parking for our building. In early discussions, there was talk of eliminating (or at least severely limiting) parking. But our research showed that, while the site was served by a bus line and was near a planned future stop of the city's rapid transit system, at best only 10% of building users and visitors would use transit. Without adequate parking, our real estate partners told us, no developer would even look at the project.

We then considered using a mechanical system that would lift cars into place and thereby reduce the total volume of the parking structure by 80%. However, when we calculated the energy costs of installing such a system, the payoff wasn't there. We went ahead with the parking structure, which proved fortuitous because we were able to use the roof to hold 17,000 sf of photovoltaics.

LESSON 12

Don't let conventional wisdom fence you in.

One of the "myths of net-zero emissions design" that we had to contend with was that a net-zero emissions building could not be taller than three stories. In fact, we were able to design a four-story building that met our goals, although we did have to use the roof surface of the parking structure to house 17,000 sf of PV panels—a reasonable solution, in our opinion.


RENDERING: HOK

Water wall garden in the net-zero carbon office prototype. Vegetated walls along the east and west facades of the links between the office bars provide aesthetic continuity and moderate the outdoor climate. The south facade has an edible food garden area (not shown) as an additional amenity for building occupants.

LESSON 13

Believe in the feasibility of achieving zero carbon emissions, at least under certain conditions and for certain kinds of clients.

While a 12-year (or even 10-year) payback may not meet the needs of speculative developers, it may be a reasonable payback period for many owners who occupy their own buildings: large corporations, colleges and universities, cultural institutions, school districts, and so on.

Moreover, a 12-year payback converts to a 6% internal rate of return. With many corporations sitting on huge cash reserves, and with "safe" investments like U.S. Treasury bond yields at historic lows, a 6% IRR may look quite attractive to many institutional and corporate building owners, particularly if they are looking to meet other societal, political, or business-related goals, such as enhancing their environmental image or achieving triple-bottom-line sustainability goals.

The experience with LEED may be instructive here. A decade ago, property owners feared that "building green" would drive up costs 20% or more. There may have been some expensive mistakes in the early days of LEED, but Building Teams quickly learned how to keep costs under control, and building product manufacturers kept coming up with new and improved products to help them do so. It didn't take long before the AEC industry figured out how to deliver a LEED-certified building at no additional cost; today, LEED Silver, Gold, and even Platinum buildings are coming in at no premium, or at most a modest one. We think a similar scenario could develop for net-zero carbon/net-zero energy buildings.

We completed our research shortly before the midterm elections of November 2010. The resulting change of leadership in the House of Representatives has effectively put off any possibility of cap-and-trade or a carbon tax—the original motivation for our study. Based on what we learned in trekking "The Path to Net Zero Co_2urt," however, we feel confident that market-driven net-zero carbon office buildings not only can but *should* be built, to reduce our carbon footprint.

The project has also inspired us to consider the possibility of how its lessons could be applied to an even greater source of energy waste and carbon emissions: the nation's existing building stock, most of which was built before 1970. BD+C

7. Action Plan: 21 Recommendations To Advance Net-Zero Energy Buildings + Homes

The editors of *Building Design+Construction* respectfully offer the following recommendations for advancing zero energy and net-zero energy buildings and homes. We consulted with dozens of experts and stakeholders in the course of our research; however, these recommendations are solely the responsibility of the editors. We believe these action items to be balanced, positive in tone, and reasonable in terms of feasibility.

We welcome your comments and suggestions. Please send them to Robert Cassidy, Editorial Director: rcassidy@sgcmail.com.

FEDERAL EXECUTIVE DEPARTMENTS + AGENCIES

1. Federal agencies need to lead the way in NZEB demonstration projects and building technology research.

For NZEB development, the past year has felt almost like the year 2000 for green building and LEED: lots of interest, a few tentative projects by heroic early adopters, many unanswered questions.

Likewise, NZEB is just getting out of the starting gate. The Department of Energy's Research Support Facility at the National Renewable Energy Lab is already providing the AEC industry with invaluable practical information on NZEB design, construction, and energy use. The General Services Administration has taken up the cause with several NZEB projects: the Columbus (N.M.) Land Port of Entry; the San Ysidro and Otay Mesa Land Ports of Entry, in San Diego; and the San Luis II Land Port of Entry, in Yuma County, Ariz., which derives 10% of its energy from a 25kW PV farm on the site. GSA is also considering ways to have its NZEB projects serve as proving grounds for advanced building technologies such as piezoelectric floors and kinetic energy machines.

On the zero-energy housing front, the U.S. Army, in partnership with Actus Lend Lease, has completed two net-zero energy homes at Fort Campbell, Ky. The units use 54% less energy than conventional homes and have roof-mounted PVs to generate electricity. These units will serve as test pads to see how net-zero energy design can be extended to the more than 4,000 new homes at Fort Campbell, and beyond to other military base housing projects.[1]

Real-world demonstration projects like these form the intellectual DNA of the net-zero energy movement. Federal executive departments like the GSA and the Department of Defense whose properties have decades-long life cycles are logical candidates for NZEB experimentation; and because they are public entities, they can provide an educational platform to extend lessons learned and best practices to the entire AEC industry. The hoped-for result: many more NZEB success stories, in both the public and private sectors.

2. The U.S. Environmental Protection Agency should allow on-site renewables to be counted in Energy Star ratings.

Currently, on-site renewables do not count in a building's Energy Star score; in fact, EPA specifically states that wind or solar energy should not be included in the estimated total annual energy use. As a result, EPA's target finder does not recognize net-zero buildings. EPA should develop a mechanism to allow NZEBs to incorporate renewables into their Energy Star scores.[2]

1 See also: Samuel Booth, John Barnett, Kari Burman, Josh Hambrick, and Robert Westby, "Net Zero Energy Military Installations: A Guide to Assessment and Planning," NREL Report No. TP-7A2-48876, August 2010, at: www.nrel.gov/docs/fy10osti/48876.pdf <http://www.nrel.gov/docs/fy10osti/48876.pdf>.

Bruce Haxton goes one step further, suggesting using surplus military bases and federal land to promote "demonstration studies" of Net Zero Energy Life Style Science Parks with business incubators focused on renewable energy technology. The Green Net Zero Energy Life Style Science Park Prototype will be displayed at the 28th Annual IASP World Conference on Science and Technology Parks, Copenhagen, Denmark, in June. At: www.iasp2011cph.com.

2 See https://www.energystar.gov/index.cfm?fuseaction=target_finder.

STATE AND LOCAL GOVERNMENTS

3. States should adopt legislation enabling local governments to pass ordinances to protect solar access to buildings.

The National Conference of State Legislatures (www.ncsl.org) and the various building code entities need to create model language, legislation, and regulations to safeguard buildings and homes from having their access to the sun blocked, which would make daylighting and the use of PVs difficult, if not impossible. This will not be an easy problem to solve in dense urban areas where tall buildings are the norm, but the code bodies must start looking into this issue. The Boulder (Colo.) Solar Access Guide, which provides for a "solar fence" to give homes in that county four hours of sunlight per day, may provide a starting point for creating such model legislation.[3]

4. Cities and counties should review their building codes, zoning ordinances, fire regulations, and design review processes for negative impacts on building-related renewable energy production.

As we learned when LEED first came along, local building and fire codes, zoning ordinances, and design review practices sometimes made it difficult or impossible to achieve certain LEED points. To address this problem, progressive municipalities did "overlays" of LEED requirements on their regulatory practices to smooth out the wrinkles. The Urban Green Council, in New York, released recommendations for greening building codes, and New York's Green Codes Task Force also provided valuable input on this issue. Last year, California launched the most wide-ranging initiative with its Green Building Standards Code.[4]

Similar efforts will be needed to eliminate unnecessary roadblocks to NZEB construction. One such obstacle: how to provide sufficient access to fire crews on rooftops with PV installations.

One potential breakthrough concept: allowing lower ventilation rates (hence, reduced energy use) in buildings with low-VOC finishes and furnishings, where indoor air quality has, at least theoretically, been optimized.

To be truly progressive, these efforts must go beyond prescriptive requirements. States and municipalities must look at NZEB codes on the basis of performance and measured outcomes. Such codes would carry with them requirements for extensive metering and monitoring of energy use in buildings.

5. Local jurisdictions should give priority permitting to legitimate NZEB projects.

"Green permitting"—giving legitimate LEED-registered projects priority in obtaining building permits—was one of the success stories of the early days of LEED. It gave "green" building owners and developers a leg up in getting their buildings to market weeks, even months, earlier than conventional projects. Creating a successful fast-track NZEB programs takes careful attention to detail (and a "with-it" administrative staff), but it can have a huge payoff for both the city and the more environmentally progressive elements of its development community.[5]

3 At: joomla.ci.boulder.co.us/files/PDS/codes/solrshad.pdf.

4 See USGBC's "Greening the Codes," at: www.usgbc.org/ShowFile.aspx?DocumentID=7403. See also: California Energy Efficiency Strategic Plan, at: http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440-D-9477-3363726F573A/0/CAEnergyEfficiencyStrategic-Plan_Jan2011.pdf.

5 The City of Chicago Green Permit program is arguably the preeminent example of such a program. See http://www.cityofchicago.org/city/en/depts/bldgs/provdrs/green_permit.html.

Army Builds Its First Net-zero Energy Homes

Campbell Crossing, a public-private partnership between Actus Lend Lease and the U.S. Army, last October completed construction of two net-zero energy homes at Fort Campbell, Ky.—the first such homes to be built on a military installation. Energy efficiency and solar thermal energy production will result in a home that can function on 54% less energy than a conventional home of comparable size. The remaining energy needs for the home will be supplied by roof-mounted photovoltaic solar panels, resulting in a home that produces as much energy as it consumes on a yearly basis.

PHOTO: COURTESY ACTUS LEND LEASE

One of two net-zero energy homes at Campbell Crossing, at Fort Campbell, Ky. The U.S. Army and Actus Lend Lease will seek LEED Platinum certification for the solar-powered prototype homes, which save $1,041 each in annual energy costs.

An annual cost savings of $1,041 per home will be returned to Campbell Crossing to help fund future projects. If these savings were projected for all 4,457 homes at Campbell Crossing, annual savings would reach $4.6 million. In partnership with Pacific Northwest National Laboratory, Actus Lend Lease will compare the performance of the homes against two non-zero energy homes to measure and ensure maximum efficiency of energy use. Key findings will be distributed to the Department of Defense and made available to the private construction sector.

A display monitor in each home will provide real-time energy monitoring, allowing military families to understand how their behavior and habits affect each system as well as the energy profile of the entire home. Campbell Crossing will provide residents with educational materials for living a net-zero energy lifestyle and request their participation in a monthly utility usage review.

Under a grant from DoD's Environmental Security Transfer Certification Program, Actus Lend Lease utilized the expertise of the National Association of Home Builders Research Laboratory and the Pacific Northwest National Laboratory. Actus is pursuing LEED Platinum certification for the two new net-zero energy homes.

Campbell Crossing LLC is a 50-year partnership between the Department of the Army and Actus Lend Lease via the Military Housing Privatization Initiative. Since 2003, Campbell Crossing has developed more than 1,000 new homes and renovated more than 2,000. It will finance, develop, build, renovate, and operate the site for 50 years. More information: www.campbellcrossingllc.com.

6. Municipalities and counties should consider bonus densities, bonus parking, or other incentives for projects that incorporate PVs or other renewables into parking structure roofs or building roofs.

Cities and counties should encourage developers and building owners to make use of the precious space afforded by parking structures and building roofs as sites for PVs (and, where possible, wind devices). Depending on local conditions, however, cities may create *disincentives* for constructing parking structures that fail to provide grid-integrated renewables; in some cases, they may even choose to ban parking structures that don't allow for or actually provide PVs on their roofs.

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7. States and localities should investigate building energy labeling and disclosure.

San Francisco is the latest city to join the District of Columbia and others in requiring commercial property owners to disclose the energy use of their buildings. The new ordinance, which goes into effect in October, requires owners to benchmark and disclose to the public the energy rating of commercial buildings over 50,000 sf against the EPA's Energy Star Portfolio Manager and to conduct an energy audit every five years. In 2013, the threshold will be lowered to 10,000 sf.[6]

"Building energy labeling" give lessees and prospective buyers valuable data that they could use to make intelligent rental or purchasing decisions, much as the label on a box of cereal provides consumers with useful nutritional information. Presumably, a building with a high Energy Star rating would command a higher rental fee or purchase price; the reverse would apply, too. It is a concept that more and more mayors and city councils will advocate as a consumer protection benefit; property owners and Building Teams would be wise to start preparing for it now.[7]

6 At: www.sfbos.org/ftp/uploadedfiles/bdsupvrs/.../LU012411_101105.pdf.

7 For more on building energy labeling, see Robert Cassidy, "Energy labels for buildings may be key to saving energy," Building Design+Construction, April 2009. At: http://www.bdcnetwork.com/article/energy-labels-may-be-key-saving-energy?page=show.

UTILITIES AND UTILITY REGULATORS

8. Public utility companies should be required to develop and implement minimum portfolio standards for renewable energy.

A number of states have enacted so-called "renewable portfolio standards," which require utilities to set the minimum megawatts of renewable energy it will produce by a specific date; this enables regulatory authorities and public watchdog groups to track the utility's progress (or lack thereof). Even though it may seem counterintuitive, utility companies have a lot to gain from encouraging renewable energy, because renewables reduce their need for increased production capacity—a very expensive and usually unprofitable proposition.

Utilities also need to gear up to allow power purchase agreements for renewable systems other than PVs, such as wood chip boilers, combined heat and power systems, central solar hot water systems, and ground-source heat pump wells.

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9. Utilities need to develop programs to encourage more extensive metering and submetering in buildings and homes.

Dan Ariely, professor of psychology and behavioral economics at Duke University, has theorized that one of the reasons consumers are so sensitive to gasoline prices is that they have to stand at the pump watching the meter go up and up and up.[8] Building owners and homeowners don't have that kind of up-to-the-second information about their energy use; if they did, they might be more conscious about saving energy. For example, a 2008 competition among the occupants of 13 buildings at Harvard University yielded $72,472 in energy savings.[9]

One suggestion: Utilities should experiment with installing miniature "energy dashboards" in buildings and homes to enable owners to track real-time electronic metering of their energy use.

8 Ariely, author of Predictably Irrational and The Upside of Irrationality, blogs at danariely.com.

9 Steve Bradt, "Going for the Green at Harvard," Harvard Gazette, 17 April 2008. At: http://news.harvard.edu/gazette/story/2008/04/going-for-the-green-at- harvard/#.

APPRAISERS AND VALUATORS

10. The Appraisal Institute and other entities in building valuation need to develop model real estate appraisal standards for NZEBs and other low-energy buildings.

There is a sense among building designers and property owners that the appraisal sector does not give sufficient credit to the added value that low- or net-zero energy use lends to a property. As the leading organization in this field, the Appraisal Institute (www.appraisalinstitute.org), with more than 25,000 members and 91 chapters, should create a task force to investigate ways to provide more equitable treatment of NZEBs and other high-performance buildings and report back to the Institute board and membership with a plan of action.

BUILDING OWNERS AND DEVELOPERS

11. Building owners need to aggressively attack lighting usage and plug loads.

As the chart on page 55 shows, lighting accounts for more than one-fourth (27%) of energy use in commercial buildings, with computers, electronics, and other plug loads accounting for a significant share as well.

Building owners need to be aware that reducing these loads can make or break an NZEB project in terms of financial feasibility and design optimization; therefore, property owners must ensure that their NZEB Building Teams aggressively target these loads. They must also include their facility staffs in the design process, so that they understand how to implement and continuously monitor the metering and controls necessary to keep these loads in line.

Supplied lighting in particular has a profound impact on NZEB design solutions and touches everything from initial design through building occupancy. It deserves careful attention from all stakeholders in net-zero energy buildings.

12. Building owners and developers who wish to build NZEBs must "invest in thinking."

It took two or three years for even the giants among AEC firms to figure out how to wring a profit out of LEED projects. There's going to be a similar, if not steeper, learning curve for NZEBs. Clients who are motivated to build NZEBs are going to have to be patient with their Building Teams, especially for their first few NZEB projects. Much of the thinking for the design, engineering, and construction of an NZEB happens at the front end, in intensive energy modeling and cost analysis.

Owners will need to find ways to compensate Building Teams fairly for spending a lot of time just thinking and testing numerous scenarios. In the long run, it will pay off in more successful net-zero energy projects.

13. Building owners should apply NZEB concepts to existing buildings, especially owner-occupied buildings.

All NZEBs start from a base of energy conservation, applying cost-effective strategies to get energy use down as low as possible; only then should renewable energy even be considered. This process should also apply to the reconstruction of existing buildings, especially those which owners intend to occupy for, say, at least 7-10 years—schools, higher education facilities, government buildings, military housing, etc. There are five million existing commercial buildings and 120 million homes in the U.S. that could benefit from energy conservation, whether or not they went all the way to net-zero.

14. Building owners should investigate financing mechanisms that make NZEBs more feasible.

The most promising such mechanism is the power purchase agreement (PPA), wherein a building owner contracts with a utility (or third party) to finance the capital cost of PVs or other electricity-generating assets, in return for selling the electricity back to the utility. The owner gets a capital investment at no upfront cost; the utility gets clean energy to sell. As the demand for photovoltaics, ground-source heat pumps, and other forms of renewable energy goes up, owners and developers seeking to build NZEBs may find PPAs to be the most reasonable source of financing for the renewable energy components of their projects.

INSTITUTIONS OF HIGHER EDUCATION

15. Educators should develop certificate programs and associate degrees to train technical personnel for jobs in energy conservation and renewable energy.

Such programs would be a natural fit for public community colleges and private technology-based institutions. In Texas, a group of colleges has created the Texas Renewable Energy Education Coalition (http://treec.org) to position the Lone Star State as a leader in renewable and sustainable energy commercialization through technical education.

One TREEC member, International Business College, El Paso, is offering a program in construction technology with a specialty in solar power.[10]

10 See http://calendar.elpaso-times.com/el-paso-tx/events/show/170791985-ribbon-cutting-ceremony.

AEC FIRMS AND BUILDING TEAMS

16. AEC firms need to take the plunge and engage in an NZEB project.

Several years ago, when building information modeling started to catch on, AEC firms had to choose their approach to the new technology. Some firms jumped in whole hog—100% of projects in BIM, no questions asked. Others experimented with a single BIM "demonstration" project—but kept their 2D drawings at the ready, just in case. A few picked a small "skunkworks" team to test BIM out to see how it could be applied across the firm. Still others said, Hmm, let's wait and see.

If NZEBs represent the next frontier in green building (and we think they do), then Building Teams that want to be in the lead need to bite the bullet and take one on. Talking about it won't do. Design and construction firms that want to command this next stage of sustainability would be well advised to pick a project (hopefully with backing from an interested client) and see how it could be approached from a net-zero perspective.

This will afford NZEB-committed firms the opportunity to experiment with numerous approaches to optimizing energy conservation, the foundation on which a successful NZEB project rests. Through empirical trial (and, hopefully, not too many errors), Building Teams likely will come to understand that no single strategy will guarantee success; instead, they will learn that it takes many different routes to energy conservation before renewable energy strategies can even be considered. Even if these early projects do not proceed to full NZEB implementation, their Building Teams will still have found more and better ways to apply diverse energy-saving measures that can be applied across all their work.

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17. AEC firms and AEC professional membership organizations need to develop mechanisms for spreading useful knowledge about NZEBs.

To step up the pace of NZEB development, AEC firms and their clients, with the help of their membership associations (AIA, ASHRAE, AGC, ABC, BOMA, CoreNet Global, NAIOP, and others) need to go beyond self-congratulatory press releases and instead find ways to share best practices and detailed technical information from their NZEB experience. Such a process would educate AEC professionals on what really works and thereby raise the bar for future NZEBs. Smaller firms with fewer resources especially need this kind of information flow and education to be able to apply NZEB thinking to their projects.

One model for this kind of information sharing was developed by three Building Teams who are currently working on separate hospital mega-projects in San Francisco. Despite being fierce competitors, these teams found a way to share ideas and information that enhanced the overall sustainability of all their projects.[11]

11 See Robert Cassidy, "3 Hospitals, 3 Building Teams, 1 Mission: Optimum Sustainability," Building Design+Construction, at: http://www.bdcnetwork.com/article/3-hospitals-3-building-teams-1-mission-optimum-sustainability?page=4.

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18. Architecture firms need to sign the AIA 2030 Commitment—and engineering and construction associations need to create 2030 Commitments for their professions.

One hundred thirty-eight architecture firms have signed the AIA 2030 Commitment, which commits them to report energy data on all their projects, not just their green or LEED buildings. The 2030 Commitment sets high standards: a predicted energy use intensity (PEUI) reduction of 50% and a lighting power density (LPD) reduction of 25%. Data on the percentage of project square footage modeled and the percentage of gross square footage where data is being collected must also be reported. All this is due at the end of March 2011; firms that fail to report their data could be asked to resign.

The AIA 2030 Commitment requires signatory firms to develop an action plan to meet its mandatory reporting requirements. Participating firms are finding that this process has encouraged them to integrate energy modeling into more of their projects, and earlier in the design process; to add language to their standard contracts with consultants, so that they, too, understand the rigorous demands of the 2030 Commitment; to discuss the need for significant energy reduction with every client; and to stay connected to clients to see how well the buildings are performing after the jobs are done.[12]

It is something of a disappointment that only 138 architecture firms in the U.S. have benefited from these hugely important "transformational" effects. But it is even more distressing that the other two members of the Building Team, engineers and contractors, have made no such commitment. Clearly, more architecture firms need to make the 2030 Commitment, and engineering and construction professional societies need to develop their own "commitments."

As for building owners, BOMA's 7-Point Challenge encourages signatories to benchmark their buildings against EPA's Energy Star tool, but that is not sufficiently granular data.[13] BOMA and other major owner organizations, notably NAIOP and CoreNet Global, need to develop energy-use data reporting mechanisms for their members; after all, building owners are the ones who have the best data.

12 AIA Seattle and partners BetterBricks, the City of Seattle, and Architecture 2030 have created the "AIA+ 2030 Professional Series: Prepare for the New Energy Frontier," an intensive 10-session training program for design professionals to help them reach the 60% reduction in greenhouse gas emissions called for in the 2030 Challenge. At: www.aiaseattle.org/aia2030.

13 See http://www.boma.org/getinvolved/7pointchallenge/Pages/default.aspx.

CONSTRUCTION TRADES AND UNIONS

19. Construction trades need training and expertise development in NZEB-related technologies, and their unions need to embrace energy-related technologies.

Construction trades and their unions need to appreciate new technologies like chilled beams and building-integrated photovoltaics that contribute to NZEBs as an opportunity for technical growth. They must avoid engaging in some of the backward-looking practices that characterized the early days of green building, as when plumbing unions fought developers who wanted to install waterless urinals in commercial buildings.

One technology facing opposition from electrical unions: LEDs, which are becoming more and more popular with designers, especially given their long life and energy savings, but which are so lightweight and easy to install that they do not require skilled union labor. Trade unions need to be training their members in new technologies, to put them in the forefront of progress in net-zero energy projects.

Buildings' Share of Primary Energy Consumption End Uses (2006)

INDUSTRY	33%
TRANSPORTATION	28%
BUILDINGS	39%
RESIDENTIAL BUILDINGS	21%
Heating	28%
Cooling	14%
Hot water	13%
Lighting	12%
Electronics	9%
Refrigeration	8%
Wet Clean	7%
Cooking	5%
Computers	1%
Other	4%
COMMERCIAL BUILDINGS	18%
Lighting	27%
Cooling	14%
Heating	13%
Electronics	8%
Hot water	7%
Ventilation	7%
Refrigeration	4%
Computers	4%
Cooking	2%
Other	14%

Source: Buildings Energy Data Book, at: http://buildingsdatabook.eren.doe.gov.

ALL STAKEHOLDERS IN THE BUILT ENVIRONMENT

20. Stakeholders must find ways to document the health and human performance benefits of NZEB projects.

Obtaining verified data on the degree to which sustainable features benefit the health and human performance of occupants of would be a huge step toward moving NZEBs into mainstream commercial use. What level of improvement in employee performance comes from daylighting, improved IEQ, and better ventilation in NZEBs? What is the reduction in sick days in NZEBs? Do children in net-zero schools get higher grades than those in conventional schools? We know that humans instinctively appreciate what Ernest Hemingway called "a clean, well-lighted place," but is the real estate market willing to pay for it?

Building owners at all levels are looking for hard data—not wishful thinking—to input into their pro formas. The commercial sector is poised to buy better buildings, including net-zero energy buildings, but they need real metrics to justify the decision.

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21. In stage two of NZEB development, stakeholders will need to look beyond single NZEBs, to net-zero campuses and communities.

Without getting too far ahead of ourselves, it is possible to see a path toward whole campuses, neighborhoods, and communities seeking net-zero status, not only for buildings but also for vehicles, industry, and community-based infrastructure.[14] LEED for Neighborhood Development may be a harbinger of things to come in the NZEB field, although the timeline for net-zero communities and cities may be decades away. Still, it is never too early for academics, city planners, utility experts, and AEC professionals to start thinking about how to create such a future.[15]

Comments? Suggestions? Send them to Robert Cassidy, Editorial Director: rcassidy@sgcmail.com

14 Nancy Carlisle, AIA, Otto Van Geet, PE, and Shanti Pless, LEED AP, provide initial guidance on net-zero energy communities in "Definition of a 'Zero Net Energy' Community," NREL Report No. TP-7A2-46065. At: http://www.nrel.gov/docs/fy10osti/46065.pdf.

15 For additional recommendations, readers are encouraged to download two recent reports from the Zero Energy Commercial Buildings Consortium: "Next Generation Technologies: Barriers and Industry Recommendations" and "Analysis of Cost & Non-Cost Barriers and Policy Solutions," at: www.zeroenergycbc.org. The recommendations in this White Paper were developed independently from those of the Zero Energy CBC.

8. Who's Who in Net-Zero Energy Buildings + Homes

Compiled by Peter Fabris, Contributing Editor

NONPROFIT AND ENVIRONMENTAL ORGANIZATIONS

Alliance to Save Energy http://ase.org/

ASE administers the **Zero Energy Commercial Buildings Consortium (CBC)** (http://zeroenergycbc.org/about/). This public/private consortium works to develop and deliver technology, policies, and practices toward a "market transition" to net-zero energy commercial buildings. The goal: for all commercial buildings in the U.S. to be high-performance, zero energy structures by 2050. These buildings are to be cost-effective and compatible with a highly reliable, low-carbon electric grid.

Within a year of its launch in 2009, 420 member organizations, including commercial buildings professionals, industry stakeholders, researchers, educators, utilities, and government agencies had joined. (*Building Design+Construction* is an affiliate member.) Two-thirds of these are involved in working groups that are identifying key barriers to NZEB development and making recommendations in their topical areas for reports to the U.S. Department of Energy.

Twelve working groups (http://zeroenergycbc.org/workinggroups/) are gathering and distributing information on innovative strategies and successful approaches, and providing market feedback regarding energy efficiency and related issues. The working groups are divided into two categories:

Technologies and Practices Working Groups

1. Building Envelope
2. Mechanical Systems, Plumbing, and Controls
3. Lighting/Daylighting and Controls
4. Process, IT, and Miscellaneous Equipment
5. Combined Heat and Power (CHP), Multi-Building Systems, and Grid Integration

Market and Policy Working Groups

6. Codes and Standards
7. Integrated Design and Building Delivery
8. Benchmarking and Performance Assurance
9. Voluntary Programs
10. Finance & Appraisal
11. Owners & Tenants
12. Workforce Development

Working group findings are posted at the CBC website. Working drafts of the final reports are available for download. Membership in the consortium is open to all organizations interested in advancing energy-efficient commercial building technologies, practices, and policies.

American Council for an Energy Efficient Economy http://www.aceee.org/

This nonprofit group is dedicated to advancing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. ACEEE's program areas include energy policy, research, and communications. Its blog (http://www.aceee.org/blog) has timely information on energy-efficiency developments.

Architecture 2030 http://www.architecture2030.org/

In 2002 architect Edward Mazria, AIA, launched Architecture 2030, a nonprofit, nonpartisan, independent organization. The group's mission is to rapidly transform the U.S. and global building sector from being the major contributor to greenhouse gas emissions, to instead becoming central to the solution to climate change, excessive energy consumption, and the resulting economic crises. The organization's 2030 Challenge calls for all new buildings and major renovations to reduce their fossil-fuel greenhouse gas-emitting energy consumption by 50% by 2010 (a deadline that obviously has not been met), and incrementally increase reductions every five years so that all new buildings are carbon neutral by 2030.

These targets may be met by implementing innovative sustainable design strategies, generating on-site renewable power, or purchasing renewable energy (20% maximum). The website includes a database of project case studies with an interactive map, white papers, videos, and a newsletter—all tracking developments in building sustainability and climate change.

Building Enclosure Council http://www.bec-national.org/index.php

The Building Enclosure Council (BEC) is a national affiliation of more than 3,000 architects, engineers, contractors, and building product manufacturers with an interest in building enclosures. The Building Enclosure Technology and Environment Council (BETEC) of the National Institute of Building Sciences and the American Institute of Architects signed an agreement to establish the BEC initiative in 2004. Currently, there are 23 local, state, and regional councils promoting the exchange of information on building enclosures and related science, such as training, education, technology transfer, weather conditions, and local issues and cases. Chapters are located in Atlanta, Boston, Charleston, S.C., Charlotte, Chicago, Dallas, Denver, the District of Columbia, Honolulu, Houston, Kansas City, Mo., Los Angeles, Miami, Michigan, Minnesota, New York City, Philadelphia, Portland, Ore., San Francisco, St. Louis, Seattle, Western Pennsylvania, and Wisconsin.

Collaborative for High Performance Schools
http://www.chps.net/dev/Drupal/node

CHPS seeks to facilitate design, construction, and operation of high-performance schools: environments that are not only energy- and resource-efficient, but also healthy, comfortable, well lit, with amenities for a quality education. CHPS criteria address site and materials selection, energy and water efficiency, and indoor environmental quality, and provide sustainable policies and innovations that can be adopted by schools and districts. CHPS is developing an Operations Report Card for existing schools, an online tool to assist facilities managers in identifying and prioritizing problem areas in their schools. The website offers training videos, webinars, slide shows, and a searchable high performance building product database.

Council of NAIMA http://www.naimacouncil.org/

The Council of the North American Insulation Manufacturers Association (CNAIMA) is an association of 15 North American companies that produce thermal or acoustical insulation: Bayer MaterialScience, CertainTeed Corp., Dow Building Solutions, Fiberlite Technologies, Huntsman International, Icynene Inc., Johns Manville, Knauf Insulation, Nu-Wool Co., Pactiv Building Products, Polyair, Roxul Inc., Thermafiber, U.S. Borax, and U.S. GreenFiber. The organization is committed to promoting legislation that will encourage energy conservation and creation of North American jobs.

Green Globes http://www.greenglobes.com/

Similar in intent to USGBC's LEED, Green Globes offers an online assessment protocol, rating system, and guidance for green building design, operation, and management. It was developed by the Green Building Initiative (http://thegbi.org). Green Globes is "interactive, flexible and affordable and provides market recognition of a building's environmental attributes through third-party verification." The Green Globes system is used in Canada and the U.S. It has also been used by the Continental Association for Building Automation (CABA) to power a building intelligence tool, called the Building Intelligence Quotient (BiQ).

Energy Future Coalition
http://www.energyfuturecoalition.org/

This broad-based, nonpartisan alliance serves as a bridge between business, labor, and environmental groups. The coalition also identifies energy policy options that can achieve broad political support; one such focus is building retrofits: *Rebuilding America* (http://www.energyfuturecoalition.org/What-Were-Doing/Energy-Efficiency/Rebuilding-America).

Rocky Mountain Institute http://www.rmi.org/rmi/

An independent, entrepreneurial nonprofit organization, RMI's industry experts, thought leaders, and engineers focus on breaking through basic challenges related to energy and resources. The organization has a focus on the built environment: http://www.rmi.org/rmi/Built+Environment.

RMI RetroFit (http://www.rmi.org/rmi/RetroFit) seeks to spur the retrofit of at least 500 buildings within five years.

RMI also aims to initiate a process to retrofit the entire U.S. commercial building stock so that it will use, on average, 50% less energy by 2050. RMI is working with building owners who control large amounts of commercial real estate to test new retrofit approaches. It also plans to work with a select group of service providers (design teams, property managers, and energy service companies, or ESCOs) to develop skills and service packages to deliver the potential level of energy savings that large-scale retrofits can achieve.

Solar Energy Industries Association
http://www.seia.org/

This advocacy group is an information clearinghouse for the solar energy industry. See http://www.seia.org/cs/about_solar_energy/how_do_i_go_solar for information on using solar in commercial and residential properties.

U.S. Green Building Council http://www.usgbc.org/

The organization behind the LEED rating system and the annual Greenbuild International Conference & Expo, the USGBC is a major force in green design and construction. This site provides webinars, podcasts, online courses, videos, and case studies on green building education.

USGBC Building Performance Partnership (http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2201) engages commercial and residential LEED building owners and managers in an effort to optimize the performance of buildings through data collection, analysis, and action. This project will yield a comprehensive green building performance database, enable standardization of reporting metrics and analytics, and establish new performance benchmarks. Participants are eligible to receive annual performance reports, report cards, and real-time data interfaces to aid in building performance goals.

PROFESSIONAL MEMBERSHIP ASSOCIATIONS

American Institute of Architects www.aia.org

AIA Local Leaders in Sustainability – Green Incentives http://www.aia.org/advocacy/local/incentives/AIAB028722?dvid=&recspec=AIAB028722

The AIA is focusing on promoting sustainability at the local, state, and federal levels by working with its partners to promote green building. Local Leaders in Sustainability – Green Incentives is an analysis of the current state of green building incentives at the state and local level. It analyzes data from local and state-level research on green incentive programs, including the Local Leaders in Sustainability study, and input from the Developers Roundtable, a discussion among stakeholders on incentive options for the building sector.

AIA Knowledge Community – Sustainability http://www.aia.org/practicing/groups/kc/AIAS077433?dvid=&recspec=AIAS077433

This page contains links to AIA's sustainability documents and has links to other resources.

AIA 2030 Challenge (http://www.architecture2030.org/2030_challenge/the_2030_challenge) asks the global architecture and building community to adopt the following targets:

- All new buildings and major renovations shall be designed to meet an energy consumption performance standard of 60% below the regional (or country) average.
- At a minimum, an equal amount of existing building area shall be renovated annually to meet an energy consumption performance standard of 60% of the regional (or country) average.
- The fossil fuel reduction standard for all new buildings and major renovations shall be increased to:
  - o 70% in 2015
  - o 80% in 2020
  - o 90% in 2025
  - o Carbon-neutral in 2030 (using no fossil-fuel GHG-emitting energy to operate)

These targets may be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power, or purchasing renewable energy (20% maximum).

AIA 2030 Commitment (http://www.aia.org/about/initiatives/AIAB079458) is a separate program from the 2030 Challenge. The 2030 Commitment requires that the 138 signatory firms predict the energy use of all of their projects and has a mandatory reporting component. The first round of reporting for the 138 firms that have signed the commitment is due 31 March 2011.

ASHRAE http://www.ashrae.org/

The American Society of Heating, Refrigerating and Air-Conditioning Engineers develops HVAC standards. ASHRAE publishes research, magazines (*High Performing Buildings*, at: http://www.hpbmagazine.org/), and newsletters and provides continuing education on improving HVAC efficiency and monitoring. Also of note: access to total building energy data on the renovated, energy-efficient ASHRAE headquarters building in Atlanta. (http://images.ashrae.biz/renovation/) The building's daily energy consumption data is part of a website feature, called "Living Lab," in which several tools are used to analyze data related to its energy use.

ASHRAE's **Standard for the Design of High-Performance, Green Buildings** (Standard 189.1) (http://www.ashrae.org/publications/page/927) was released in January 2010. The energy efficiency goal of Standard 189.1—which was developed in conjunction with the Illuminating Engineering Society of North America (IES) and the USGBC—is to provide significant energy reduction over the ANSI/ASHRAE/IESNA Standard 90.1-2007. It offers a broader scope and provides minimum requirements for siting, design, and construction of high-performance green buildings. According to ASHRAE, by applying the minimum set of recommendations, the new standard leads to site energy savings ranging from 10% to 41% over those provided by ASHRAE Standard 90.1-2007.

Building Owners and Managers Association International (www.boma.org) is an international federation of more than 100 local associations and affiliated organizations whose members own or manage more than nine billion sf of commercial properties.

BOMA 360 Performance Program http://www.boma.org/GETINVOLVED/BOMA360/Pages/default2.aspx

This program evaluates properties on six major areas of building management: building operations and management; life safety/security/risk management; training and education; energy; environment/sustainability; and tenant relations/community involvement. Every aspect of building performance is assessed, and scores are based on how buildings meet an extensive checklist of best practices.

BOMA Market Transformation Energy Plan and 7-Point Challenge http://www.boma.org/SiteCollectionDocuments/Org/Docs/Advocacy/Market_Trans_Web030210.pdf

Launched in July 2007, the BOMA 7-Point Challenge aims to reduce energy consumption in commercial buildings by 30% by 2012. Since then more than 120 BOMA member companies and BOMA local associations have endorsed the 7-Point Challenge and have made improved energy performance a priority across company portfolios.

National Association of Home Builders
http://www.nahb.com/

NAHB provides information and education on sustainable home building using renewable materials to conserve energy and environmental resources. NAHB sponsors the NAHB National Green Building Program and the University of Housing Certified Green Professional designation for builders, remodelers, and others in the home building industry.

FEDERAL GOVERNMENT AGENCIES

U.S. DEPARTMENT OF ENERGY

http://www.energy.gov/index.htm

The DOE and the GSA are the primary drivers in the federal government toward net-zero energy structures. DOE spearheads several initiatives concerning energy efficiency and building construction:

The Net-Zero Energy Commercial Building Initiative http://www1.eere.energy.gov/buildings/commercial_initiative/

This initiative aims to achieve market-ready, net-zero energy commercial buildings by 2025. American Recovery and Reinvestment Act funds were used to accelerate and expand partnerships with major companies that design, build, own, manage, or operate large portfolios of buildings and that commit to achieving exemplary energy performance. This funding helped expand the number of partnerships from 23 to about 75 through a competitive process.

CBI also includes a National Laboratory Collaborative on building technologies, concentrating the efforts of five National Laboratories—Argonne, Lawrence Berkeley, Oak Ridge, and Pacific Northwest National Laboratories, and the National Renewable Energy Laboratory—on the net-zero energy goal, and the Commercial Building National Accounts, which conducts cost-shared research, development, and deployment for new building technologies among major national companies. The website offers commercial reference building models, advanced energy design guides, energy simulation software, and a high-performance building database.

Ongoing R&D activities in support of the CBI include:

Commercial Lighting Solutions

DOE, in partnership with top lighting designers, architects, and commercial end users, is developing commercial lighting solutions that focus on systems design for different building and lighting-use scenarios. A series of "design vignettes" provide lighting layouts, component specifications, and daylighting designs. The solutions are then entered into a free, interactive Solid State Lighting website (http://www1.eere.energy.gov/buildings/ssl/).

Building Envelope R&D http://www1.eere.energy.gov/buildings/envelope_walls.html

This site has information on the Building Technologies Program's research and development on the building envelope: walls, roofs, foundations, and windows and doors. The Building Envelope and Windows R&D Program Blog (http://www.eereblogs.energy.gov/building-envelope/) covers up-to-date R&D program activities.

Commercial Building Energy Alliances http://www1.eere.energy.gov/buildings/alliances/index.html

Commercial energy alliances are national forums to evaluate new technologies and share best practices and practical experiences in energy efficiency. For instance, the Retailer Energy Alliance has held two supplier summits where building owners, operators, and suppliers worked on strategies for dramatic energy reductions. The alliances are a collective buying voice for the industry to encourage building material suppliers to create more energy-efficient equipment.

Commercial Real Estate Energy Alliance
http://www1.eere.energy.gov/buildings/alliances/commercial_real_estate.html

This partnership of commercial real estate owners and operators works with DOE to reduce energy consumption in commercial real estate. Alliance Project Teams cover six areas in commercial real estate buildings and operations, develop best practices toolkits, and conduct research into innovative, cost-effective technologies. The six areas are: Lighting and Electrical, HVAC Systems, Hospitality, Shopping Center and Retail, Whole Building Integration and Renewable Energy, and Existing Buildings. Project teams conduct studies, such as technology and system specifications, with DOE's national laboratories.

Commercial real estate owners and operators who wish to join CREEA must choose at least one project team of interest. Building product suppliers can also participate by submitting descriptions of new technologies for evaluation. Two industry-specific offshoots of this organization were formed for retailers and hospitals.

Retailer Energy Alliance http://www1.eere.energy.gov/buildings/alliances/retailer_energy_alliance.html

Because most retailers build multiple buildings with the same or similar designs, energy-efficient strategies can be adopted widely throughout a company's building portfolio. Lessons learned and technologies used in one company are often easily transferred to another. Members include Walmart, Target, Macy's, and J.C. Penney.

Hospital Energy Alliance http://www1.eere.energy.gov/buildings/alliances/hospital_energy_alliance.html

Leading healthcare companies and industry groups are working to reduce facility expenses and provide a more comfortable environment through energy-efficient hospitals. By investigating advanced technologies emerging from the national laboratories, alliance members are creating a national forum to share technology solutions and influence the energy performance of medical equipment and systems.

Commercial Buildings Key Publications http://www1.eere.energy.gov/buildings/commercial_initiative/publications.html,

This repository of reports and documents produced by DOE's national laboratories covers building planning and performance, energy use and benchmarks, HVAC, and lighting.

Building Technologies Program http://www1.eere.energy.gov/buildings/commercial_landing.html

This website includes software tools that model building energy flows and calculate tax deductions for federal energy-efficiency incentives. It also contains links to a list of vendors that offer high-performance windows, and a high-performance building database with case studies of energy-efficient buildings.

Building America http://www1.eere.energy.gov/buildings/building_america/

Building America forms research partnerships with all facets of the residential building industry to improve the quality and energy efficiency of homes.

High Performance Green Building Partnership Consortia http://www.hpcgbp.org/

Public and private sector groups promoting high-performance green buildings and net-zero energy commercial buildings are recognized by DOE as members of the High Performance Green Building Partnership Consortia. DOE uses consortia information to develop a report to Congress on the status of the CBI.

U.S. Environmental Protection Agency
Federal Green Building Requirements Website
http://www.epa.gov/greeningepa/projects/requirements.htm

"Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings" is available for download on this site. It contains the green design goals that 22 federal agencies have pledged to follow on new construction and renovation projects.

U.S. GENERAL SERVICES ADMINISTRATION
GSA Sustainable Design Program
http://www.gsa.gov/portal/content/104462

GSA, which is responsible for managing most federal office buildings outside of the military, has recently increased its minimum requirement for new construction and substantial renovation of federally owned facilities to LEED Gold. Until recently, GSA had required LEED Silver. GSA has commissioned a number of government agency facilities that seek zero or net-zero energy use (see Chapter 2).

Sustainability Matters http://www.gsa.gov/graphics/pbs/oaspublications.pdf
This USGBC program publishes case studies and best-practices that address GSA's sustainability initiatives and strategies at all stages of a building's life cycle.

NATIONAL LABORATORIES

Lawrence Berkeley National Laboratory
http://www.lbl.gov/

This DOE lab conducts research on green energy and efficiency. Of particular note are these reports: "Scale Matters: An Action Plan for Realizing Sector-Wide 'Zero-Energy' Performance Goals in Commercial Buildings" (http://escholarship.org/uc/item/1kf4t1nh?display=all) and "Optimal Technology Investment and Operation in Zero-Net-Energy Buildings with Demand Response" (http://escholarship.org/uc/item/9334229b?query=zero energy).

The lab also has a program dedicated to **Building Technologies:** http://btech.lbl.gov/btd.html.

Research Groups under this program include: Windows and Daylighting, Commercial Buildings, Lighting, Demand Response, and Energy Simulation Software.

The site http://btech.lbl.gov/publications.html contains the lab's publications related to buildings, with research papers and newsletters about fenestration, daylighting, and energy simulation.

National Renewable Energy Laboratory
http://www.nrel.gov/

NREL is the nation's primary laboratory for renewable energy and energy efficiency research and development. The lab's scientists and researchers aim to accelerate research from scientific innovations to market-viable alternative energy solutions. This page, http://www.nrel.gov/buildings/, contains work related to buildings. This page, Electricity, Resources, and Building Systems Integration Center: http://www.nrel.gov/eis/erbsi_center.html, contains research in heat transfer, thermal dynamics, and systems engineering to reduce the energy consumption of buildings.

Oak Ridge National Laboratory
http://www.ornl.gov/

The lab's Energy Efficiency and Renewable Energy section, http://www.ornl.gov/sci/eere/, addresses renewable generation, electricity distribution, and end use in buildings. Focus areas include:

- Building Envelope (http://www.ornl.gov/sci/ees/etsd/btric/)
- Solar Energy Technologies (http://www.ornl.gov/sci/eere/research_solar.shtml)
- Cooling, Heating and Power (http://www.ornl.gov/sci/engineering_science_technology/cooling_heating_power/)
- Whole-Building & Community Integration
- Residential, Commercial & Industrial Energy Efficiency (http://www.ornl.gov/sci/ees/etsd/btric/residential.shtml)
- Weatherization (http://www.ornl.gov/sci/eere/research_weatherization.shtml)

Oak Ridge also uses its own facilities as a sustainability lab. Information on that initiative can be found here: http://sustainability-ornl.org/default.aspx. This page, http://sustainability-ornl.org/campus/Pages/buildings.aspx, has details on efforts to green the lab's buildings.

ADDITIONAL RESOURCES

Database for Analyzing Sustainable and High Performance Buildings http://www.gbapgh.org/content.aspx?ContentID=92

Run by the Green Building Alliance, the Database for Analyzing Sustainable and High Performance Buildings (DASH) aims to link green building information to real estate. Financial data, cost effectiveness, and financial incentives of building performance will also be addressed. DASH is in development and GBA hopes to have a beta version available in late 2011.

National Institute of Building Sciences
http://www.nibs.org/

NIBS was authorized by Congress to serve as an interface between government and the private sector, and to support advances in building science and technology to improve the built environment. The NIBS High Performance Building Council's (http://www.nibs.org/index.php/hpbc/) goal is to put standards in place to define performance goals of a high-performance buildings. NIBS houses the Building Enclosure Technology and Environment Council (http://www.nibs.org/index.php/betec/), a voluntary membership council charged with encouraging optimum energy use of buildings through a better understanding of how overall, complex building components interact with each other and with the environment. NIBS also publishes the Whole Building Design Guide (www.wbdg.org) and the *Journal of Building Enclosure Design* (http://www.wbdg.org/references/jbed.php).

Whole Building Design Guide http://www.wbdg.org/

The Whole Building Design Guide provides government and industry practitioners with one-stop access to up-to-date information on a wide range of building-related guidance, criteria, and technology from a "whole buildings" perspective. The guide is a collaborative effort among federal agencies, private-sector companies, nonprofit organizations, and educational institutions. Multiple links between various sections of the guide and the Web allow access to relevant online information related to a topic, including design tools, federal mandates, and government and nongovernment standards. You can also browse in-depth technical summaries, called Resource Pages, written by industry experts. BD+C

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2003 White Paper on Sustainability
2004 Green Building Progress Report
2005 Life Cycle Assessment and Sustainability
2006 Green Buildings and the Bottom Line
2007 Green Buildings Research White Paper
2008 Green Buildings + Climate Change
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