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

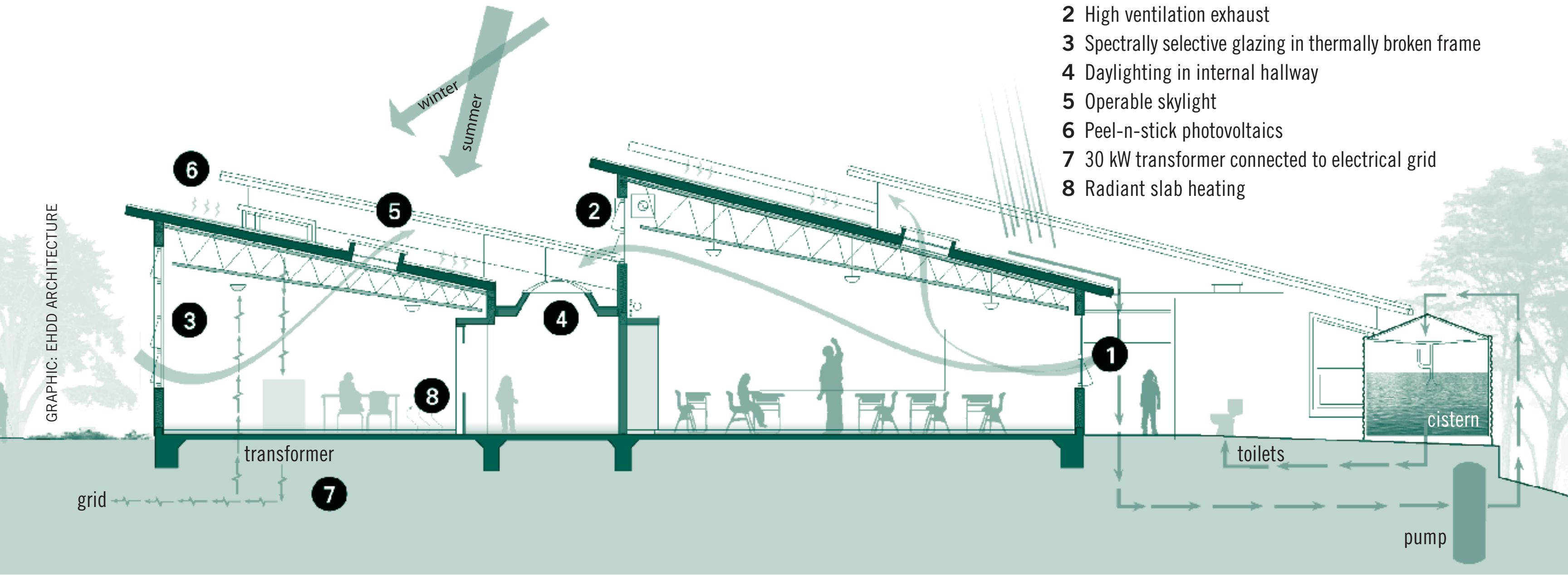
The Otay Mesa (Calif.) Land Port of Entry, one of a number of net-zero energy projects commissioned by the U.S. General Services Administration, will be powered by a 280 kW photovoltaic system. The GSA is also testing more than a dozen "proving ground technologies," such as kinetic energy machines. Tate 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



1 Low ventilation intake
2 High ventilation exhaust
3 Spectrally selective glazing in thermally broken frame
4 Daylighting in internal hallway
5 Operable skylight
6 Peel-n-stick photovoltaics
7 30 kW transformer connected to electrical grid
8 Radiant slab heating

GRAPHIC: EHDD ARCHITECTURE

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.

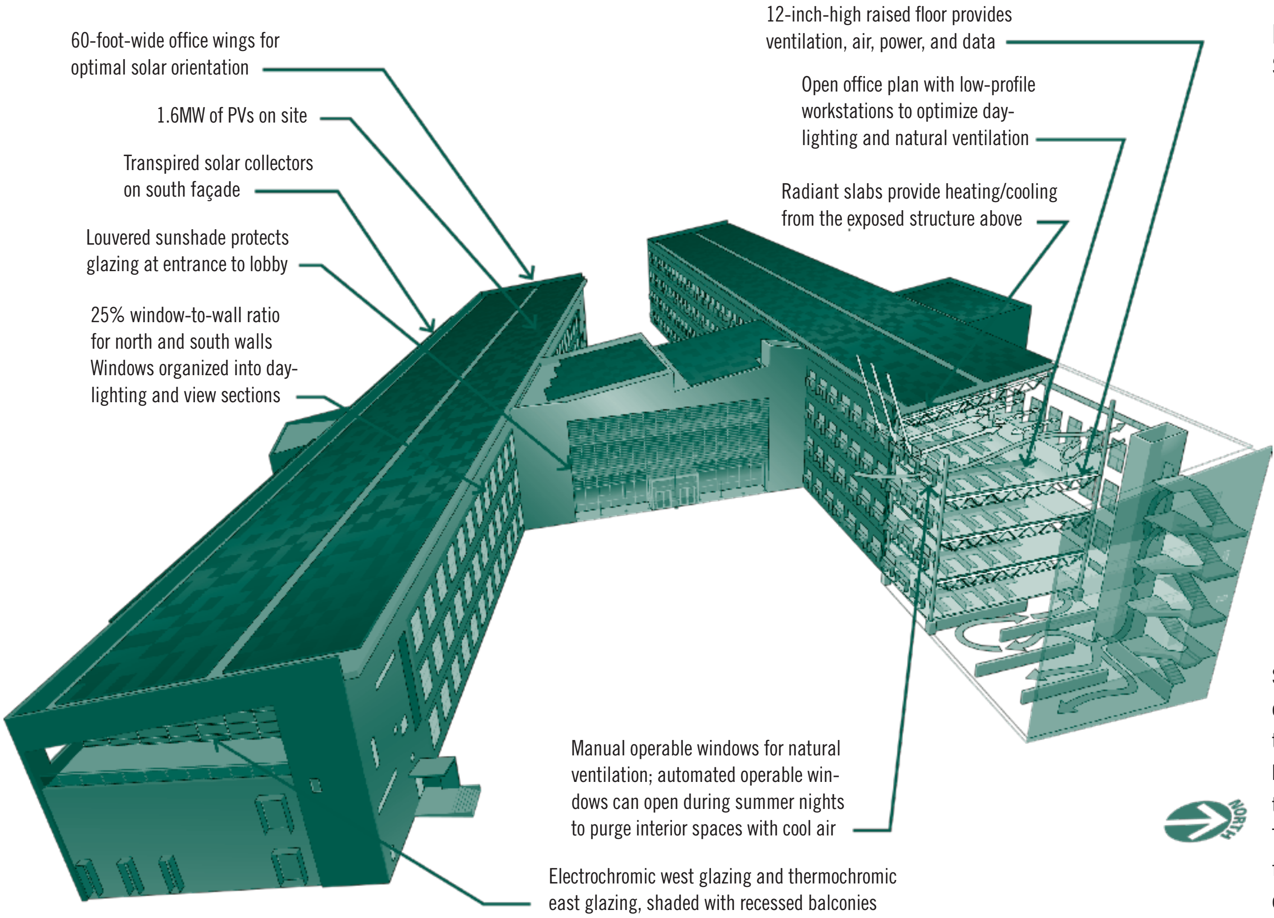
WHAT ABOUT ECONOMIC FEASIBILITY?

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



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.

Source: National Renewable Energy Laboratory

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