

net-zero energy design

AND THE LIVING BUILDING CHALLENGE



ROBERT BENSON PHOTOGRAPHY

The recently completed net-zero energy R.W. Kern Center, Hampshire College, Amherst, Mass., was designed to meet the Living Building Challenge. Bruner/Cott & Associates (architect) led the Building Team: Foley Buhl Roberts and Associates (SE); Berkshire Design Group (CE); Kohler & Lewis Engineers (mechanical); R.W. Sullivan (electrical); Rybak Engineering (FP); O'Reilly, Talbot & Okun Associates (geotechnical engineer); South Mountain Co. (building envelope); Lewis Lighting Design; Integrated Eco Strategy (LBC materials vetting); Cutler Consulting (codes); Kalin Associates (specs); Richard Burke Associates (landscape architect); Strategic Building Solutions (Cx); and Wright Builders (CM).

LEARNING OBJECTIVES

After reading this article, you should be able to:

- + **EXPLAIN** how the Living Building Challenge influences the design approach to net-zero energy projects.
- + **DISCUSS** the “reduce/produce” approach to net-zero energy design.
- + **LIST** renewable strategies for various building types and project scales.
- + **SUMMARIZE** the relationship between building feedback and occupant behavior as it relates to successful net-zero energy design.

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Net-zero buildings are, by definition, buildings that use less energy than they produce over time. Effective net-zero design demands more than just piling on renewable energy sources. It requires an integrated process of evaluating needs, setting goals, and tailoring solutions to each project, site, and client.

For net-zero buildings to proliferate, AEC professionals need a new way to think about energy use in buildings. The Living Building Challenge offers an approach that goes beyond “doing less bad” to one that creates buildings that have a positive, regenerative impact on people and the environment.

The LBC is a design philosophy, advocacy tool, and aspirational model that provides a framework from which to examine build-

‘Net-zero indicates you’re living within your means. Net positive makes a shift to giving back.’

—Brad Liljequist, International Living Future Institute

ing energy, one that is “socially just, culturally rich, and ecologically restorative,” according to its parent organization, the International Living Future Institute (ILFI). The LBC champions resiliency and self-sufficiency, as well as beauty, efficiency, and even human happiness. It supports integrated design by defining a shared set of values for the design team, owner, and contractor long before a specific design is formulated. It challenges Building Teams to think beyond cost, time, and program to pursue a values-driven design process that gives equal weight to energy efficiency, environmental impact, and human health, so that the project can have the greatest positive impact.

The LBC is organized into seven “Petals”—Place, Water, Energy, Health & Happiness, Materials, Equity, and Beauty. To meet the requirements of the Energy Petal, a project must provide 105% of its energy needs on site with renewable resources as well as on-site energy storage for resiliency. No combustion is allowed in the LBC; nor is the purchase of off-site renewable energy permitted. The results are validated by a one-year performance period.

The Living Building Challenge shifts the discussion of energy from “What’s possible?” to “How do we get there?” As noted above, net-zero energy buildings rely on renewable energy sources—solar, wind, hydroelectric, or geothermal—that can be generated on site. The intent of net zero is to move buildings toward clean energy and away from the current power grid for their energy needs. The building industry has recognized its role in mitigating climate change through such efforts as the AIA 2030 Challenge, which aims to make all new buildings net zero by 2030. Eco Districts, 2030 Districts, and Living Communities apply this goal at the macro scale.

The LBC framework provides an elegant and cost-effective strategy for net-zero energy: first, *reduce energy demand* as much as possible; then (and only then) *produce renewable energy on site* to meet any remaining demand. This approach streamlines the design process and optimizes the potential of renewable energy technologies on any building initiative.

STEP 1: REDUCE ENERGY DEMAND

Reducing a building’s energy demand is critical to successful net-zero design. Minimizing the energy load allows the Building Team to consider a wider variety of renewable technology solutions, increase floor-area ratio relative to renewable sources, or reduce the amount of renewable energy required. The LBC Energy Petal encourages design teams to “prioritize reductions and optimization before technological solutions are applied to eliminate wasteful spending—of energy, resources, and dollars.”

Effective energy reduction relies on an integrated design process that involves the entire Building Team from the start. This allows greater design flexibility and enables architectural and technical solutions

to be worked out in parallel. The first step: goal setting. Each member of the Building Team—including the owner—needs to commit to a firm set of performance goals and net-zero design goals to guide the project. The LBC goes beyond net zero to net positive by dictating a specific energy-generation target: 105% of project demand. To encourage resiliency, the LBC requires enough battery storage to support at least one week of emergency lighting and refrigeration.

Energy modeling is a crucially important tool in leveraging both energy consumption and production to optimize design choices. Done well, energy modeling can increase the likelihood that a project will meet its energy goals. For net-zero designs, the energy model should consider both the predicted use and the site-generating capacity.

The *predicted use* is an estimate of the amount of energy that will be used by a building based on input and assumptions on building

NET-POSITIVE IN ACTION

The R.W. Kern Center, Amherst, Mass.



ROBERT BENSON PHOTOGRAPHY

The R.W. Kern Center, a recently completed, \$7.3 million admissions and welcome building at Hampshire College, Amherst, Mass., is pursuing LBC certification. Beginning with an energy model, a team of expert environmental, structural, and mechanical consultants led by architect Bruner/Cott & Associates rethought traditional energy system design to create a building which lives within its means. It is oriented along an east-west axis, allowing glazed elements to be effectively shaded with exterior horizontal blinds and a large overhang. The 17,000-sf building’s tall, slender windows bring in natural light, drastically reducing the need for artificial lighting during daytime operating hours.

The team also minimized energy use for active systems. Heat-recovery ventilators provide fresh air without wasting indoor heat. An air-source heat pump system efficiently conditions indoor spaces while providing individual temperature control. Occupancy and daylight sensors control the LED lighting fixtures. Plug and lighting loads are metered and displayed centrally in an interactive dashboard to provide daily feedback to occupants with the intent of adjusting user behavior to reduce individual energy use. The Building Team reduced the overall energy demand of the building to a projected EUI of 23 kBtu/gsf/yr.

size, location, use, building type, occupancy type, occupant behavior, system types, and system and envelope inputs. It is usually measured as energy use intensity, or EUI, the energy use per square foot in thousands of British thermal units per gross square foot per year (kBtu/gsf/yr) or kilowatt-hours per gross square foot per year (kWh/gsf/yr).

Energy modeling can begin very early in the process as a “shoe-box” model with benchmarks and rough metrics and continue to gain definition throughout the design process.

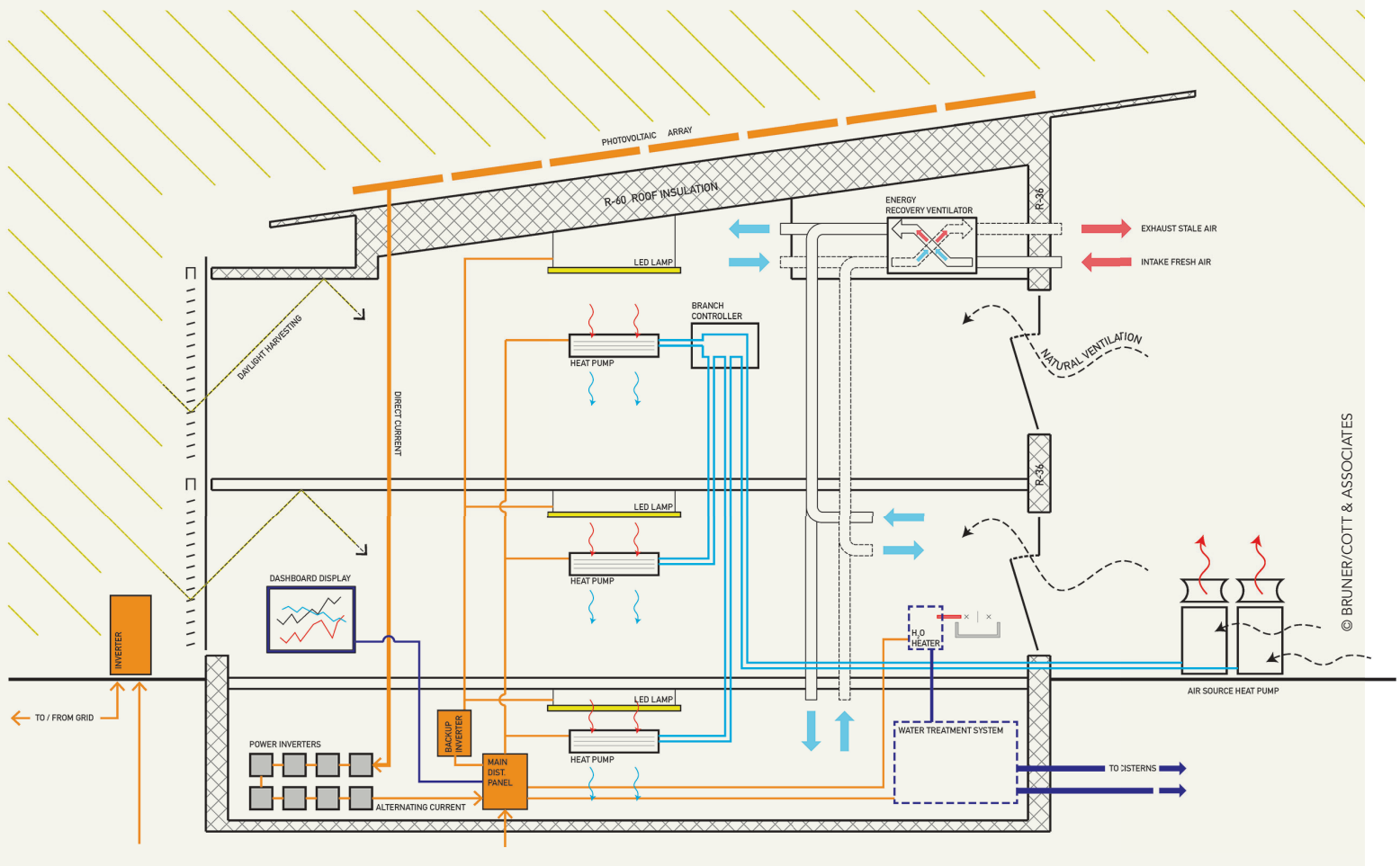
The second part of the modeling equation is *production or generating capacity*—the amount of energy that can be produced on site. For a photovoltaic panel system, this would be based on the available roof and wall area, the efficiency of the panels, and the average annual hours of sunshine in a particular climate. A wind source model would be based on the size of the wind turbine and the historic annual wind speeds on

the site. The modeling stage is a good time to determine which type of renewable energy is most likely to meet the project’s demands. It goes without saying that the energy model must be as accurate as possible, for it forms the foundation of many subsequent decisions on the project’s size, shape, efficiency, and renewable strategies.

With the modeling complete, the size, shape or envelope design of the building can be refined relative to its energy-generation potential and target EUI. For example, minimizing energy-intensive program elements or increasing the amount of exterior insulation could significantly reduce the building’s predicted EUI.

By understanding both the demand and production aspects of the energy model, the design team can begin to define a range of building area, building height, EUI target, and overall goals for the energy-generation aspect of the project.

The designers opted for a laminated timber frame with a standard wood-cavity perimeter wall. Rather than using standard single-stud framing, the Building Team developed a double-stud system with 2x6 and 2x4 wood members to reduce thermal bridging. This took advantage of lumber sizes available from local mills and also allowed the use of 12-inch-thick cellulose insulation instead of rigid foam insulation. The R-60-rated roof (opposite) provides space for a 118 kW, 6,092-sf SunPower E-Series PV array. Hampshire College has committed to developing 19 acres of PV arrays, which will provide 100% of the campus’s electricity. This will make Hampshire the first U.S. residential college to generate all of its electricity from on-site renewable sources.



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USING PASSIVE STRATEGIES EFFECTIVELY FOR NET-ZERO

Lowering a building's EUI is a key ingredient in net-zero design. *Passive strategies*—strategies that do not require energy for operation—must be given top consideration. Start with site-scale opportunities like building orientation and shape to take advantage of natural light and prevailing winds to reduce the need for artificial systems. Thoughtful landscaping and shading devices can also help minimize solar gain and reduce the demand for air-conditioning.

In cold climates, tuning the window-to-wall ratio is one of the most effective strategies. Marc Rosenbaum, Director of Engineering for South Mountain Company, recommends a window-to-wall ratio of 40% or less. "Extra glazing adds material cost and increases HVAC system size without adding any benefit," he says.

Next, an effective building enclosure is critical. Net-zero projects usually have insulation values well beyond code. In the Northeast, for example, it is common for net-zero buildings to be designed with R-40 walls and R-60 roofs, nearly twice that required by most local codes. Windows are frequently triple glazed with assembly R-values between R-6 and R-8 (standard windows average R-2). New glass technology balances visible light transmitted with heat gain and glare.

Reducing air infiltration through the use of a continuous air barrier is also important. To be effective, the air barrier must be field inspected and tested to make sure its performance matches the design assumptions. For low-energy buildings, thermal bridges from the structure to the interior must be avoided. Active shading devices, such as roller shades or exterior blinds, are often deployed on net-zero designs, especially on south and west façades. They can be connected to daylight sensors or building automation systems to increase their utility.

On LBC projects, designers of super-efficient buildings must overcome an additional obstacle: the project cannot use materials that are harmful to people or the environment. This rules out many common insulations that may contain formaldehyde, toxic flame retardants, respiratory irritants, or foaming agents that emit greenhouse gases. It also calls into question membranes, sealants, and fixtures that may perform well but not comply with the LBC's Red List of toxic materials

LIVING BUILDING CHALLENGE 3.0

Imperatives in color are most relevant to net-zero energy design.

PLACE

1. **Limits to Growth**
2. Urban Agriculture
3. Habitat Exchange
4. Car-Free Living

WATER

5. Net-Positive Water

ENERGY

6. **Net-Positive Energy**

HEALTH & HAPPINESS

7. Civilized Environment
8. **Healthy Interior Environment**
9. Biophilic Environment

MATERIALS

10. **Red List**
11. **Embodied Carbon Footprint**
12. **Responsible Industry**
13. Living Economy Sourcing
14. **Net-Positive Waste**

EQUITY

15. **Human Scale + Humane Places**
16. Universal Access to Nature+Place

PLACE

17. Equitable Investment
18. JUST Organizations

BEAUTY

19. Beauty + Spirit
20. **Inspiration + Education**

or whose life cycle is nonsustainable. Charley Stevenson, LEED AP BD+C, Founder, Integrated Eco Strategy, says, "Focusing only on EUI might miss the mark on something more important: human health. Giving all performance criteria equal weight is the critical component of the LBC. It's not a matter of trading lower indoor air quality for higher energy efficiency—we need all of it at once. There's no technical reason not to do so."

Stevenson believes the best systems are simple, proven, and effective. Cellulose insulation is one low-tech, high-performance material he recommends. It can be combined with new vapor-permeable membranes to create systems that deliver a high level of insulation with a relatively small carbon footprint. Be aware, however, that cellulose works best with wood construction. It is not considered appropriate for curtain-wall construction where there is no cavity.

Employed effectively, passive strategies can lead to a building that uses considerably less energy than the business-as-usual approach prescribed in current codes.

OPTIMIZING BUILDING SYSTEMS IN LBC PROJECTS

A structure that is properly oriented, well insulated, airtight, and shaded will be more temperature stable and can employ smaller, more efficient mechanical systems. "Many buildings jump right to low-energy distribution systems such as displacement ventilation, active beams, and radiant systems as a fix for a high-load space," says mechanical engineer Bungane Mehlomakulu, Principal, The Integral Group. "That approach overlooks the intent of these systems: to

efficiently deliver heating and cooling to occupants." He says that designers should first review the external and internal loads to make sure they are low enough to take advantage of low-energy systems. With loads reduced, the project engineer can shift the focus to "designing a space for human comfort, not just air temperature."

A common approach to comfort design is to separate the ventilation loads from space heating and cooling. Ventilation is usually handled by a dedicated outdoor air system (DOAS) with heat- or energy-recovery capability, often in mixed-mode with operable windows. This maintains optimal air flow even when heating and cooling are not required. Energy used for hot water heating should also be minimized, perhaps by using solar thermal, heat pump, or high-efficiency electrical technologies.

Though net-zero building systems can technically be powered by traditional fuel sources, in LBC projects they must run on site-generated electricity without the aid of combustion.

Reducing lighting loads is crucial to reducing overall energy demand. The use of LEDs, occupancy controls, and daylighting strategies has more or less become standard practice in many new construction and retrofit projects. “Net-zero design requires a shift in our approach—thinking about how to design a visual environment for people, as opposed to providing a one-dimensional footcandle target,” says Will Lewis, Principal, Lewis Lighting Design. It starts with daylighting. “In the evening, we want to keep connected loads low, not provide more light than is needed.”

Think about what needs to be directly lighted and what doesn’t, he says. Focus the light where it needs to be and allow secondary surfaces to receive ambient light. A less prescriptive lighting standard supports this approach. It used to be that 300 footcandles’ intensity

must prove itself. “This is where the knowledge base and experience of the design team comes into play,” says architect Jason Jewhurst, AIA, with Bruner/Cott & Associates. “We have to know how to detail the envelope correctly, specify and test air tightness, specify the right kind of glazing, and then ensure that the passive strategies become realities to generate results.”

The performance-testing period is especially important when it comes to occupant-dependent energy uses such as plug loads, heating, and cooling. As the energy associated with architecture and building systems goes down, the impact of occupant behavior on energy use goes up. Occupant energy use that is higher than the modeled assumption can derail the net-zero energy goals of a project, even if all the systems function perfectly.

Building Teams and their building owner clients need to work with building occupants and facilities managers to understand use patterns, get the best information possible, and leave space for conditions to change. One strategy is to include detailed metering systems and feedback mechanisms to enable occupants to monitor and understand the building’s energy use. This allows them to learn about the energy systems they use every day, and to understand the impact of their behavior on the building’s overall performance. In this context, heating, cooling, and electricity become vehicles for human engagement with the environment.

Lessons Learned in RENEWABLE ENERGY DESIGN

UNDERSTAND the connection between energy models and constructed buildings. Models are only as good as the quality of input and information. During design and construction, the building must reflect the model inputs.

REALIZE that project aspects may change along the way. Use an energy safety factor linked to the type of building and its number of variables.

THINK of PVs as an investment, with payback similar to a bond, but with more than financial benefits. Although first costs for solar energy can be daunting, there are many financing and leasing options.

FIND creative ways, such as competitions, lease arrangements, and feedback systems, to encourage building occupants to manage their energy use. When mechanical and envelope loads are reduced, plug loads become a larger percentage of energy consumed.

was required on the surface; now, 20 ftc and a task light can work—“if the overall composition is right,” says Lewis. He recommends working with simpler fixtures that have fewer components and focusing on manufacturers who participate in the LBC’s Red List disclosure.

An integrated design process becomes especially important when designing building systems, as many low-energy mechanical systems are often visible and need to be carefully integrated into the architectural aesthetic. A collaborative, communicative team is also essential from an LBC perspective, as mechanical systems are often the most complex elements to vet for Red List compliance.

PROVING PERFORMANCE UNDER THE LBC

For a building to be certified under the Living Building Challenge, performance must be proven based on a year’s worth of energy use and production data. Energy models be damned—the building really

STEP 2: PRODUCE UNMET ENERGY DEMAND

In selecting a renewable-energy system for a building, the site-capacity information from the energy model can be used to determine which energy sources will be able to meet the demands of the building within the constraints of the site, budget, timeline, and performance goals. Choosing a renewable energy source involves a process of elimination. For LBC projects, designers must also take into account the product life cycle and environmental impacts of a proposed system. Following are the most common renewable systems:

- **Photovoltaics** can easily be added to existing infrastructure, are increasingly less expensive, and pose no danger to local wildlife. However, Building Teams should carefully consider the environmental impacts of producing and disposing of PV panels.
- **Wind power**, either ground-based or roof-mounted turbines, can be an option for sites with prevailing winds. Wind systems can be expensive and can draw opposition from vocal constituent groups.
- **Geothermal systems** harness the power of underground heat. They are expensive at small scale and are not an option on most sites. Ground-source heat pumps are sometimes mislabeled as geothermal. While they do use the ground as a heat sink, they cannot power themselves without another source of electrical energy and are therefore not inherently renewable.
- **Hydroelectric power** depends on the availability of a river or tidal flow. Building Teams must also consider the potential impact on the regional ecosystem.
- **Biomass**—the burning of plant-based fuels for energy—is considered a renewable source by the U.S. Department of Energy. Biomass is prohibited under the LBC, as it requires combustion.

Under the LBC, the project's renewables strategy must use the site conditions to create a system of optimum efficiency. Imperative 01, Limits to Growth, further stipulates that the project cannot disturb ecologically sensitive areas. The entire project, including its renewable system, must also maintain and support natural habitat.

The LBC stipulates that renewables systems must be implemented on site. It does, however, allow the option of "scale jumping," or using a neighborhood or campus system to meet the energy requirements. Scale-jumping must also create additional performance or cost efficiency, habitat preservation, or significant infrastructure improvement to meet the LBC goal of "reducing the scale of the conventional utility's network."

To date, every certified LBC project has used PV systems, alone or in combination with other technology. The PV industry is currently experiencing dramatic growth. U.S. PV capacity grew from <1,000 MW in 2008 to an estimated 18,000 MW today. This growth, along with improvements in panel and inverter technology, brought the per-watt installed cost of PVs down 50-70% from 2008 to 2014; in many markets, solar energy is now price-competitive with conventional fossil fuel power.

Improvements in energy-storage technology will be needed to make solar feasible on a large scale. Without storage capacity, the intermittent nature of solar power makes it difficult to integrate with the existing electrical utility system, which depends on controllable energy flow to meet fluctuating demand. The LBC Energy Petal requires energy-storage capacity for at least a week's worth of emergency lighting and power. This requirement should stimulate design teams to consider how to insulate their projects from the risks of regional energy supply loss and harsh weather events.

NET-ZERO AND LBC ON THE HORIZON

The net-zero building sector is growing. The New Buildings Institute's 2015 List of Zero Energy Buildings counted 29 verified commercial or public net-zero projects; another 152 were in design or construction—an increase of 300% since 2012. In 2012, there were just four certified LBC projects. Today, there are 11, with another 314 registered projects in the design, construction, or occupancy-testing phase. Another 15 projects have achieved net-zero energy certification under the LBC Petal program.

We have seen that the best way to achieve net-zero energy is to *reduce energy loads* through passive design, efficient mechanical systems, and behavioral change, then *use renewable sources* to produce the power needed to meet the remaining energy demands. This approach streamlines the design process and optimizes the potential of renewable energy technologies.

The LBC approach to energy requires an integrated, holistic approach that balances energy priorities with respect for human health and well-being, long-term environmental impact, and a sense of spirit and beauty. It asks us to expand our definition of a successful project beyond the cost/efficiency/client satisfaction paradigm to evaluate the positive impact of our buildings. It also challenges us to be progressive on every project—to advocate and experiment in a way that im-

NET-ZERO/LIVING BUILDING CHALLENGE TERMS

CARBON NEUTRAL – a project that achieves net-zero emissions between the amount of carbon released and the amount of carbon offset or sequestered, either on site or through the purchase of offsets.

GREENHOUSE-GAS NEUTRAL – a project that achieves net-zero emissions for gases beyond carbon, such as methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride.

NET POSITIVE – a building that produces more than 100% of its energy needs from on-site renewable resources.

NET-ZERO ENERGY – a building that uses the same amount of energy that is produced on site on an annual basis.

NET-ZERO READY – a building that is designed to be easily transferred to a renewable energy source at a later date.

OFF-GRID – a stand-alone building not connected to an off-site energy utility facility or shared energy grid.

PASSIVE DESIGN – design that takes advantage of the climate to maintain a functional and comfortable environment.

PREDICTED ENERGY LOAD – estimated amount of energy used by a building, based on size, occupancy, and systems, to create a baseline for designing renewable-energy strategies.

RENEWABLE RESOURCE – a resource that regenerates naturally and can be used again, such as solar energy, wind, and geothermal energy; biofuels are renewable in that they are derived from plant matter, which can be naturally replenished.

SITE CAPACITY – the amount of energy that can be produced on site, based on available area and the type and location of the renewable energy used.

proves the industry as a whole, beyond the scale of a single structure.

By applying integrated energy design within the framework of the Living Building Challenge, *Building Teams can do better than net zero—they can achieve net positive*. "Net-zero indicates you're living within your means," says Brad Liljequist, ILFI Director of Net Zero Energy. "Net positive makes a shift to giving back."

> EDITOR'S NOTE

This completes the reading for this course!

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