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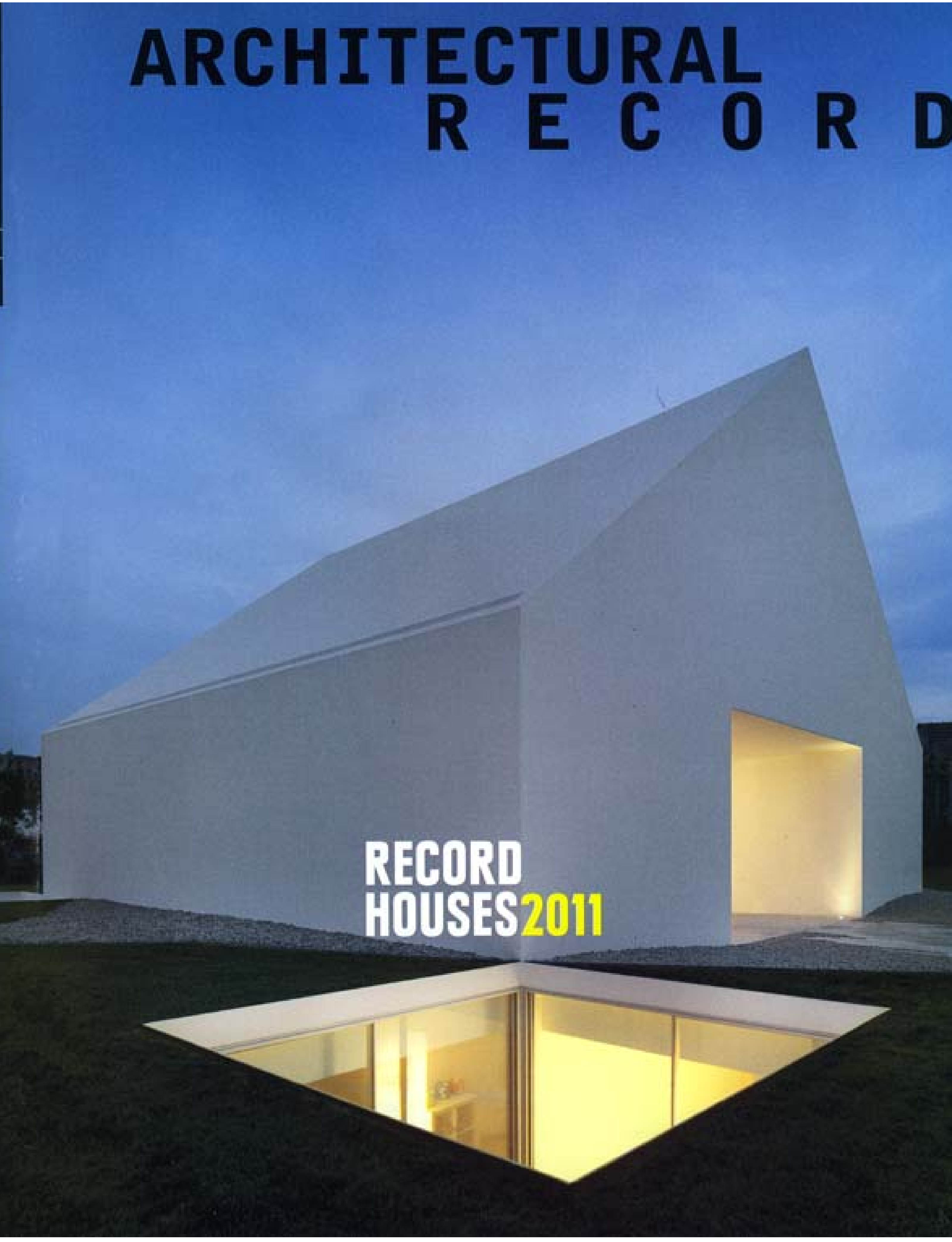

RECORD HOUSES 2011

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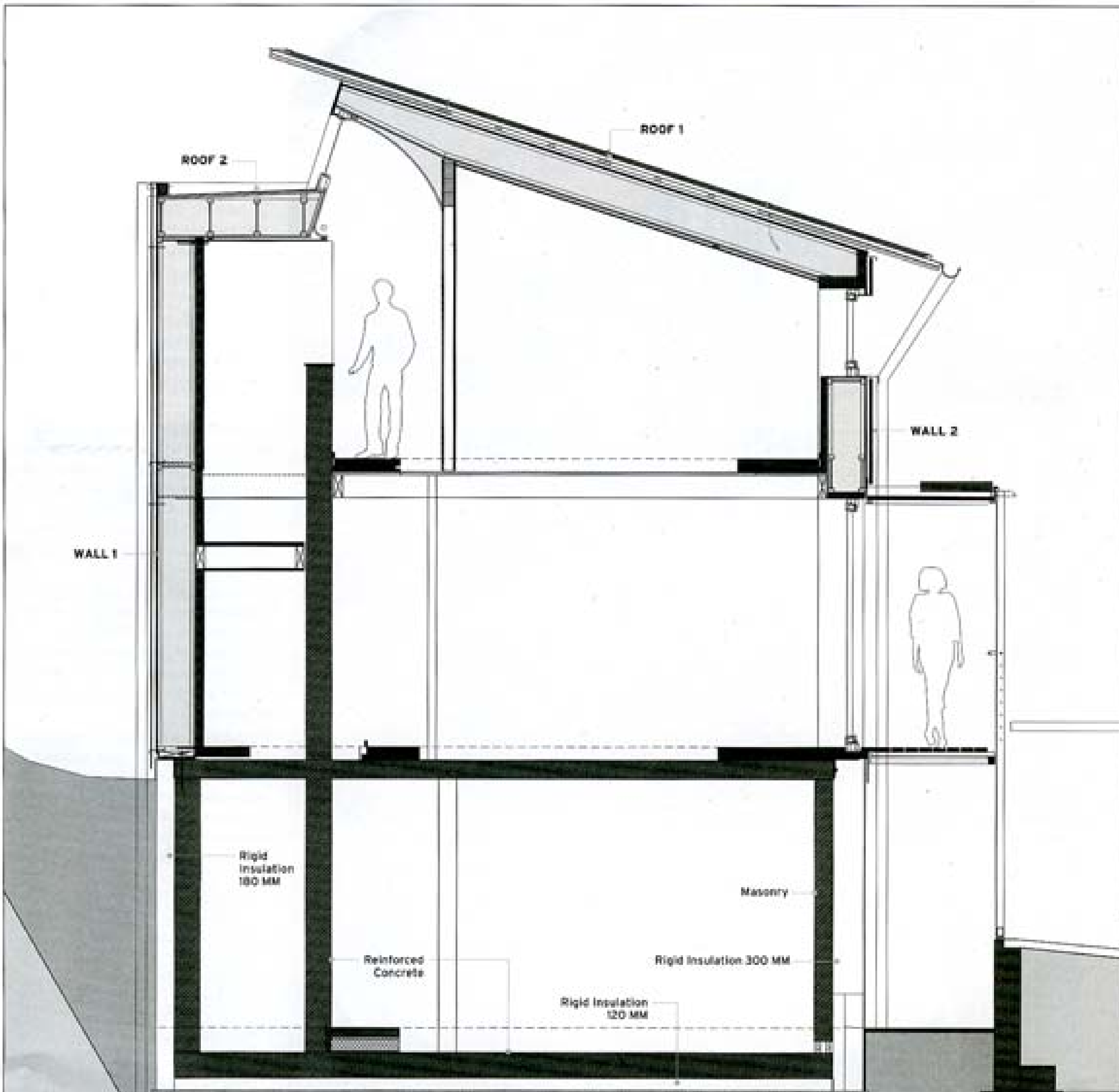
Low Energy, but High Impact

The Passive House system, a design and construction concept with considerable traction in Europe, begins to take hold in the United States. By Michael Cockram



SECTION - LENGDORF HOUSE

SOMETIMES IDEAS HAVE to be exported, transformed, and reimported before they take root. Such is the case with the concept of the superinsulated house, which has recently returned to the United States from Germany in a rigorously defined building certification program known as Passive House. Its stringent energy requirements have filled a void for architects and clients looking for tangible performance-based benchmarks.

Beginning with the energy crisis in the 1970s, two threads evolved in the U.S. green building movement. One school advocated passive solar design, which balances south-facing glass with thermal-energy-storing mass. Another group pushed for lightweight, airtight, and superinsulated construction. But, as American political and research priorities moved away from green design in the 1980s, much of the momentum shifted to Europe. In many ways, Passive House is a marriage between the mass-plus-glass passive solar and the light-and-tight superinsulating camps.

The concept of Passive House grew out of the collaborative research of Wolfgang Feist of Germany and Bo Adamson of Sweden, with the first projects built in the early 1990s. In 1996, Feist founded the Passivhaus Institute in Darmstadt, Germany. It oversees the certification process and remains the guiding force behind the movement.

Building to a benchmark

To qualify for certification a building must meet three basic criteria, which are the same for all projects, regardless of location or climate: annual energy consumption for heating and cooling is limited to 4,755 Btu per square foot; air infiltration is set at a maximum of 0.6 air changes per hour at 50 pascals of pressure; and annual primary energy usage (energy consumed by appliances, lighting, and other devices not directly related to heating and cooling) is capped at 11.1 kilowatt hours per square foot.

The Btu and air-infiltration limits are around 10 times more stringent than those for a home built to the

IMAGES: COURTESY ARCHITEKTURWERKSTATT VALLENTIN

ABOVE AND OPPOSITE: **Some European Passive House advocates have adopted typical American construction techniques. Architekturwerkstatt Vallentin's house in Lengdorf, Germany, has an engineered-wood-joist frame, which provides a deep wall cavity for insulation.**

WALL 1

FACADE BOARD 8 MM

BATTENS/AIR GAP 40 MM

PERMEABLE SHEATHING 16 MM

ENGINEERED-WOOD JOISTS WITH CELLULOSE INSULATION 356 MM

ORIENTED STRAND BOARD 15 MM

AIR GAP 60 MM

DRYWALL 15 MM

WALL 2

LARCH WOOD SIDING 24 MM

BATTENS/AIR GAP 30 MM

PERMEABLE SHEATHING 16 MM

ENGINEERED-WOOD JOISTS WITH CELLULOSE INSULATION 356 MM

ORIENTED STRAND BOARD 15 MM

AIR GAP 40 MM

DRYWALL 15 MM

ROOF 1

PHOTOVOLTAIC PANELS

BATTENS/AIR GAP 30 MM

HORIZONTAL BATTENS 40 MM

PERMEABLE SHEATHING 16 MM

ENGINEERED-WOOD JOISTS WITH CELLULOSE INSULATION 356 MM

ORIENTED STRAND BOARD 15 MM

AIR GAP 24 MM

DRYWALL 15 MM

ROOF 2

ROOF MEMBRANE

ORIENTED STRAND BOARD 22 MM

ENGINEERED-WOOD JOISTS WITH CELLULOSE INSULATION 356 MM

ORIENTED STRAND BOARD 15 MM

AIR GAP 24 MM

DRYWALL 15 MM

Along with the intelligent positioning of overhanging balconies and wood screens, which serve as shading devices, recent advances in window technology allowed Vallentin to glaze significant portions of the south facade of a Passive House in Berlin.

International Residential Code, and the primary energy limit is one-third of the average U.S. residence's consumption. Reaching the targets usually requires wrapping the building in a thick, superinsulated overcoat; sealing it in an airtight envelope; taking advantage of passive heating and cooling; and using high-efficiency appliances and fixtures.

Although it's not a prerequisite, a trained Passive House consultant often guides the process. He or she advises on ways to meet the standard, evaluates the building using software in the Passive House Planning Package (PHPP), and prepares project documentation for final certification by the Passive House Institute. Passive House consultants are required to have a basic knowledge of building science and must complete a nine-day intensive course.

In 2008, German-born architect Katrin Klingenberg cofounded the Passive House Institute US (PHIUS) in Urbana, Illinois. Since then, the concept has gone from the green building fringes to a movement with more than 200 PHIUS-qualified Passive House consultants across the country. PHIUS has certified 13 houses to date with at least 40 more in process.

One of the projects awaiting certification is an addition to a 181-year-old farmhouse in Freeman Township, Maine, designed by New York City-based BriggsKnowles Architecture + Design. The new piece makes subtle geometric shifts and is articulated with clean, planar detailing. "The form of the house, with its simple aggregated volumes, is in keeping with the typology of this area of Maine," says firm partner Laura Briggs, adding that the design's low skin-to-volume ratio helps keep heat loss to a minimum.

A code-built house in this region typically would have walls with a thermal resistance, or R-value, of 20. The roof would be about R-38, and the basement slab around R-10. But the BriggsKnowles project has R-49 walls, a roof that is R-57, and R-74 beneath the concrete-slab floors. To reach those values, the architects used engineered-wood-joist framing filled with blown-in cellulose insulation for both the walls and the roof. Then they wrapped the entire box in 2½ inches of rigid insulation, helping to minimize thermal bridging of the more conductive wood members. Under the floor slab they placed 16 inches of rigid insulation. The amount of insulation keeps surface temperatures close to the interior air temperature, so even the exposed concrete floors, important for thermal mass, don't feel cold to the touch.

One of the biggest issues with early superinsulated houses was indoor air quality. Loose construction allows more fresh-air infiltration and helps to dissipate contaminants that "off-gas" from materials or are emitted from other indoor sources. But infiltration comes at a high price in heat loss. The Passive House system resolves this conundrum with an efficient air-to-air heat exchanger that warms or cools incoming fresh air. The BriggsKnowles team opted for a U.S.-made Energy Recovery Ventilator (ERV), which has the capacity to pull humidity from the incoming air. A simpler Heat Recovery Ventilator (HRV) can be used in climates where humidity is less of a concern. Both HRVs and ERVs need to be at least 75 percent efficient in recovering thermal energy, according to Passive House guidelines.

Letting in the light

Until recently, superinsulated buildings often had very small and very few windows, since glazing can be a significant source of heat loss. But advances in window technology have fostered the production of triple-glazed units with very low U-values (the U-value is the inverse of the R-value and describes how well a building element conducts heat). Triple-glazed units with U-values as low as 0.09 – a level unimaginable just a few years ago – are now readily available in Europe. A few North American manufacturers also make windows that meet Passive House-recommended U-values of 0.14 or less.

Swiss-born architect Tim Eian, who practices on both sides of the Atlantic, asserts that the lapse in U.S. development gave Europe a generous head start in Passive House-related technologies. By now, Europe has much

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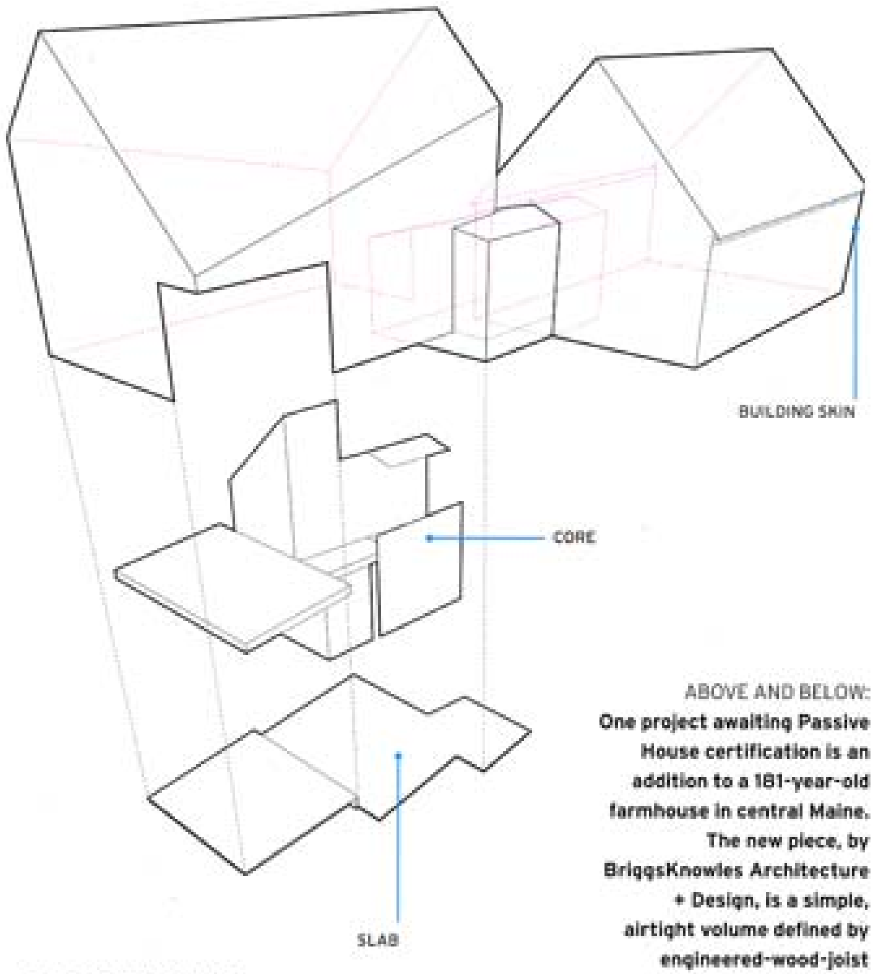
Learning Objectives

1. Discuss the goals and history of the Passive House program.
2. Outline the Passive House-certification criteria.
3. Describe the methods typically deployed for meeting these criteria.
4. Explain how the Passive House program differs from the LEED rating system.

AIA/CES Course #K1104A



ABOVE AND BELOW: **One project awaiting Passive House certification is an addition to a 181-year-old farmhouse in central Maine. The new piece, by BriggsKnowles Architecture + Design, is a simple, airtight volume defined by engineered-wood-joist framing filled with cellulose insulation and wrapped with rigid insulation.**

greater momentum, with more than 15,000 certified projects, compared with a handful in North America.

But the relationship between the continents is a symbiotic one. To facilitate high insulation levels, many European architects are turning to American wood-frame construction, using engineered-wood joists to create deeper wall cavities. Such is the case for the Dorfen, Germany-based Architekturwerkstatt Vallentin. Principals Gernot and Rena Vallentin have decided to limit their practice to Passive House designs.

A common criticism is that the standard's requirements push houses to be compact and somewhat "boxy." The Vallentins combat this tendency with subtle variations of form, color, texture, and materials. On the interior of their house in Lengdorf they take advantage of double-height spaces and carefully place windows to provide a feeling of spaciousness and balanced daylighting.

Not all Europeans are so gung ho about the system, however. German architect and structural engineer Werner Sobek advocates energy-efficient buildings that rely on active technology, allowing them to be more open and responsive to the environment. He also criticizes the Passive House standard for not considering the embodied energy in elements such as rigid insulation.

Climate adaptations

Feist initially pushed the idea of relying solely on internal gains and the HRV to heat the buildings – a viable strategy in Germany's relatively mild climate. But the United States has much more regional variation with temperature and humidity extremes. The steamy South presents one of the most difficult challenges. While the BriggsKnowles project in Maine can rely on its ERV for cooling, a project in a predominantly hot and humid climate requires a different approach. For his own Lafayette, Louisiana, Passive House residence completed last year, architect Corey Saft used

superinsulation and passive techniques to reduce heat gain.

"Shading and ventilation become crucial in this climate," Saft says. He oriented south-facing windows to take in the predominant winds on the ground floor. A bank of north-facing windows, placed high in a double-height space, takes advantage of cross and stack ventilation. All windows are protected with exterior shades and the exterior is clad with a "rain screen." In this typical Passive House detail, vertical furring strips are attached to exterior rigid insulation so that there is a gap between the insulation and the siding. The space provides a channel for water to escape. But Saft found that venting the space at both the top and bottom dissipates a substantial amount of heat. "On the south elevation I measured a 20 degree temperature drop from the siding to the insulation layer," Saft says. "The rain screen is essentially a whole house-shading device."

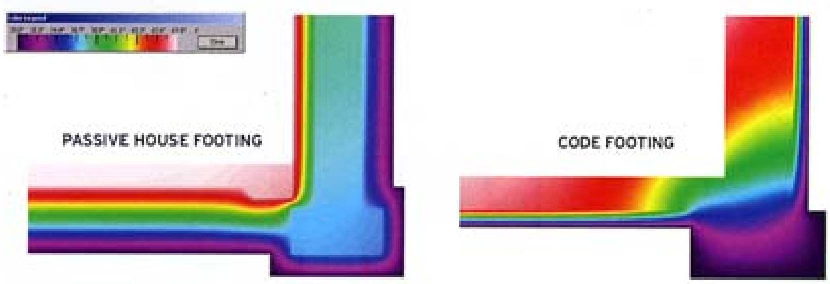
In this climate zone, the glazing should generally have a low Solar Heat Gain Coefficient (SHGC), which means

RIGHT: **Architect Brian Fuentes is building a Passive House for himself on the outskirts of Boulder, Colorado, that combines a modular straw-bale and braced-frame system with structural insulated panels.**

that the glazing is treated to limit the amount of solar heat transmitted to the interior of the building. The lower the SHGC, which is expressed as a fraction between 0 and 1, the less heat is transmitted. On the Saft house, the SHGC is around 0.29 on all windows. But a Passive House designed for New England, where heat gain is desirable for much of the year, might use glazing with an SHGC of around 0.64. Projects that maximize solar heating in the winter but control heat gain in the summer will sometimes use windows with a high SHGC on the south facade (where the windows can be easily shaded in the summer months) and low SHGC on other orientations where sun controls aren't as effective.

Foundation Thermal Study

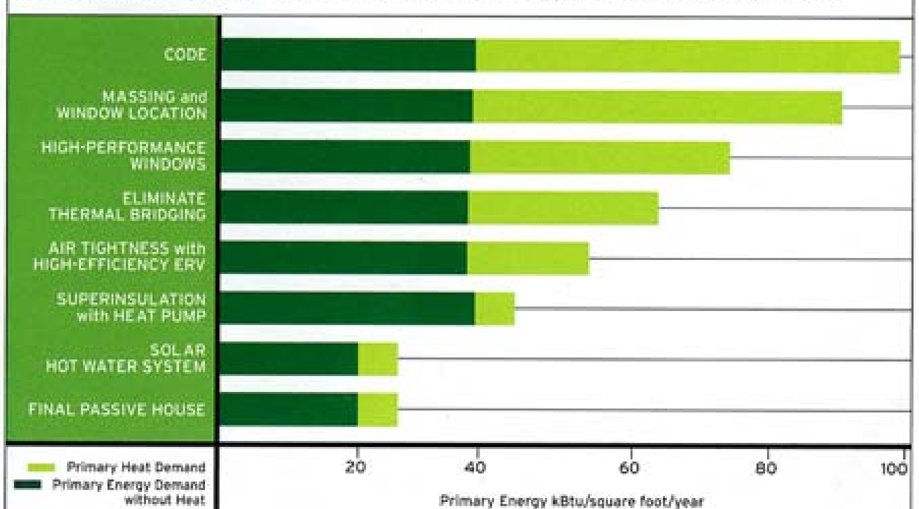
Albert, Righter & Tittmann Architects markedly decreased heat loss through the foundation of a house in Charlotte, Vermont, by providing 12 inches of rigid insulation under the slab and 10 inches along the perimeter walls.



SOURCE: ALBERT, RIGHTER & TITTMANN ARCHITECTS

Annual Energy-Use Analysis

For the Vermont project, Albert, Righter & Tittmann studied the cumulative energy savings achieved through the deployment of an array of Passive House strategies.



SOURCE: ALBERT, RIGHTER & TITTMANN ARCHITECTS

House of straw (and foam)

Boulder, Colorado-based architect Brian Fuentes has six Passive House projects on the boards, including a home he is building for himself on the outskirts of the city from the remnants of a dilapidated 1880 miner's house. He is using an unusual modular system in which straw bales are set into a braced wooden frame and arrive at the site as prefinished wall units. The roof will be made of structural insulated panels (SIPs) supported by glue-laminated beams. Since SIPs are made of solid-foam panels with sheathing bonded to the exterior surfaces, they are a good material for reducing thermal bridging. Also, because SIPs interlock at the edges, they help make the building airtight.

Unlike LEED, Passive House focuses solely on reducing energy consumption. It has no requirements for water conservation or sustainable site development, for example. Fuentes prefers the Passive House system. "LEED has done a good job of getting the idea of green building out there, but Passive House fills in the energy performance side," he says.

Instead of LEED's matrix of points, Passive House certification relies on PHIUS verification in the three benchmark areas. A blower door test is required to demonstrate compliance with the air-infiltration standard, while a software program included in PHIUS's PHPP analyzes the Btu and electrical-consumption levels. Some components such as ERVs and windows are pretested and certified by the Iinstitute. But others need to be analyzed in the PHPP. For example, BriggsKnowles verified that a specially fabricated skylight for the house in Maine was within the overall energy limits by entering the unit's specifications into the PHPP software.

The PHPP software assumes that thermal bridging will be eliminated in the details of the house. When construction details vary from the assumptions of the PHPP, consultants often rely on a supplemental program developed by the Lawrence Berkeley National Laboratory called THERM. This software measures how a particular assembly is performing in terms of heat transmission. It's also a useful tool for studying heat transfer in any exterior element, from window details to foundation designs.

Costs and benefits

Although many architects and clients have voiced concern about the costs associated with the additional materials and products required by the Passive House system, advocates say that much of the added expense of superinsulating is offset by reduced mechanical systems. In Europe, where a quarter of new residences are built to the Passive House standard, costs are now about 5 percent higher than standard construction, according to PHIUS's Klingenberg. Architect and consultant Eian estimates costs for quality construction in the United States at 10 to 20 percent more than average costs. But even at that rate, the payback period for the investment in high-performance components and insulation can be fairly short. BriggsKnowles projects a 5-year payback on the project in Maine.

The long-term affordability of the standard is reinforced by the fact that nonprofit organization Habitat for Humanity has built several Passive House projects. Boston-based Albert, Righter & Tittmann Architects designed the first modular Passive House for the organization's affiliate in Charlotte, Vermont. The house uses only 20 to 30 percent of the total energy of an average code-compliant house. To stay within the primary energy-consumption budget, the firm specified efficient appliances and fixtures. The client paid a bit more for features such as a condensation dryer. It helped conserve energy and eliminated the need for exhaust ducting, which can be a significant source of heat loss.

Passive House adherents are looking beyond new construction to the challenge of renovating historic buildings to meet the criteria. Retrofitting such structures requires finding aesthetically sympathetic methods for reducing air infiltration and adding insulation. Brooklyn-based Prospect Architecture is working to bring a 19th-century brownstone in a landmarked section of the New York City borough up to the Passive House standard.

Although Passive House has been primarily a residential program, it's spreading to other building types in the United States. Two schools have recently been completed on the East Coast and an office building for a farm workers union is on the boards at Green Hammer Design & Build in Portland, Oregon. In Europe, Passive House reaches into all building categories, including educational buildings, multifamily housing, and factories.

A resolution passed by the European Union's parliament calls on member states to require that all new buildings meet Passive House criteria beginning in 2012, bolstering growth of the standard. Although the system is still in its infancy in the United States, the recent flurry of Passive House projects is already proving that it's possible to dramatically reduce energy consumption and greenhouse gas emissions at a reasonable cost. ■

Michael Cockram is an architectural designer, educator, and writer who focuses on the environment.

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