

The logo consists of the letters 'PHB' in a bold, sans-serif font. The 'P' and 'H' are teal, and the 'B' is orange. They are set against a white background that is part of a larger graphic element.

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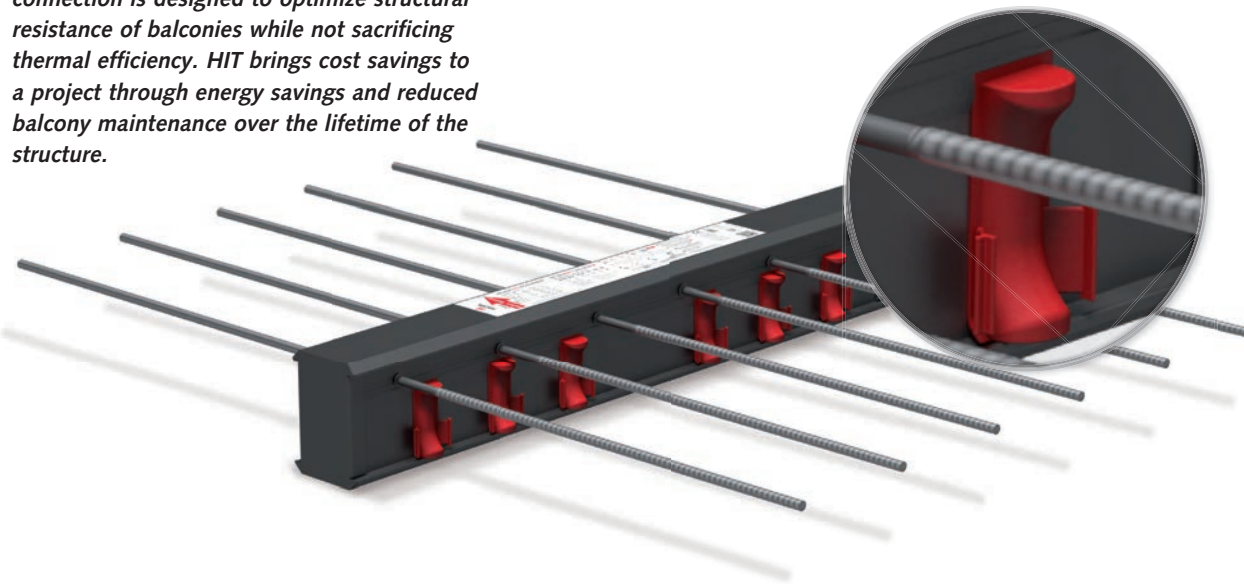
A teal-colored rectangular box containing the text 'Spring 2018' in white, sans-serif font. The box is positioned in the lower right area of the image, overlapping the building and the foreground.



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Cover: Pax Futura; Rendering courtesy of NK Architects

## EDITORIAL

As 2018 begins, the world feels pretty chaotic, and yet predictable—with drought, fires, and mudflows wreaking havoc in my home state of California. I say predictable because we are experiencing exactly what the climate models have been forecasting for some time: more extreme weather events of all sorts. I doubt any of us needs reminding that the climate clock is ticking more loudly and more urgently with each passing year, month, day.

Scaling up carbon-sipping buildings is one key to maintaining any shred of climate sanity. That's why we are thrilled to keep reporting on Passive House progress. From ever-larger Passive House high-rises (Rising Towers in Vancouver, p. 8) to commercial-building retrofits (New Training Center in Northeast, p. 34) to single-family homes in challenging climates (Low-Carbon Living at Nordeast Nest, p. 44 and Bringing Comfort and Efficiency to the Dallas Market, p. 64), each project in this issue delivers insights that can be applied and reapplied.

Not surprisingly, there are some promising developments that didn't quite make it into the pages of this issue and yet deserve mentioning. In 2017 California joined the ranks of states that award points in their Low Income Housing Tax Credit applications for meeting Passive House certification requirements (see Passive Affordable Housing—In a Growing Number of States, *Passive House Buildings: North American Highlights 2017*, p. 11). Further north, Oxford County in Ontario, Canada, is offering a similar financing carrot to developers of affordable multiunit housing that meet Passive House requirements. This tactic definitely scores as a scalability incentive.

Whether you're designing, renovating, building, or consulting on a Passive House project, we hope you can find news you can use in our Building Science section. Get some perspective on kitchen ventilation controversies, discover a new approach to delivering cooling, and figure out how to securely affix cladding over thick layers of insulation. Passive House is deeply rooted in building science, which, like all sciences, is ever evolving.

To help us stay up to date, keep your project, industry, and research news coming across our desks; e-mail us at [passivehousebuildings@gmail.com](mailto:passivehousebuildings@gmail.com). We are always interested in hearing from our readers, and so are our sponsors. Be sure to let them know that you learned about them in the pages of *Passive House Buildings*.

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# CANADIAN Take on *Energiesprong*



Photos courtesy of CanmetENERGY, Natural Resources Canada

In Canada, buildings are responsible for about 18% of the nation's carbon emissions, with residential buildings making up 10% of that total. As Mark Carver, project officer with Natural Resources Canada (NRCan), says, "That's an opportunity."

The opportunity to retrofit existing housing, though, hasn't been taken up as enthusiastically as it needs to be to meet the federal government's climate goals. NRCan has been incentivizing home retrofits for the last decade, says Carver, with some successes. However, only about 4% of the retrofits involved adding on insulation from the exterior to sharply reduce a home's heating-energy use. "Generally speaking, these are expensive interventions

that are seen as having a low return on investment," says Carver, "and they can be disruptive."

But then he heard about the energiesprong approach, first pioneered in the Netherlands, which uses panelized components added on to the exterior of a house to drive down the cost and time required for deep energy retrofits. "They've made a lot of progress in squeezing the cost down from 140,000 Euros per unit to about 60,000," he says. The time required to implement a deep energy retrofit of a typical row house in the Netherlands has also dropped, from about ten days to as little as one day.

Energiesprong has been the inspiration for NRCan's Prefabricated Exterior Energy Retrofit (PEER) project,

which Carver heads up. The project's overarching vision is to enable the Canadian manufacturing and renovation industries to commercialize new prefabricated façade retrofit technology, according to Carver. "We are borrowing where possible from the energiesprong approach and adapting where needed to a Canadian context: our climate zones, our industry, and our building traditions," he says.

Since PEER started up in 2016, the team has convened an industry working group, and they jumped a bit ahead of their time line to complete their first pilot late last year. "We decided we needed to get our hands dirty," says Carver.

The research group started with a very small building—actually a construction trailer in NRCan's CanmetENERGY complex in Ottawa. Although small, it has all the requisite components that would need addressing: walls, windows, doors, and service penetrations. They scanned the building using a 3D laser scanner and imported the information into a building information modeling (BIM) software program. Using that information, they fabricated two types of panel in an NRCan lab facility and attached them to the trailer. Having put moisture sensors in the panels, they will be comparing cost, buildability, and moisture performance of the two different assemblies.

One panel type looks like a structural insulated panel wall, but instead of having two OSB skins, it only has one on the exterior. On the interior is a low-density fiber insulation, such as fiberglass or mineral wool, that is compressible enough to be able to conform to a building's

surface irregularities. They installed a 2 x 10 rim board at the top and bottom of the nail base to give the panels enough rigidity so that they can be hoisted into place by a crane. The other panel type is a conventional wood frame panel. In the pilot, it is a 2 x 4 panel that is stood off from the existing building by about 5 inches. The required R-value is achieved by filling both the stud cavities and the standoff cavities with dense-packed fibrous insulation—fiberglass, mineral wool, or cellulose—that is installed on-site through predrilled holes.

Carver and his team are pleased with how their pilot process went and are refining the designs of the assemblies with an eye to scaling up their pilot. Just as in the Netherlands, social housing is a likely catalyst market, because of the uniformity of the housing units, according to Carver. And because of the scarcity of affordable housing units, no one wants to move out, even temporarily. "Housing providers can't displace tenants in affordable social housing, so a retrofit that can happen from the exterior makes sense," he adds. There are roughly 650,000 social housing units in Canada, of which 100,000 are three stories or less, making them good candidates for this approach.

In 2018 the PEER team will continue to collaborate with their industry working group to identify manufacturers who would be interested in these opportunities. They are also working with building capture specialists to perfect that process—and looking toward 2019 for the potential launch of a larger pilot program.

—Mary James



# Rising Towers in VANCOUVER

The latest entry in the world's tallest Passive House competition will be a standout—and not just because of its height. The Vancouver-based project, known as 1400 Alberni, is being designed by Robert A.M. Stern Architects, renowned for its modern take on classic building styles. Clad in a traditional stone veneer, two tow-

ers, one 43 and one 48 stories, will flank a smaller connecting building and courtyard. At 650,000 square feet (60,387 square meters) and roughly 400 units, the project will be the largest Passive House in Canada by a huge margin.

The property, which will also include a 10,000-ft<sup>2</sup> day care and a new park, is being developed by Landa Global Properties and being built by Asia Standard Americas. The developers committed to achieving the Passive House standard, says Eesmyal Santos-Brault, CEO of Recollective Consulting and the sustainability consultant for the 1400 Alberni project, because they wanted its brand recognition and all that the brand implies—superior comfort, indoor air quality, and efficiency. City regulations favoring achieving Passive House levels of efficiency were also a big impetus. And cost estimates showed that the



Renderings courtesy of Landa Global



price gap between meeting minimum city requirements and the Passive House standard was small.

Santos-Brault and the design team have devised building assemblies that are technically feasible and consistent with the Passive House requirements, but at press time the design was still at an early stage, and the details were in flux. “To a large extent the mechanical system requirements will drive the design,” says Santos-Brault. Because the building is so large and relatively dense, heating won’t be a primary concern. He hopes to use air drawn through an earth tube adjacent to the parking garage to pretemper the ventilation air, reducing

both the heating and cooling loads. Together with high-efficiency heat recovery ventilation, this system is expected to operate with minimal supplementary heating.

“We are more likely going to be maxing out on the cooling load,” Santos-Brault says, “so we are more concerned about designing not to overheat.” The building’s classic facade, with its smaller window-wall ratio than is found in many of Vancouver’s all-glass towers, will be a plus when it comes to hitting Passive House performance targets.

Primary energy is also a concern, says Santos-Brault, as he tries to estimate the types and numbers of plug loads per unit. He has talked about possibly installing kill switches in each unit that will turn off nonessential electric loads with just one master switch.

Santos-Brault hopes that this project will be a trend setter in redefining the typical Vancouver tower. The city of Vancouver is encouraging and requiring higher-performance buildings, but at the same time approving the construction of towering glass boxes. That’s a real contradiction, he says. He is excited to be working on a project that is embracing both a new form and a star quality of performance.

—Mary James

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# Pursuing PASSIVE

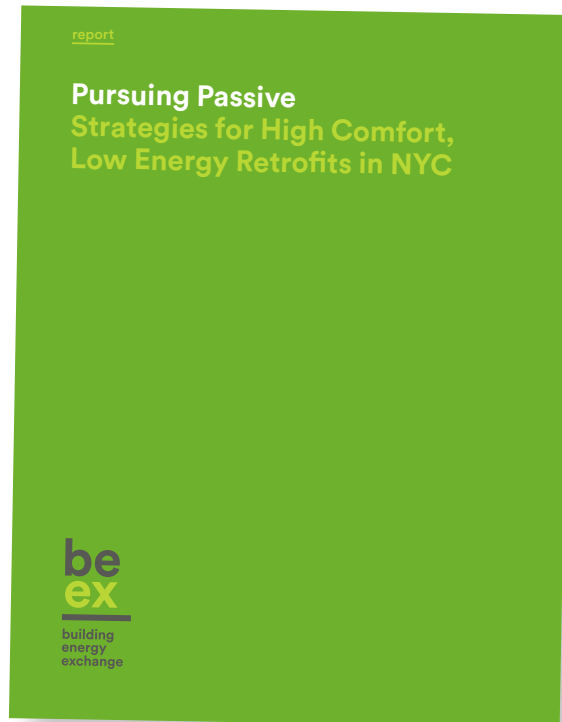
Eschewing the ostrich stance, New York City has set assertive targets to reduce carbon emissions by 80% by 2050. Given the city's density, that goal roughly translates into cutting carbon emissions from buildings by 60%. Achieving those reductions will require highly efficient new and existing buildings. Stepping in with some very practical guidance is the Building Energy Exchange (BE-Ex), a New York City-based nonprofit that supports energy efficiency in buildings through research, education, and exhibits on display in its Manhattan resource center. BE-Ex is releasing a report in early 2018 titled *Pursuing Passive*, detailing the steps required for a deep energy retrofit of a typical New York City multifamily building.

In partnership with the PHI, in Darmstadt, Germany, and Steven Winter Associates, in New York, BE-Ex chose to study an existing 16-story masonry building in Brooklyn that has 163 units and was built in 1950. It has a 21% window-wall ratio and zero insulation in its walls. Yes, that's right, zero. "The building we selected is typical of postwar construction that is taller than seven stories," says Yetsuh Frank, the managing director for strategy and programs at BE-Ex. There are estimated to be more than 300 million square feet of multifamily buildings that fit this profile, nearly 6% of all New York City buildings.

BE-Ex analyzed the strategies and construction methods needed to attain EnerPHit certification for the building, along with how the retrofit could be phased. As housing is always at a premium in New York, all retrofit measures would have to be implemented with the tenants in place.

The advantages and disadvantages of adding insulation from the exterior or the interior are covered in the report. Essentially, insulating from the interior is possible but not practical, as this work could only be done when units became vacant, and this approach doesn't solve the primary thermal bridge issues of the existing building. Insulating from the exterior would create much less disruption. The big disadvantage of the exterior approach is the expense of erecting scaffolding for a 16-story building.

The good news from the PHPP model is that adding only 2 inches of exterior insulation and replacing the poorly performing windows would trim the building's energy use by two-thirds. With 858 windows in the

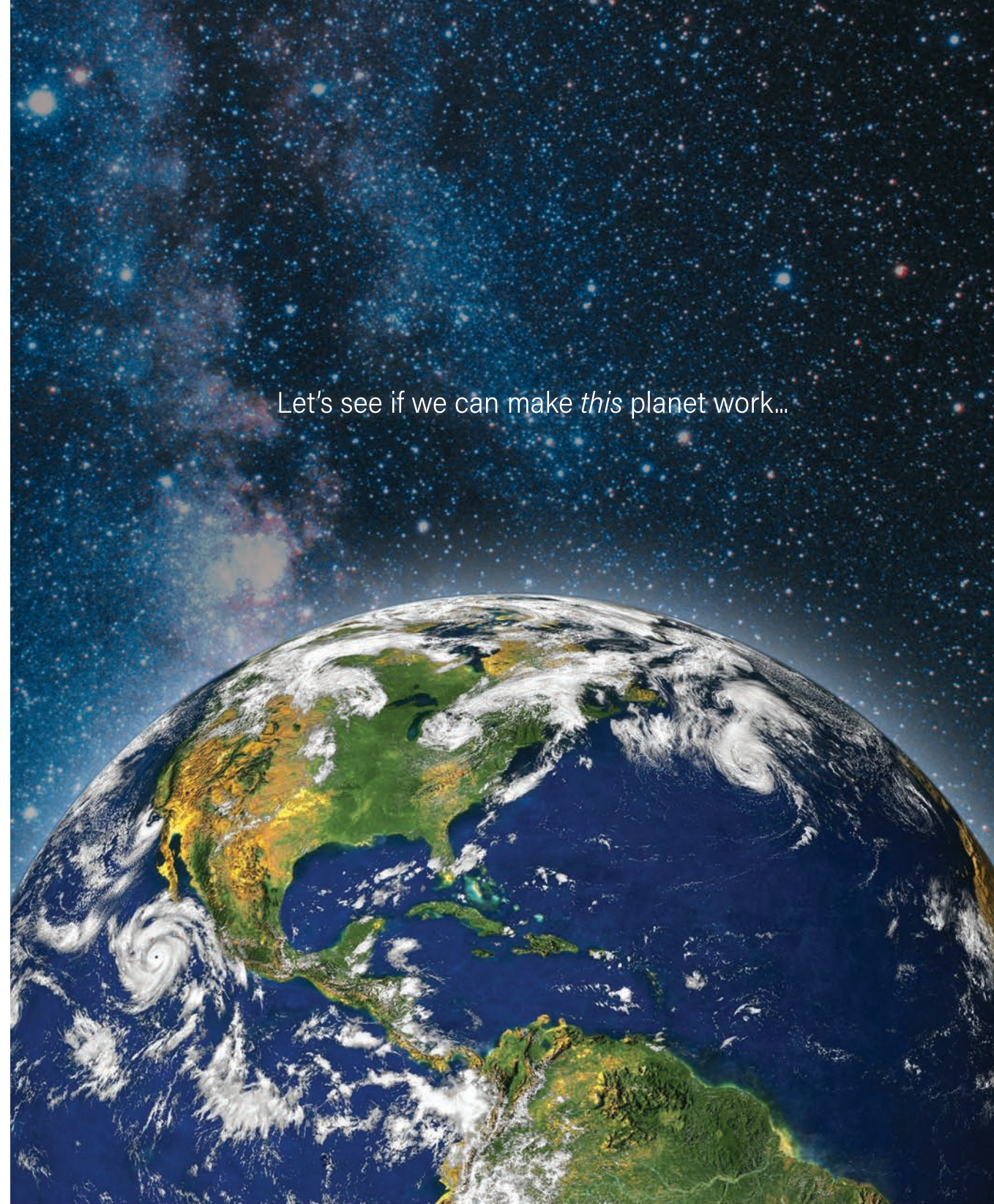


building, that cost would not be inconsequential, but triple-glazed windows with high-performance frames would bring multiple benefits, including greatly enhanced comfort for the occupants.

Heating and domestic hot water are currently supplied by a central steam plant, with hot water piped through the building 24/7. "Even if you meet the heating demand targets of Passive House with an improved envelope, this heavy hot water load swamps the primary energy cap," says Frank. Cooling by window air-conditioning units doesn't help either. Fortunately, the envelope improvements would reduce loads enough to make way for HVAC updates, such as possibly a variable refrigerant flow (VRF) system that could provide both heating and cooling. Ventilation could be supplied either by a centralized system, repurposing the existing exhaust shafts, or by new in-wall units for each apartment distributed at the perimeters.

The study is intended to provide a playbook of the different upgrade strategies and phasing options, while indicating some basic capital planning options for interested owners. Retrofit costs have been estimated, but at a fairly high level, says Frank, since real costs in New York City are highly dependent on labor costs, which can fluctuate widely. "If the study results in useful guidance for this segment of the building sector, we hope to do similar studies for different building typologies," says Frank.

—Mary James



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# Is Efficiency Dead?

## *Passive House's Role in the CLEAN-ENERGY REVOLUTION.*

Despite the best efforts of the fossil fuel industry and its friends in the White House, the clean-energy revolution is upon us and gathering steam. It's exciting stuff—a steady drumbeat of tech breakthroughs, record-breaking deployment rates, and free-falling prices. We're entering a time of exponential change and smashed assumptions about our energy system, our energy consumption, and the prospects for solutions to the global climate crisis.

But as this clean-energy revolution unfolds, what does it mean for energy efficiency in our buildings? If it becomes cheaper to slap solar panels onto a building than to insulate and air seal it, does Passive House even make sense as a climate action strategy? Should we ditch energy efficiency for clean energy?

This binary, either/or view of clean energy versus efficiency presents a false dichotomy. In fact, building energy efficiency has never been more relevant than it is today. Let's take a look at why, as viewed through a series of lenses.

### THE WIDE-ANGLE LENS

While in many ways the climate crisis is wickedly complex, climate math is pretty simple, at least as it relates to energy. Japanese economist Yoichi Kaya has described carbon emissions as a product of four factors: population,

We also know that global population will rise in coming decades, likely to somewhere north of 9 billion people. We also hope, if we care about economic justice, that GDP per capita will increase as hundreds of millions of people around the world rise out of poverty. So the first two factors in our emissions math will be increasing, not decreasing. That puts a lot of pressure on the last two factors—energy intensity and carbon intensity. Eventually, one of these factors will need to hit zero in order for emissions to zero out, and the only factor for which that is technically possible is carbon intensity. But we don't have a lot of time to wait for that to happen. We need to see both energy intensity and carbon intensity decrease rapidly if we are to have any hope of slashing emissions by 50% per decade. We need to deploy deep energy efficiency and renewable energy wherever we can, as soon as we can. We need Passive House buildings all over the place, and solar panels covering them.

Research findings from the Grantham Institute of Imperial College London; Carbon Tracker Initiative; DNV GL—a global assurance and risk management company; and the Energy Transitions Commission all concur: There is tremendous potential for clean energy to propel us toward our Paris climate goals, but without deep energy efficiency in our buildings, we will likely miss the mark.

When it comes to clean energy and Passive House, it's not either/or, it's both.

### THE POSITIVE CASH FLOW LENS

Let's zoom in from the macro scale to the micro—the individual building site—and get right to the critique that practically every Passive House practitioner has heard. In the binary view of renewables versus efficiency, the argument against efficiency is that it's too expensive. Never mind that according to the independent think tank

Pembina Institute, the average construction cost premium of Passive House projects is 6%, or that data from the Pennsylvania Housing Finance Agency suggest that this premium could be as low as 2% for multifamily buildings (see Figure 2). With up-front costs as low as 2%–6%, ongoing utility bill savings can offset the bigger mortgage or construction loan required to fund Passive House construction. Passive House can be cash flow positive from day one of occupancy.



FIGURE 1.

gross domestic product (GDP) per capita, energy intensity of the economy (per unit of GDP), and carbon intensity of that energy (emissions per unit of energy consumed) (see Figure 1).

We know that to reach the goals of the Paris agreement (limiting warming to well below 2°C), global carbon emissions need to peak by 2020 and then decrease by 50% by 2030, decrease by another 50% by 2040, decrease by another 50% by 2050, and so on. No small task.



Rendering and all graphics courtesy of NK Architects

Moreover, policy mechanisms like PACE (property assessed clean energy) financing can eliminate the split-incentive problem. A building owner can invest in Passive House performance, and the debt service for that investment remains with the property itself. Future buyers enjoy the benefits of Passive House and take on the loan payments—again, all cash flow positive. Why not make the investment, create a better building, and enjoy positive cash flow? You can do the same with solar panels, if you like.

When it comes to positive cash flow and Passive House, it's not either/or, it's both.

### THE NET ZERO SITE LENS

A popular way of thinking about buildings and climate change is through a net zero lens. Over the course of a year, you generate as much renewable energy on site as your building consumes, on a net basis. In the summer, your building is a net producer, and in the winter it's a net consumer. Can you just call it good? Well, no, actually, for a couple of reasons.

In northern settings, and particularly in northern urban settings where both space and solar access are limited, the quick and easy argument for energy efficiency in net zero projects is real estate. There simply is not enough roof area on a typical two-story home in Seattle, for example, to achieve net zero energy

performance without Passive House levels of efficiency. The same is true for multifamily buildings in Seattle: The only route to a four-story net zero apartment building is deep energy efficiency (see Figure 3).

If, however, your building is in suburban California, where both space for on-site solar panels and insolation

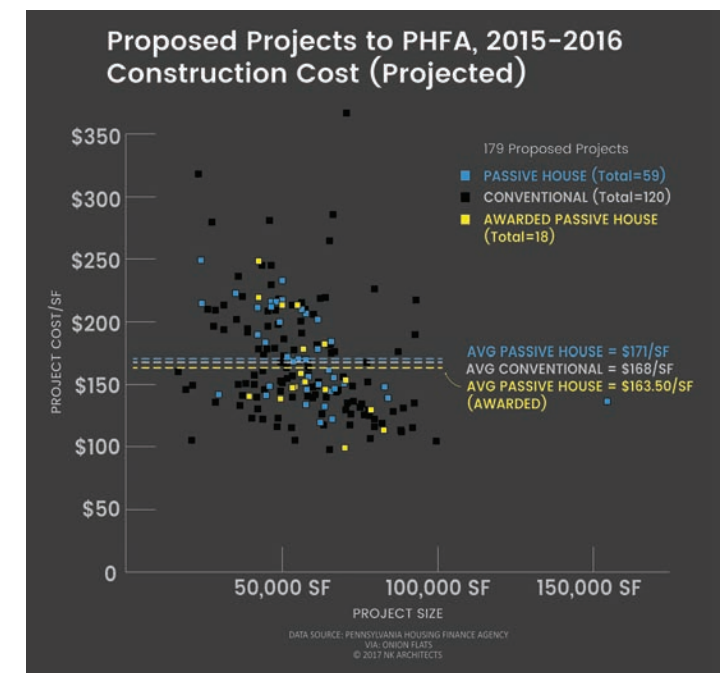
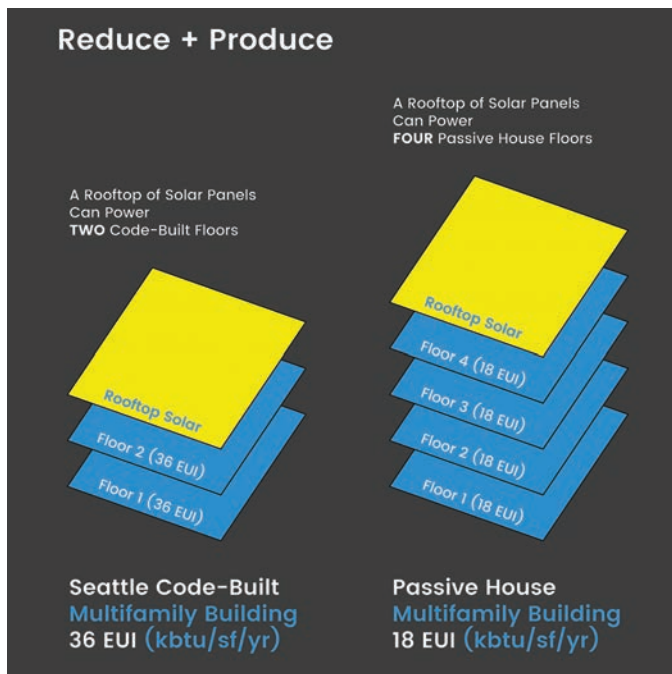


FIGURE 2.





**FIGURE 3.**

for those panels is plentiful, deep efficiency may not be necessary in your net zero energy math. You might think you can get away with a pretty mediocre building and make up the difference with cheap solar panels. Not so fast. There's something called the Duck Curve.

Graham Irwin, of Essential Habitat in Fairfax, California, was among the first in the Passive House community to write about the Duck Curve, a daily dynamic in California energy markets that net zero energy buildings might worsen. Happily, so much solar energy is being deployed in California that demand for nonsolar energy during the sunniest part of the day is approaching—sometimes even reaching—zero. (This dip in demand is the belly of the “duck.”) The problem is that in early evening, just as people arrive home and power up their houses and HVAC systems, the sun goes down and all that solar energy disappears from the grid. This one, two punch of the drop in solar energy and spike in home energy consumption causes demand for nonsolar energy to ramp up extremely rapidly. (This spike in demand is the neck of the “duck.”)

Carbon-intensive peaker plants have to kick in to supply this evening energy demand, negating much of the emissions benefit of net zero energy buildings' rooftop solar systems. The power of Passive House design is that it turns your building into a virtual thermal battery, maintaining even interior temperatures throughout day and night with almost zero energy input. If more buildings in California were Passive Houses, fewer households would be powering up their HVAC

systems in early evening, and that spike in demand for dirty energy would flatten out the neck of the “duck” every day. As more utility-scale battery storage facilities come on line, and as behind-the-meter home battery storage becomes cheaper, that will further flatten the “duck.”

When it comes to rooftop solar and Passive House, it's not either/or, it's both.

**THE SEASONAL LENS**

Exciting as batteries are for both grid and home energy storage on a daily basis, they are ill equipped to deal with the seasonal intermittency of solar energy. One of the trickier clean-energy puzzles that humanity will need to tackle is how to power northern climates during the winter. Part of the solution will be more widely interconnected energy grids, so that southern sun can provide northern supply. Part of the solution will be wind and hydro. Another part of the solution will be power-to-gas, where

excess solar energy produced wherever and whenever it is most plentiful is used to split water into hydrogen and oxygen, and that hydrogen is stored as fuel. But another key part of the solution lies in our buildings, because the thermal battery of deeply energy-efficient buildings is perfectly suited for seasonal storage. By dramatically reducing winter heating load, Passive House buildings could play a starring role in solving the northern winter load conundrum.

When it comes to a clean winter grid and Passive House, it's not either/or, it's both.

**EFFICIENCY IS THE ULTIMATE DISTRIBUTED-ENERGY RESOURCE**

The core reason that deep energy efficiency is likely to remain centrally important both to the clean-energy transition and to global climate action is that it is the ultimate distributed-energy resource. Not only can energy efficiency be deployed virtually anywhere, but that efficiency performs best exactly when it is most needed—during peak demand. Energy efficiency flattens out the peaks and valleys of demand, both on a daily and on a seasonal basis, making it more practical to fill in the gaps with renewable energy, battery storage, and demand response.

Not only is Passive House still relevant in these early days of the clean-energy revolution, but it will support the revolution's future success.

**ZACK SEMKE** is chief marketing officer at Nicholson Kovalchick Architects in Seattle, Washington.

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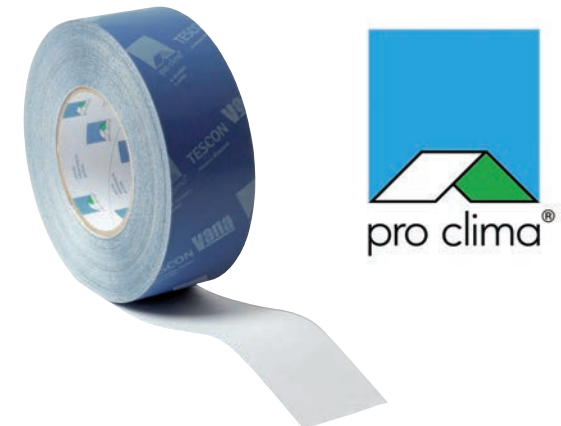
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*Rural Build rendering by Jeff Brink*

# The RURAL Build

**B** arlisWedlick Architects has been working on custom residential commissions in New York's Hudson Valley for 25 years. In 2010, we designed the first Passive House project in the state, the Hudson Passive Project. The lessons we learned designing that home inspired a new optimism for the possibilities of our work to significantly contribute to the need for greater energy conservation. Columbia County Habitat for Humanity, our local chapter, came to us in 2011 to hear more about the energy-saving possibilities of Passive House. Together, we realized that the very low energy requirements of Passive homes could provide a new avenue of affordability for the homes in our community.

Through our six-year collaboration with Habitat, we have completed three two-family projects. With each of our building projects, we have made adjustments to our home design to address unique site conditions, to increase the energy efficiency of the homes, and to improve the economy of the build. Each project has employed the Passive House principles of a compact form and a superinsulated and airtight envelope. We've tested various building assemblies to identify the most cost-effective approach, while also testing various approaches to the mechanical systems. Throughout this process, we have pursued the highest level of building energy efficiency possible, while maintaining an approach that maximizes the participation of volunteer builders and keeps our construction budgets low.

In December of 2017, two new families moved into our fifth and sixth Passive Houses. These homes, built in Valatie, New York, represent the evolution of our design studies and testing. But six homes do not come close to meeting the need for affordable housing in our region. Our next step to meet this demand is to expand the impact and reach of the Habitat model by growing a network of volunteer professionals and partners to provide more homes at a faster rate. What we've named

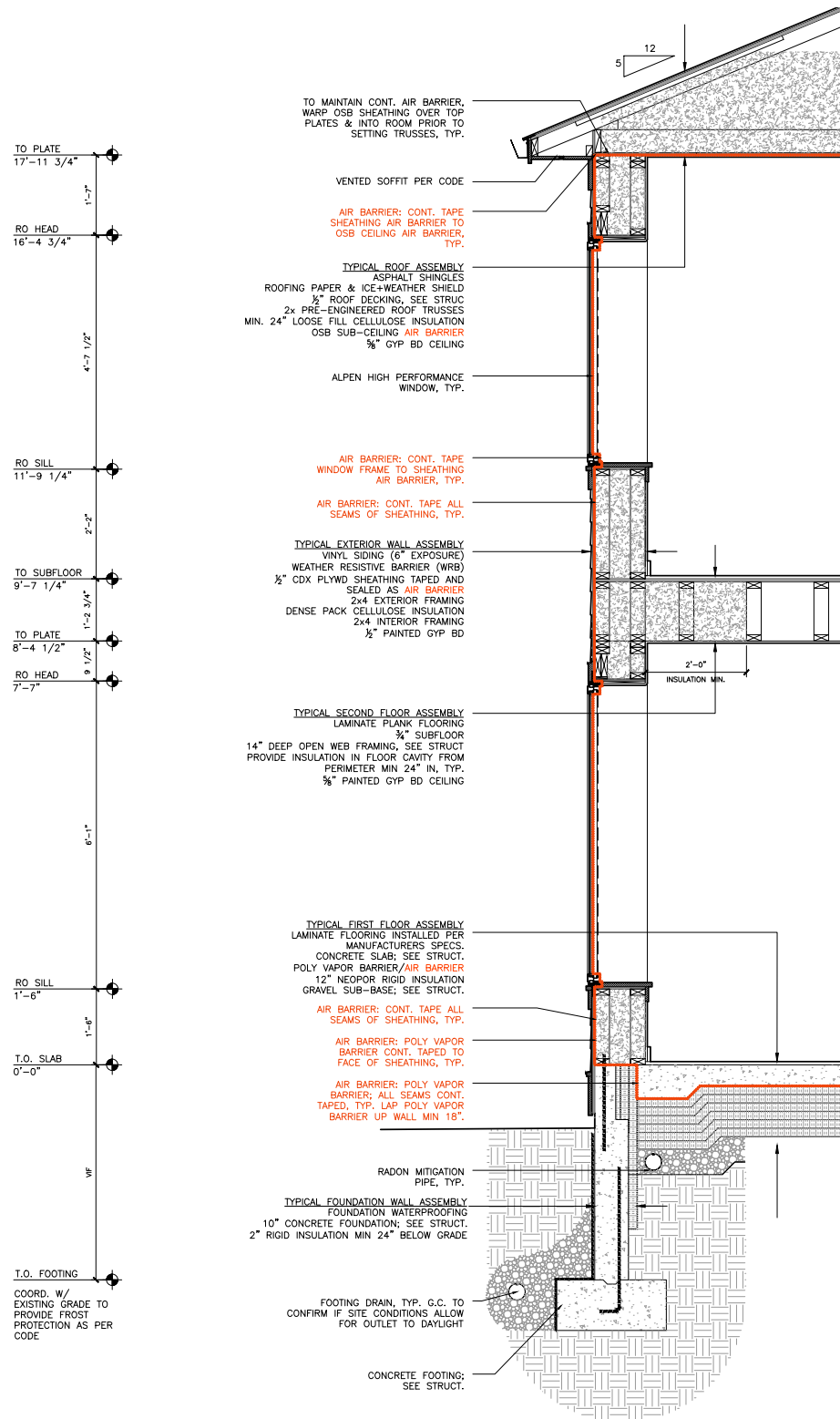
The Rural Build is our effort to take what we've learned through our Habitat for Humanity work and share it with like-minded landowners, architects, and builders in the hope of persuading more community members to join us.

Each of our recent homes is a two-story, three-bedroom house of about 1,300 square feet, built in a side-by-side configuration like a townhouse. The exterior wall assemblies include a 12-inch-thick double-wall construction with 3 inches of sprayed-foam insulation at the exterior sheathing and a cavity filled with dense-packed cellulose. This double-wall assembly was found to be most economical, as it leveraged the volunteer framing crews and allowed the electrical install to be done using a conventional construction approach. Large casement windows with a high R-value were set in a proprietary sheathing system for a continuous, airtight assembly.

The roof system relies on engineered roof trusses, also insulated with cellulose. Parallel chord floor trusses complete the building's frame. The mechanical systems in this all-electric home include a single wall-mounted mini-split, an ERV for fresh-air intake and exhaust, and a high-efficiency water heater.

With these common building components, properly designed and constructed to meet Passive House metrics, Habitat is able to economically provide new, low-maintenance homes. The utility costs are a rather constant \$40 a month—a reasonable amount that also relieves families of the burden of winter heating-cost spikes.

The Habitat model, together with the generous community support from volunteers and donors, enables Habitat to sell the Passive homes we developed for it at a cost totaling about \$800 a month, including mortgage costs, taxes, insurance, and those low utility costs. In our community, where the median home price is about \$250,000 and where most of the more-affordable homes require significant investments for maintenance and



1 WALL SECTION @ SOUTH WALL



BarlisWedlick Architects' first Habitat project; photo by Ber Murphy

heating costs, it is common for families with modest incomes to pay well over 30% or 40% of their income for housing. These families are Habitat's applicants. They are households earning less than \$44,000 annually, and households that can least afford an unanticipated home repair or a spiking heating bill. The affordability of the Habitat homes has a game-changing impact on these families' domestic budgets by freeing up some income for a variety of other needs.

We are struck by the tremendous benefits and economic advantages that this Passive House model provides for families with modest incomes. Unfortunately, many of the jobs in our community do not provide an income commensurate with the cost of living here. Just 100 miles from New York City, this area is a popular weekend destination for New Yorkers who buy second homes here, driving up land and housing costs. Due to this dearth of affordable housing in our region, we are facing a declining population. A great effort is required to preserve our agrarian economy, which, in turn, will preserve the beautiful, historic, and pastoral landscape of the Hudson Valley.

**ARCHITECT AND CERTIFIED PASSIVE HOUSE CONSULTANT MARC BAILEY** established the Hudson River Studio—BarlisWedlick's office in Hudson, New York—in 2007.

**Passive House Metrics**

Heating energy	Cooling energy	Total source energy	Air leakage
2.1 kBtu/ft <sup>2</sup> /yr	0.18	43.7	0.87 ACH <sub>50</sub>
0.6 kWh/ft <sup>2</sup> /yr	0.10	12.8	
6.5 kWh/m <sup>2</sup> a	0.60	138.0	

**Products**

**Windows**  
Alpen HPP

**Air/Moisture Control**  
Siga

ZIP System Sheathing and Tape

**Ventilation**  
Zehnder America



# Embracing CLIFFSIDE Challenges

**P**lacetailor, a cooperatively owned design and development company in Roxbury, Massachusetts, thrives on challenges. Developing and designing high-performance spec housing is par for its course, with roughly two dozen units completed in Roxbury. Even with this experience, the site where its five-unit Fort House development is now rising at first seemed to be unbuildable, says Travis Anderson, design director. The very steep site was dominated by a 30-foot retaining wall, a veneer shoring up a cliff of Roxbury pudding stone. With analysis, Placetailor determined that the lot was in fact buildable, just a bit more risky than your average spec Passive House development.

The five roughly 1,200-ft<sup>2</sup> units are designed to take full advantage of the site's slope, with bedroom areas generally on lower floors and the kitchen, dining, and living areas on the upper floors to soak in the sweeping views. Three of the units are townhouses with dramatic views westward toward rolling hills. The maisonette on the north end will house two units in its massing, and its

penthouse unit will provide views of the Boston skyline.

The other four units have their own versions of penthouses—small enclosed head houses that afford access to the roof deck. The head houses' fixed 3 x 8 south-facing windows will act as light scoops for the stairway and hall below and capture solar gain, contributing significantly to the overall energy balance.

Making a functional roof deck required designing a flat roof assembly—a new approach for Placetailor. The assembly is being constructed using 2-foot-deep open-web joists. Two inches of polyiso above the sheathing will prevent condensation problems. The cavity will be filled with loose-fill cellulose, achieving an R-value of 84.

Placetailor is acting as green building consultant, codeveloper, design collaborator, and general contractor on this project, with assistance from business partners Colin Booth and Grant Scott. With its team of five architects or designers and a construction crew of eight full-time carpenters, Placetailor typically tackles all aspects of design and construction in-house. However,



Rendering courtesy of Placetailor

for this project it brought in a structural engineering firm to help design a foundation and retaining wall that required 8- to 12-foot footings. “We lucked out with the overall soil conditions and location of the ledge under the foundation,” says Anderson. No further anchoring or pinning was needed.

The foundation consists of interlocking ICF blocks with 2½ inches of foam on both sides of the reinforced-concrete wall in every block. This system has several advantages, of which the biggest is that Placetailor's own crew can install the blocks with no need for an outside concrete contractor.

The 15-inch-thick, double-wall assemblies, insulated with dense-packed cellulose, will deliver an R-value of 56. A rain screen gap will keep bulk water out of the assembly, and a membrane on the interior surface of this gap will serve as both a weather-resistant barrier and the air barrier. The rain screen gaps are being built using furring strips of varying thicknesses to create texture and shadows in the facade. A mixture of cedar shake, cedar lap

siding, and fiber cement board adds to the visual interest.

This type of wall construction has worked reliably for Placetailor in many projects. “We have built these walls a number of times over the last eight to ten years,” says Anderson, “and we’ve never had moisture or durability problems.” Placetailor also doesn't have problems hitting its airtightness targets, reliably achieving 0.3 to 0.4 ACH<sub>50</sub> in its housing units. However, even its standards don't stay standard for too long. “We are always looking at ways to make efficiency improvements,” he adds.

Comfort will be maintained by mini-split heat pumps. Each home will have two evaporator heads, one on the middle floor and one on the top floor. Each unit will also have its own high-efficiency HRV located on the middle floor. Water heating will most likely be supplied by a hybrid heat pump water heater.

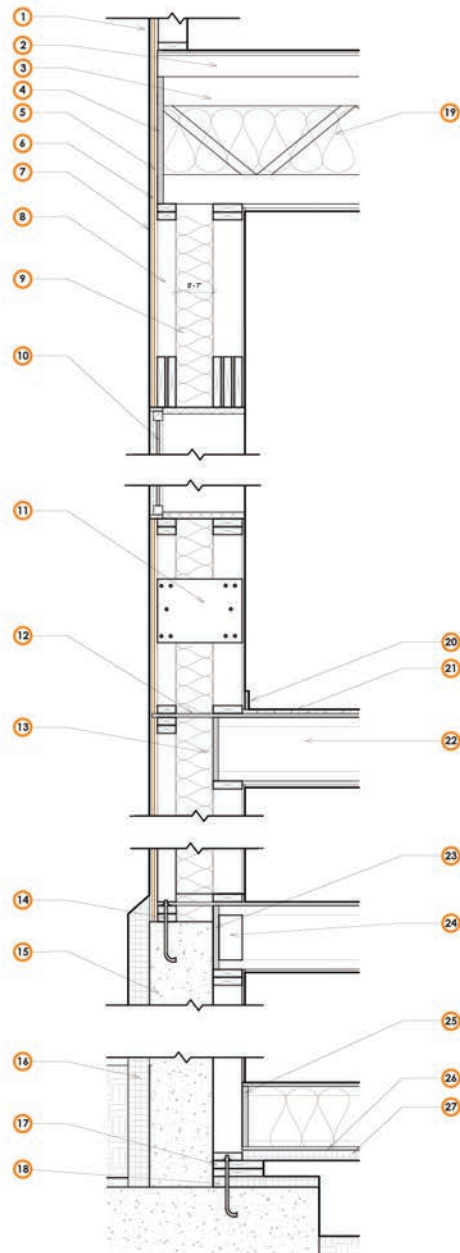
Musing somewhat wistfully on the year-round comfort that these units will provide, architect and Placetailor co-op owner Miriam Gee says, “We design and build spaces that we would all love to live in.” She adds that Placetailor

also aims to keep the total costs reasonable enough—very roughly around \$200 per square foot—that the mortgage needed to buy one of its units would be within reach for all of them.

Indeed, Anderson is counting himself among the lucky ones; he recently moved into a Placetaylor home—a customized, ground floor unit in a four-family building called Copeland Park. He, his wife, Marisa, and their baby, Simone, are the first Placetaylor family to move into a Placetaylor home. They are excited to be the guinea pigs



Rendering courtesy of Placetaylor



- 1 PARAPET
- 2 2" POLY ISO
- 3 24" OPEN WEB TRUSS JOIST @ 24" OC
- 4 1 1/8" TIMBERSTAND LSL RIMBOARD
- 5 7/16" CDX PLYWOOD SHEATHING
- 6 SIGA MAJVEST VAPOR BARRIER
- 7 CLADDING
- 8 2 X 4 KD DOUBLE STUD WALL WITH 7" SPACE @ 24" OC
- 9 R56 DENSE PACKED 4 LB CELLULOSE INSULATION
- 10 SHUCCO TRIPLE PANE LOW-E TILT-TURN WINDOW
- 11 7/16" OSB 12"X16" GUSSETT PLATE
- 12 3/4" ADVANTECH SHEATHING SPANNED FROM JOIST TO EXTERIOR OF DOUBLE WALL
- 13 1 1/8" TIMBERSTAND LSL RIMBOARD
- 14 1/2" 36 ROD EVERY 36"
- 15 12" CONCRETE RETAINING WALL
- 16 4" POLY ISO
- 17 2X10 PT SILL PLATE
- 18 HIGH LOAD THERMAL BREAK 2" FOAMGLU
- 19 24" LOOSE FILL CELLULOSE R83
- 20 1X4 HARDWOOD BASEBOARD
- 21 3/4" HARDWOOD TOUNGE AND GROOVE FLOORING
- 22 11 7/8" TJI 230 (TYP) @ 24" OC
- 23 1 1/8" TIMBERSTAND LSL RIMBOARD
- 24 2X COMPRESSION BLOCK
- 25 1 1/8" TIMBERSTAND LSL RIMBOARD
- 26 5/8" DENSE GLASS SHEATING
- 27 2" POLY ISO

### Passive House Metrics

Heating energy	Cooling energy	Total source energy	Air leakage
3.6 kBtu/ft <sup>2</sup> /yr	4.20	31.1	0.6 ACH <sub>50</sub> (design)
1.0 kWh/ft <sup>2</sup> /yr	1.20	9.1	
11.2 kWh/m <sup>2</sup> a	13.20	98.0	

testing out some new high-design yet low-cost options and will be keeping close track of their energy usage.

Placetaylor broke ground on the Fort House last fall and expects to be wrapping up construction around the end of the year. Although it is taking a large risk putting a building in an unlikely site, Gee and Anderson don't sound too worried. Placetaylor has its own brand of fans—a list of potential customers who have asked the co-op to notify them when new units open up.

—Mary James

### Products

#### Air/Moisture Control

Siga  
ZIP System  
Sheathing and Tape



#### Ventilation

Zehnder America





Rendering by NK Architects

# PAX FUTURA

In a bustling neighborhood south of downtown Seattle, a 35-unit multifamily Passive House building is under construction. It's the brainchild of Sloan Ritchie, president of Cascade Built, and developer, builder, and owner of Pax Futura. Although Cascade Built has had plenty of Passive House experience, this project is Ritchie's first Passive House apartment building, and is also a first for Seattle.

"It's new territory," Ritchie says succinctly. He is referring to the design of the project's cooling system, but the same can be said about other aspects of this ambitiously forward-looking development.

Filling a pressing need for new rental housing, the four-story building will offer 6 one-bedroom units, 26 studios, and 3 live/work spaces on the ground floor. Located close to a light-rail station and numerous retail establishments, the 50-foot by 100-foot site has a walk score of 94. In keeping with Seattle code allowing developers to eschew parking garages in specified dense neighborhoods, Ritchie opted for bike parking instead of a garage that only would have been able to accommodate six cars—an economically unsound choice and a waste of valuable living space, he points out. By limiting the building height to four stories he also was able to forego building an elevator, eliminating a potential primary-energy hit.

With Passive House the goal from the outset, designing the building envelope was pretty straightforward, says Brittany Porter, architect and certified Passive House consultant with NK Architects, the project's designer. "This project validated what we already knew about the compatibility between multifamily and Passive House," says Porter. Careful detailing and modeling are critical to any project's success, no matter the scale, she emphasizes, but multifamily buildings come with inherent advantages.

The foundation assembly is a fairly standard slab-on-grade with 4 inches of rigid insulation and a vapor barrier

below the slab. The R-68 roof assembly includes more insulation than is typical but not by a huge amount. The exterior roof insulation consists of tapered polyiso—up to 1 foot thick in some locations. Interior to that is the air barrier and sheathing, supported by 9½-inch I-joists insulated with fiberglass batts.

A primary question was how to get enough R-value in the walls yet not take up too much space on a small lot. The answer relied heavily on a structural insulated panel wall that uses a graphite-enhanced EPS to deliver a roughly 15%–20% higher R-value. The taped panels will serve as the air barrier. "It's a typical 6-inch wall, but it's significantly more thermally efficient," says Porter.

Thanks partly to this thermal efficiency and partly to the high occupancy per square foot, the building easily meets the Passive House heating target using double-pane windows. Seven household-sized HRVs, each one serving three to five dwelling units, will supply continuous fresh air. Thanks to this semidecentralized system, duct runs were minimized, sharply reducing typical efficiency losses. When needed, electric-resistance cove heaters, mounted on the ceiling, will provide supplemental heating.

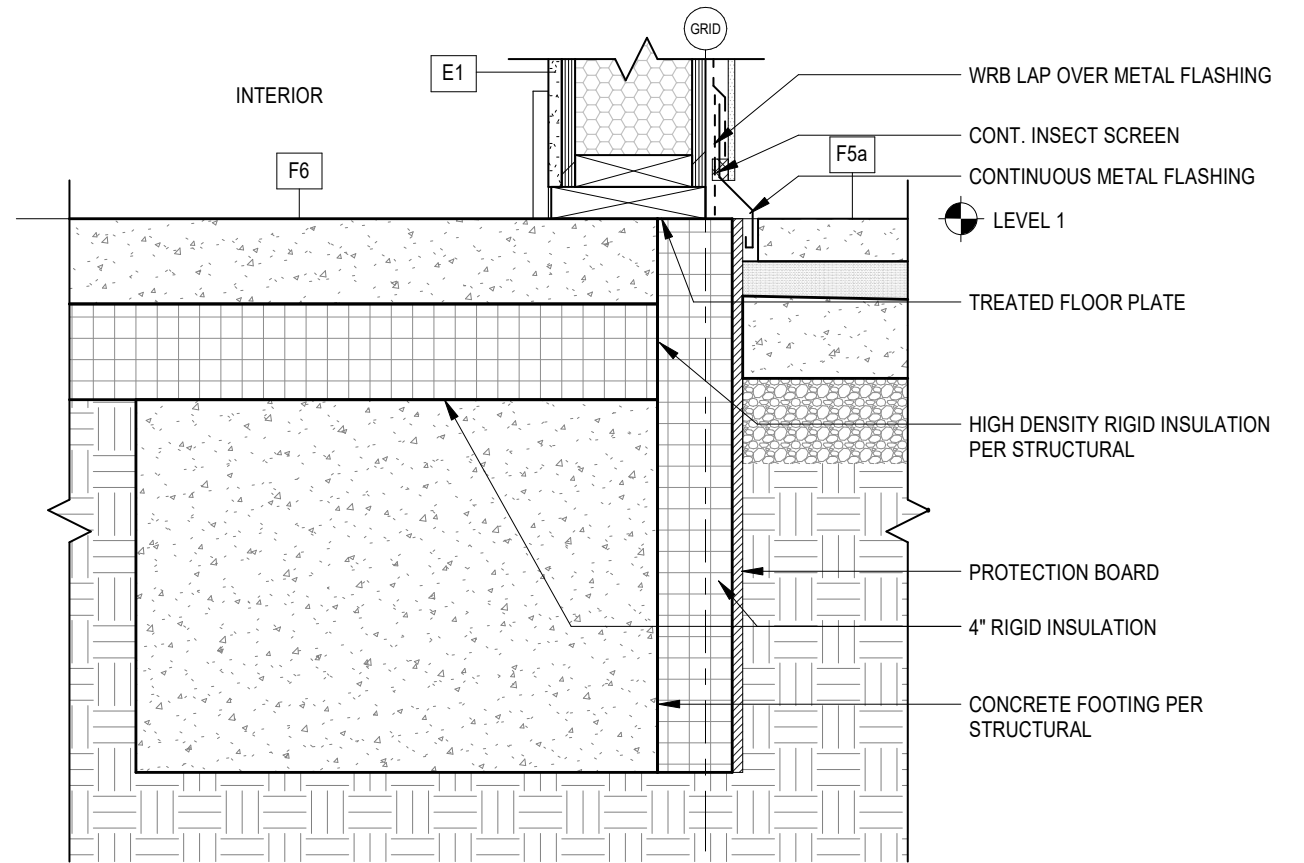
Cooling is a little more complicated. Most of the units in this C-shaped building face west and feature 7-foot tilt-and-turn windows on this facade. To shade each of them, Ritchie opted to install two cedar-slatted sliding screens, one 3 feet and one 4 feet long. The tenants can pull one or both across a window and even double them up across a portion of the window if desired. "In our climate people are used to opening and closing windows and shades," says Porter. For this neighborhood and the likely demographic, she adds, it's not a stretch to assume that the occupants will be willing to engage in maintaining their indoor comfort.

Although Seattle is far from being a cooling-dominated climate, the climate is changing, says Ritchie,





Rendering by NK Architects



Detail by NK Architects

**Passive House Metrics**

Heating energy	Cooling energy	Total source energy	Air leakage
2.4 kBtu/ft <sup>2</sup> /yr	1.0	54.0	0.6 ACH <sub>50</sub> (design)
0.7 kWh/ft <sup>2</sup> /yr	0.3	15.8	
7.6 kWh/m <sup>2</sup> a	3.0	170.0	

and summertime temperatures in the 90s are becoming more common. Still, most summer days are pleasantly temperate, and air-conditioned housing is a rarity. To take the edge off on hot days, Ritchie has chosen to use a centralized heat pump and send its refrigerant through each of the seven HRVs, cooling the supply air when the outdoor temperature rises above a designated setpoint. It's a novel, energy-efficient means of providing a tempered indoor climate.

With the heating and cooling load minimized, domestic hot water is typically the largest load left in a multifamily building. "If we can reduce that load, it will

be a benefit to us and the larger community," Ritchie says. Meeting a high bar for environmental benefits, the water heating system relies on a renewable technology that some have characterized as down for the count—a roof-mounted solar-thermal system. This solar-thermal system, designed by a local company, has been optimized to perform well even in Seattle's typically cloudy weather. Ritchie is excited to be trying it out.

And the final mountain to scale? Plug loads, says Porter. That's the biggest unpredictable load, but with 35 small units, the plug load density is expected to be high. To reduce this load a bit, individual washers and dryers

are not included in the units. Instead, shared laundry facilities on two floors are available in semiconditioned spaces that are outside of the thermal envelope.

Offsetting the building's electrical use will be a roof-mounted PV system. The likely tenants of this Passive House building hopefully will be excited about its many efficiency features and will act strategically to maximize the impact of this renewable resource—carrying the building ever closer to net zero energy and carbon emissions on an annual basis.

—Mary James

**Products**

**Air/Moisture Control**

Siga



**Ventilation**

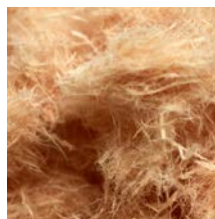
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# New TRAINING CENTER in Northeast



*Photo by Stuart Bernstein*



*Rendering courtesy of Auburndale Builders*

**A** new training center for Passive House and high-performance building education recently opened in Newton, Massachusetts, conceived and constructed by Auburndale Builders. The Studio for High-Performance Design and Construction occupies one end of the newly renovated Auburndale Builders office. The existing building was a one-story concrete garage 70 feet long and 20 feet wide, with concrete floors, walls, and ceilings.

When Auburndale Builders started retrofitting the commercial space, owner Nick Falkoff knew he would be using passive principles, but wasn't convinced the project would attain the full PHIUS performance benchmarks, due to such preexisting conditions as a concrete floor and steel beams that served as excellent thermal bridges. "We went down a slippery slope to passive," says Falkoff. Architect Jack Synnott and Michael Hindle, the Certified Passive House Consultant for this project, helped lead Auburndale down the slope.

When the construction crew started excavating the concrete floor to replace the cracked slab, they discovered

peat moss underneath it. Suddenly superinsulating the slab became a logical next step, especially as the firm had enough rock wool insulation left from a previous project to install 12 inches of it under a new floor. From there, Hindle gradually turned the dials in the model to see what would get them to passive, says Falkoff.

The wall assemblies were enhanced with 4 inches of exterior stone wool insulation. Three layers of salvaged 4-inch blocks of XPS, which otherwise would have gone to a landfill, were added to the roof assembly. Plenty of high-performance, quadruple-pane glazing, especially at the south-facing end, brings in ample daylighting to the classroom and offices. Blinds embedded in between the third and fourth panes can adjust solar gains and glare. Wall-mounted PV panels extend over the south-facing façade, forming a tuned solar awning that shades the glazing from high summer sun and allows the low winter sunlight in to heat the rooms.

Designing a ventilation system that could serve from 5 to 30 occupants posed challenges, not to mention balancing code-required, per-person ventilation

### Passive House Metrics

Heating energy	Cooling energy	Total source energy	Air leakage
3.7 kBtu/ft <sup>2</sup> /yr	1.5	7.1	0.8 ACH <sub>50</sub>
1.1 kWh/ft <sup>2</sup> /yr	0.5	2.1	or 0.02
11.5 kWh/m <sup>2</sup> a	4.8	22.5	CFM <sub>50</sub> /ft <sup>2</sup> of envelope area

specifications with primary energy limits. The company ended up using two ERVs, a smaller one for the office and a larger one for the classroom, whose speed can be boosted when occupancy increases. Ductless mini-splits with two condensers and four heads supply the heating and cooling.

Course offerings at the studio are intended to fill local and regional knowledge gaps. The ventilation challenges helped inspire the first class in the newly retrofitted building—a course on commissioning Zehnder systems. Architect and Passive House builder Adam Cohen taught a one-day course on Passive House multifamily buildings in January. “I like facilitating these activities,” says Falkoff. He envisions presenting one-day minicourses to give builders an introduction to Passive House for those who don’t have the time or commitment yet for a full training. While he hopes and expects this influx of experts will strengthen the Passive House community, he also sees benefits to his own company, including more training for his staff on the most current building science. “I think we will be doing well by doing good,” he says.

For more information on course offerings, visit [www.studiohpc.com](http://www.studiohpc.com).

—Mary James

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#### Windows & Exterior Doors

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#### Insulation

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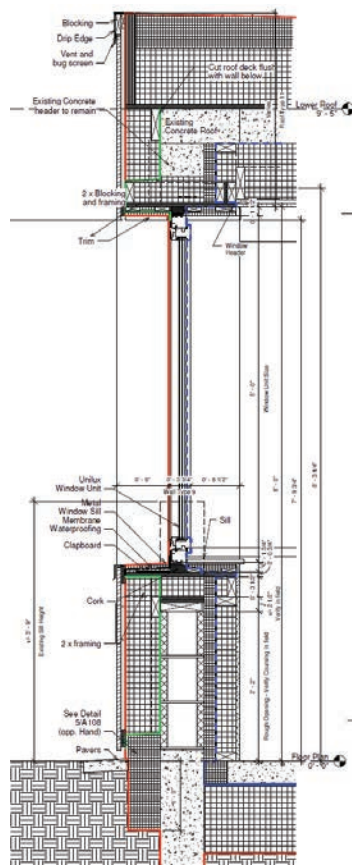
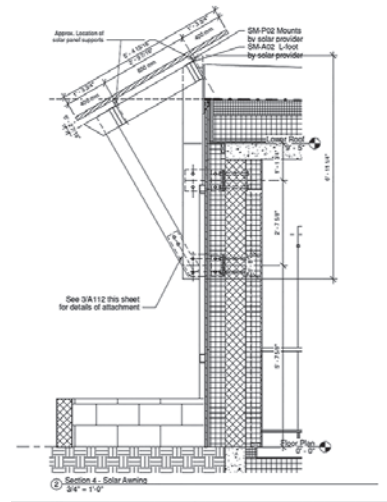
#### Air/Moisture Control

Siga



#### Ventilation

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# SACRED HEART Residences



Photo by Don Pearce Photographers

**B**uilding large-scale multifamily housing presents unique challenges. When you add Passive House and Energy Star certifications to the traditional tasks, and a mandate for market-rate pricing, the challenges get tougher. The Sacred Heart Residences in Allentown, Pennsylvania, met all of these objectives.

The Sacred Heart Residences is a four-story, 78,000-ft<sup>2</sup> mixed-use building with parking, community, management, and tenant space on the first floor. The upper three floors contain 61 one- and two-bedroom units ranging in size from 700 square feet to 975 square feet. Completed, and waiting for final Passive House certification at press time, the project had total construction costs of approximately \$144 per square foot.

According to Anthony Noga from Kitchen & Associates in Collingswood, New Jersey, a Certified Passive House Consultant (CPHC) and the project's lead architect, these costs are more economical than those found in the major urban corridors like New York and Philadelphia. According to the general contractor, the Passive House requirements added a little over 5% to the construction contract. That premium was spent primarily on

- mechanical equipment (\$400,000),
- air sealing (\$117,000),
- windows (\$110,000),
- insulation (\$62,000), and
- doors (\$26,000).

For projects this complex, critical design decisions have to be made quite early in the process, certainly before construction starts. Such Passive House details as air barrier locations, air-sealing methods, insulation levels, and thermal bridging often require multifaceted solutions when a project includes various programmatic uses. As a first step, the integrated design team had to decide which portions of the building were to be inside the thermal barrier and which were outside. The tenant and community spaces were definitely inside, and it was decided that the laundry rooms would be as well. However, the trash chute and compactor room, along with the parking, were left outside. Each of these decisions triggered specific air barrier detailing.

As one example, consider the first floor. The air barrier between the parking area and conditioned space is at the ceiling; in the remaining first-floor spaces, the air barrier is continuous from under the slab to the exterior walls, inclusive of the tenant space. The ceiling and wall air barriers are both a proprietary sheathing, while the slab has a 6-mm polyethylene air and vapor barrier. The intersection of these two materials on the outside of the first-floor sheathing was tricky and prone

to damage due to construction sequencing. Because this intersection was identified as a weak point, a liquid-applied membrane was added to the interior of the sheathing there. This kind of detailing led to the project's respectable 0.56 ACH<sub>50</sub> infiltration.

The specifications for the various assemblies are quite reasonable: R-31 2 x 6 walls with 2 inches of exterior insulation and cavity insulation, R-11 slab-on-grade with R-15 at the perimeter, and an R-62 roof, including 11 inches of open-cell spray foam plus 4 inches of continuous polyisocyanurate. Similar to the roof, the garage ceiling contains open-cell spray foam, the proprietary sheathing, and an additional 4 inches of continuous polyisocyanurate rigid insulation below that.

The Lithuanian-made uPVC tilt-and-turn windows have U-factors ranging from 0.16 to 0.18. They were installed with liquid flashing and expanding-foam tape. American-made fire-rated exterior entry doors, with a 0.24 U-factor and 0.39 solar heat gain coefficient, were installed instead of the German equivalents that match the windows. This choice allowed the team to avoid dealing with the complexities of integrating German entry hardware with the building's American access-control system.

The mechanical systems presented some interesting challenges. As with many other North American projects, humidity was an issue. In Allentown, it can be difficult to maintain acceptable humidity levels during the shoulder seasons. Typically, humidity is controlled with cooling equipment. However, when the outdoor temperature is below comfort levels, and the outdoor humidity is high, air-conditioning is not a reasonable solution, and an ERV by itself would have introduced excessive humidity into the living spaces. This problem was solved by installing one central ERV per floor connected to a variable refrigerant flow (VRF) heat pump for dehumidification, with ventilation air ducted to each dwelling unit. The exhaust air is ducted back to the ERV. Additional heating and cooling loads are met by individual, ducted mini-splits in each apartment.

Another challenge was providing makeup and exhaust air for the laundry rooms while maintaining the air barrier. Each laundry room is outfitted with a custom plenum mounted behind the dryers. The sealed plenums contain the makeup air and dryer exhaust ducts. According to Noga, "This is a challenging detail to implement, and is being refined on each successive project."

Blower door testing for the project required two blower doors, one at the first-floor community room, and the other at the fourth-floor roof deck access door. Innova, the project's Passive House and Energy Star rater, did the blower door testing, and the unit-by-unit Energy Star

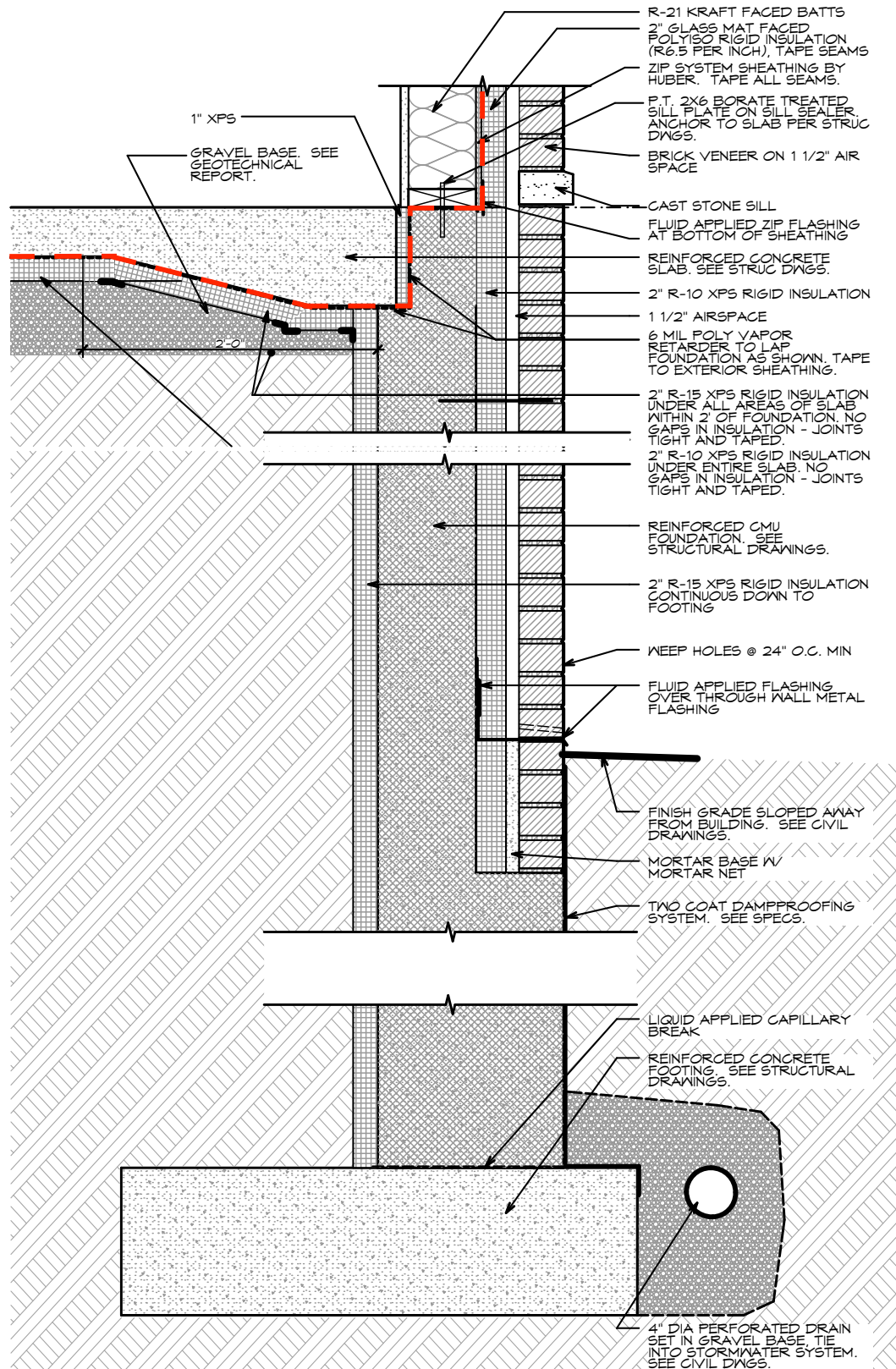


Photo by Don Pearce Photographers

commissioning. Building Science Corporation assisted with the preliminary testing.

This was the first Passive House project for this assembled project team. However, all team members understood the importance of Passive House concepts. The Passive House consultant, WRT, had taken the training. Noga had attended CPHC training during the preparation of the construction documents. The general contractor's site superintendent and project manager both had taken PHIUS's builder training.

The building was undergoing PHI certification at press time. As an exploratory exercise, the project team had examined how the building would perform under PHIUS+ certification. It modeled the building in WUFI and evaluated the impacts of the two organizations' critical differences:

- PHIUS pass/fail criteria change with the climate zone; PHI criteria do not.
- PHIUS assumes that the North American grid is "dirtier" than PHI, using a source energy factor of 3.16 instead of 2.6—and that affects the primary energy calculation.
- PHI limits primary energy to 38 kBtu per square foot per year; PHIUS limits it to 6,200 kWh per year per person.

The team concluded that because PHIUS's primary energy limit is calculated on a per-person basis, and it would not be able to meet this target, the project would not qualify for PHIUS+ certification. However, as PHIUS rules allow offsetting the higher primary energy limit with a renewable-energy system, the team realized that

it could have met the target if it had added a 100-kW PV system to the building. The team also evaluated alternatives and found that with some reasonable changes, such as ventilation flow rates and efficiencies, window specifications, and a reduction in assembly R-values, the building could have qualified for PHIUS+ certification, and partially offset the first costs of the 100-kW PV system.

—Steve Mann

### Passive House Metrics

Heating energy	Cooling energy	Total source energy	Air leakage
3.8 kBtu/ft <sup>2</sup> /yr	2.5	37.6	0.56 ACH <sub>50</sub>
1.1 kWh/ft <sup>2</sup> /yr	0.7	11.0	
11.8 kWh/m <sup>2</sup> a	7.7	118.5	

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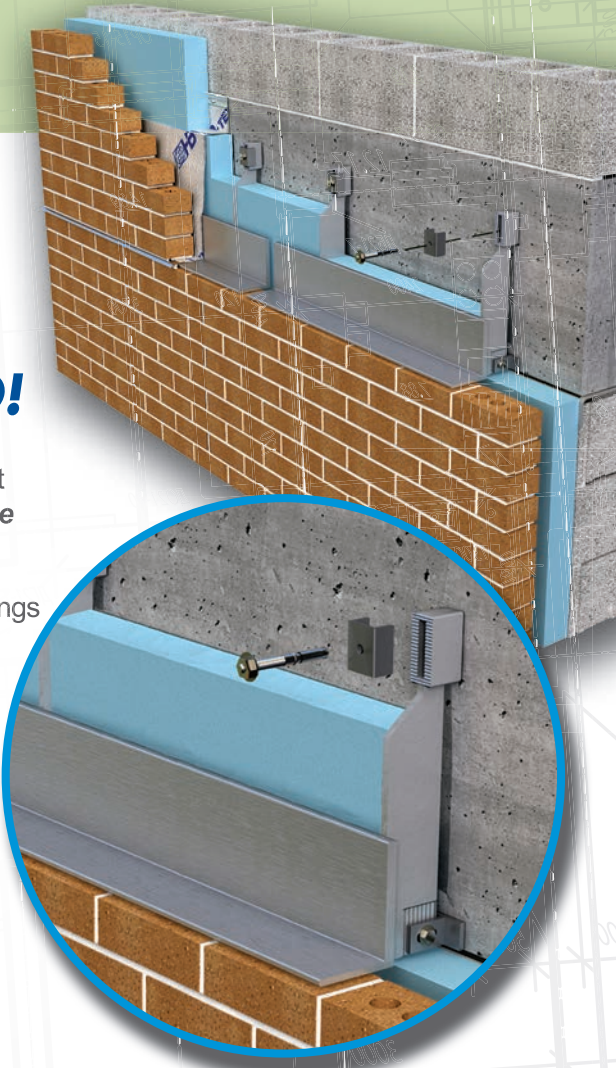
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# Low-Carbon Living at NORDEAST NEST

In Minnesota and a host of other states with really cold climates, solar heat gain can determine whether a given single-family house will be able to meet the Passive House heating target. Spoiler alert: Nordeast Nest is a single-family residence built on a tight lot in Minneapolis, Minnesota, with a neighbor to the south that completely blocks wintertime sun on that façade. Tim Eian, principal of TE Studio in Minneapolis, Minnesota, and designer of Nordeast Nest, realized from the beginning that it wouldn't be possible to insulate the home enough to reach the 15 kWh/m<sup>2</sup> heating target. Not in his climate. Not with that shading. But he still could create a house with a shrunken carbon footprint, one that met the slightly more relaxed Passive House Institute's Low Energy Home with Passive House Components criteria.

His clients came to him with some very clear goals. They wanted to be able to live in a low-carbon yet high-comfort environment, demonstrating to their three young children and to the larger community that the two goals are not oppositional.

Their new home succeeds from multiple perspectives. The family has reduced the home's operating carbon footprint by 96% compared to an average home in the same zip code, thanks to a combination of Passive House strategies and purchasing wind energy for their electricity use. And through a series of pragmatic decisions, the construction costs were kept to less than \$200 per square foot in an area where custom homes often cost \$250 per square foot.

Visually the home bridges the gap between a more conventional look and a contemporary sensibility. The roof's slightly off-center pitch breaks from the traditional look of the lap siding and larger window trim, and also provides the perfect angles for increased solar gain for a

future PV system should it be added. "It's not an exotic building, which is part of its charm," says Eian. "People can relate to this house."

Many of the construction techniques used also weren't exotic, but were given Passive House twists. The foundation's concrete slab rests on 6 inches of EPS. The below-grade exterior walls consist of 11-inch insulating concrete forms (ICFs) with an additional 4 inches of EPS for a total R-value of 39.

Above grade, the R-51 exterior walls start with 2 x 6 framing that is insulated with mineral wool batts. The ¾-inch OSB structural sheathing serves as both the air barrier and vapor retarder. Beefing up the walls on the exterior are 12-inch I-joists insulated with dense-pack cellulose. The wood siding was attached over a ventilated rain screen gap. The very high performance, triple-pane wooden windows are probably the most exotic component of the assembly. The front and rear entry doors, which feature a wood finish and a polyiso core, were custom made by a local company.

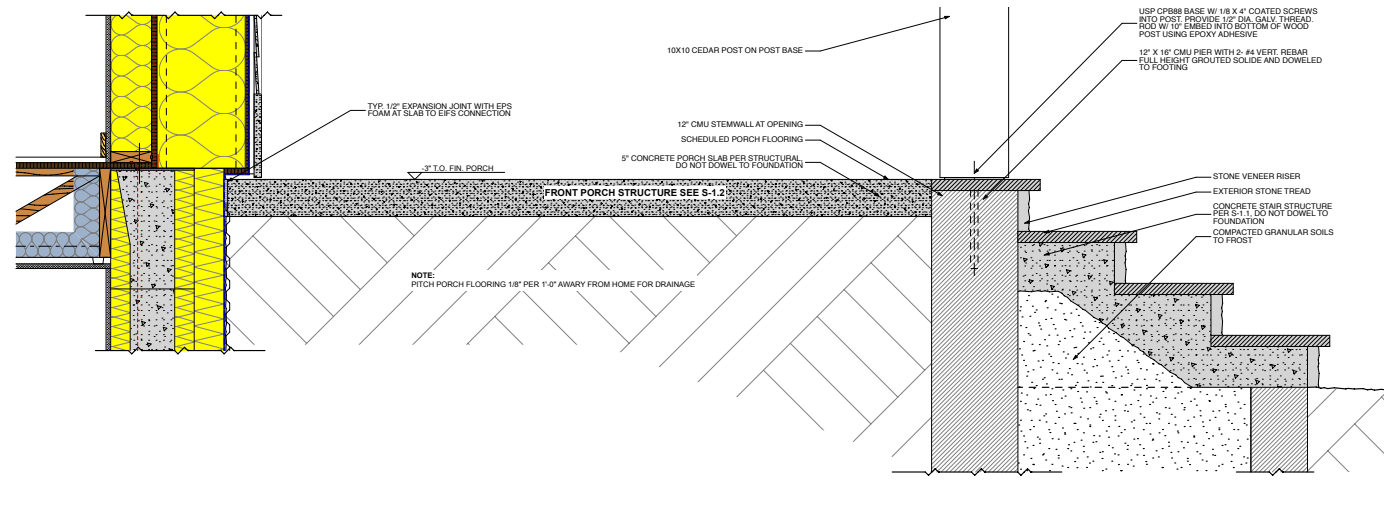
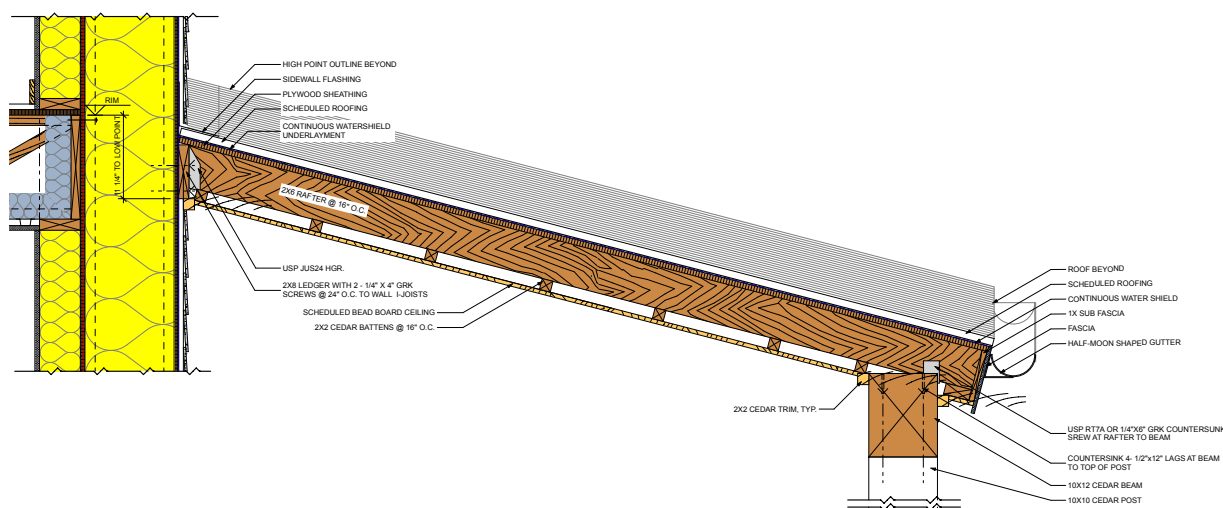
The roof is designed to be a cold assembly with the thermal boundary at the second floor's ceiling. Twenty inches of loose-fill cellulose insulate the home from the attic's temperature swings. A service cavity below the air and vapor barrier ensures that ceiling fixtures and mechanicals do not protrude into this part of the building envelope.

The home's three bedrooms and two baths are on the second floor, with the kitchen, dining, and living rooms on the ground floor, along with a mud room and a powder room. The basement has a family room, an unfinished bathroom, a guest bedroom, and a small storage room, which also holds the ventilation system and gas-fired, high-efficiency water heater. Heating and cooling are



Photo by Corey Gaffer Photography





Front door Connection Detail, © TE Studio, Ltd.



Photo by Corey Gaffer Photography

supplied to the two main floors by ducted heat pump systems. The basement level is heated by electric-resistance radiator panels.

On the main floor, a sealed-combustion gas fireplace—a unit with the highest efficiency they could find—gets used mostly on the coldest days of the year, when the heat pump would be resorting to electric-resistance heating. The intake and exhaust runs were kept as short as possible to minimize any thermal bridging. Because the home is so airtight and superinsulated, a single heating source can keep the whole house toasty, as the family found out not too long after moving in. “In the dead of winter in their first year both heating devices went belly up,” says Eian, “so I loaned them a little space heater, which they put in the basement, and it heated the whole house for a couple of weeks until the repairs were done.”

The home stands as a testament to what can be accomplished by applying Passive House principles even in a difficult climate and on a challenging site. On an annual basis this family of five uses 14,000 kWh, gas included, to operate the home and an electric car, drawing most of their power from carbon-free wind energy. That’s a very successful, environmentally friendly lifestyle.

**Passive House Metrics**

Heating energy	Cooling energy	Total source energy	Heating load	Cooling load	Air leakage
8.6 kBtu/ft <sup>2</sup> /yr	2.5	33.0	5.4 Btu/hr/ft <sup>2</sup>	2.7	0.4 ACH <sub>50</sub>
2.5 kWh/ft <sup>2</sup> /yr	0.7	9.7	1.6 Watts/ft <sup>2</sup>	0.8	
27 kWh/m <sup>2</sup> a	8.0	104.0	17 Watts/m <sup>2</sup>	8.4	

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—Mary James



Photo by Daniel A. Levy

# WOODSTOCK Passive House

**D**an Levy, certified Passive House consultant (CPHC) and builder, is president of Green-spring Building Systems in Woodstock, New York. He is a passionate advocate of autoclaved aerated concrete (AAC). To demonstrate and promote its many advantages, Levy chose to build his first Passive House using AAC blocks.

AAC was invented by Swedish architect Johan Eriksson in 1923. It's composed of sand, gypsum, lime, cement, and a trace of aluminum powder. During manufacturing, a chemical reaction takes place that entraps air bubbles in the resulting masonry units. AAC weighs 80% less than concrete but retains half of its compressive strength, and it has an insulation value of roughly R-1 per inch. It can be worked with standard woodworking tools, making assembly very easy—in theory; more about that later.

From a Passive House perspective, AAC is a perfect building material in many ways. In addition to its respectable R-value, it provides both an air and bulk water barrier. AAC is vapor open, but the capillary action breaks down rapidly. If exposed to water, the outside gets wet, but it dries back out without damage. You just can't leave an unfinished building exposed to the elements for extended freeze-thaw cycles.

The blocks are joined with thin-bed mortar, using a notched trowel. As they are air and water resistant, no membranes are required. AAC is also highly durable; it has a four-hour fire rating and is pest and mold resistant. A properly built AAC building should last for centuries, but if remodeling is called for, AAC can be recycled.

The Woodstock Passive House is a 2,373-ft<sup>2</sup>, two-story, single-family home plus a 576-ft<sup>2</sup> garage with an upstairs apartment. Both structures were built to Passive House

standards, but only the house was certified by PHIUS. Although Levy is a CPHC, architect Gal Gabriel designed the building and did the modeling, first in PHPP, then later in WUFI. She liked that WUFI includes static and dynamic modeling, plus comfort and hygrothermal analysis. As the official tool for PHIUS+ certification, it also includes the PHIUS climate-specific space-conditioning targets.

The construction is all foam free. The foundation footings are wrapped in 10 inches of cellular glass, more commonly known as foam glass. (Foam glass has no petroleum-based foam.) The 4-inch concrete slab also has 10 inches of foam glass underneath for a floor R-value of 34. The walls are 8 inches of AAC plus 6 inches of mineral wool, in addition to plaster and siding, for a composite R-value of 34. The roof assembly was built using scissor trusses with raised heels, allowing for 24 inches of blown-in cellulose for an R-value of 86. Although the wall insulation is somewhat lower than is recommended for a Passive House in climate zone 6, the floor and roof values are somewhat higher, mitigating the walls' shortfall.

Both all-electric units have identical mechanical systems: heat pump water heaters, 9,000-Btu mini-splits with one head per floor, ERVs, and electric kitchen appliances including induction cooktops. Clothes drying is done with a ductless heat pump dryer. The electric consumption is offset by a 7.6-kW PV system on the roof of the main house.

The site could be net zero, Levy says, if he could just train his tenants to keep their windows closed and enjoy their Passive House comfort. One tenant in particular likes to keep the windows open even in 30°F–40°F weather, substantially increasing mini-split run times and reducing the ERV's capabilities.

AAC is not without its problems. Used widely in Europe and somewhat in North America for commercial buildings, AAC is not generally used in the United States for residential construction due partly to supply constraints; there is currently only one manufacturer here. The AAC blocks for the Woodstock Passive House were shipped from Florida, adding a few thousand dollars to their raw cost.

There are other factors, however, that outweigh the material cost. For Levy, the biggest advantage is long-term durability, which is arguably less with stick-framed construction. Also, air sealing, critical for a Passive House, is much simpler. Properly installed AAC blocks, with no additional detailing, have been tested to leak as

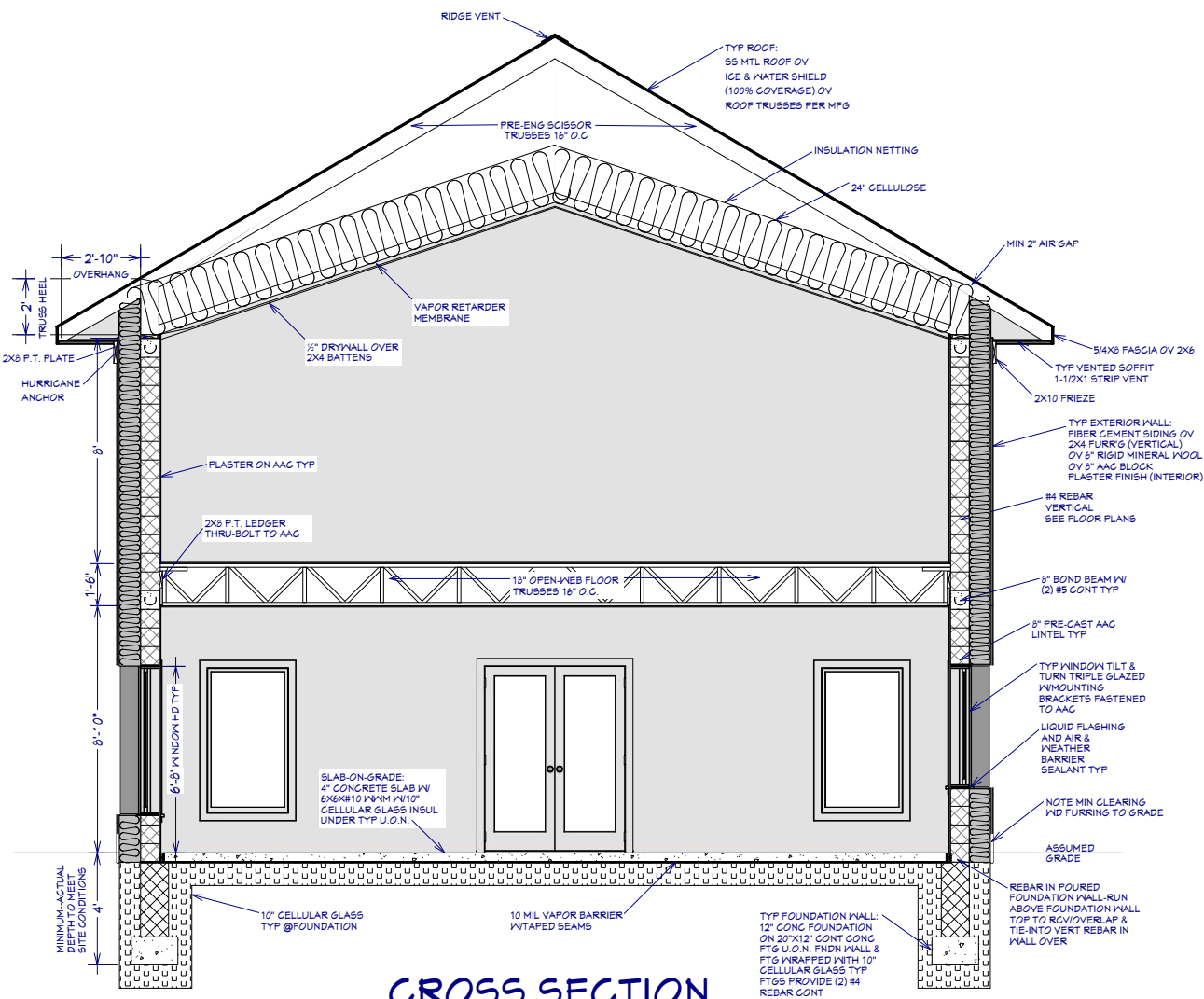
little as 0.01 ACH<sub>150</sub>, a pressure 3 times higher than the traditional infiltration test.

Crew training, at least in North America, may be an additional cost. Although AAC blocks are supposedly easy to assemble, it takes the right crew mindset, and tools and techniques that may not be familiar to standard masonry crews. Levy first asked the foundation crew to raise the walls, but they insisted on using standard concrete masonry unit assembly techniques. After parting ways with that subcontractor, Levy trained a pair of skilled carpenters in a few hours. They completed the job flawlessly.

Levy is convinced that AAC is by far the easiest way to build an energy-efficient and durable building. As he



Photo by Daniel A. Levy



**Passive House Metrics**

Heating energy	Cooling energy	Total source energy	Heating load	Cooling load	Air leakage
5.9 kBtu/ft <sup>2</sup> /yr	1.4	25.0	4.6 Btu/hr/ft <sup>2</sup>	2.4	0.5 ACH <sub>50</sub>
1.8 kWh/ft <sup>2</sup> /yr	0.4	7.4	1.3 Watts/ft <sup>2</sup>	0.7	
18.8 kWh/m <sup>2</sup> a	4.3	79.0	14.5 Watts/m <sup>2</sup>	7.4	

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points out, Passive Houses are first and foremost about energy efficiency and comfort, but durability is equally important. An AAC building requires very little shell maintenance, and it has no effective change in infiltration over decades, perhaps centuries. The combination of Passive House design principles and AAC could well be a serious solution to help mitigate climate change.

—Steve Mann



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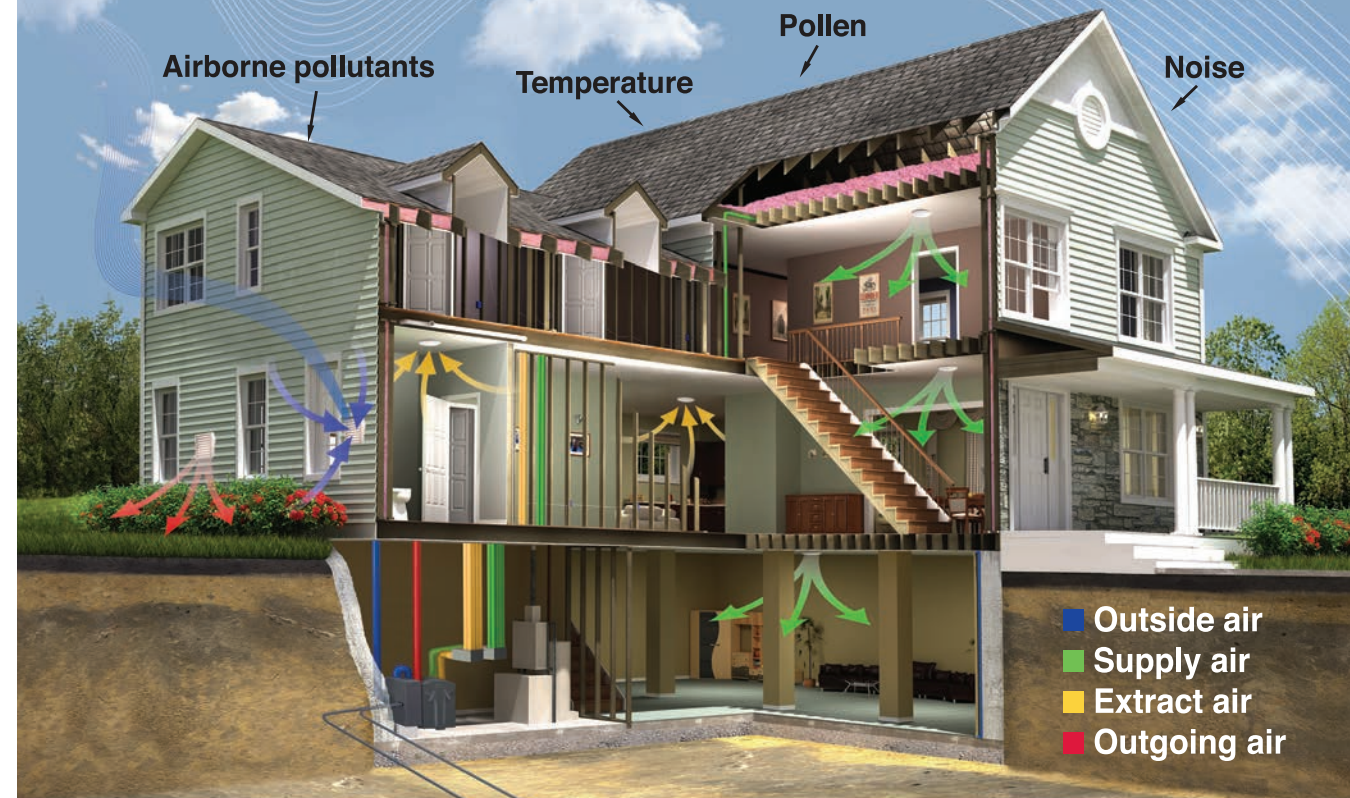
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# The PERLITA Passive House

—An Affordable Path to Meeting  
CALIFORNIA'S NZE GOAL



Photo courtesy of Xavier Gaucher

**W**hen I moved from France to Los Angeles in 2015, I was surprised to find no Passive House construction completed or even under way in Southern California. The climate is similar to that found in the Mediterranean countries, where there are already many Passive House buildings.

Did people think it was not worth it because of the mild climate? Did they think it was too expensive? Neither conjecture makes sense to me. If the climate is mild most of the time, then when the weather changes and it becomes cold or hot outside, poorly constructed buildings become very uncomfortable. And the number of days above 95°F in Los Angeles have been projected to triple in the next 30 years. The energy bills here can get quite high, especially in summer. On top of that, Los Angeles has many iconic architects' houses, which are often used as a reference for designing new houses. However, these houses are designed with no comfort criteria, making them very unpleasant to live in—which must be very upsetting considering the price of real estate!

On top of all those motivations, California has set a very aggressive goal for all new residential construction—single-family and multifamily buildings up to four stories—to be net zero energy (NZE) starting in 2020, with a start date of 2030 for the other types of building. Because Passive House construction simplifies meeting the NZE requirement, I was astonished not to see a surge in these types of building.

So when we found a house to buy that needed serious renovations, we decided to make it a Passive House. Starting with what had been done in southern Europe and in the first Passive House in Mexico, I searched for the required solutions to meet the Passive House standard in Los Angeles. My goal was to demonstrate a path to creating high-efficiency buildings, in general—not only for single-family homes—so finding appropriate local solutions that were also cost-effective was a priority.

Running the first PHPP models, we realized that double-pane windows and continuous ventilation without heat recovery were perfectly suitable for us and would save money. That seemed to simplify the way forward,

but that wasn't entirely the case. If only double-pane windows with the proper efficiency had been easy to find! We needed a Passive House window manufacturer who could guarantee the airtightness not only of the windows, but also of the doors, including sliding glass doors. After much searching, I found a reasonably priced double-pane wooden window with a Passive House-quality frame and a National Fenestration Rating Council rating from Zola Windows; the window's U-value is 0.26, and its solar heat gain coefficient is 0.39.

Regarding the ventilation, we went with two fans, one to bring in fresh air and one to extract the exhaust air, both operated with the same variable-speed controller. We designed our HVAC ductwork to carry both the fresh air and the conditioned air, to avoid having two separate duct circuits. The HVAC unit is a new 1-ton air-handling unit capable of operating at high static pressures, which the manufacturer launched with our project. After a few weeks living in the place, I can attest that everything is working great.

Concerning the building envelope, we didn't have to change much from what was required to meet California's Title 24 building standard—although we did have to almost double the insulation in the 2 x 4 walls from the R-13 requirement. Regarding the airtightness, the crew's inexperience in that domain, the material we used, and the fact that this was my first Passive House meant that we were not able to reach the 0.6 ACH<sub>50</sub> standard for new construction. But we reached the retrofit target of 1 ACH<sub>50</sub>, which allows us to qualify for EnerPHit certification. In retrospect, framing could have been improved to minimize thermal bridges, but seismic requirements were often an excuse not to do so. However, the mild climate helped us get by even with this less than optimal wood framing.

Version 9 of PHPP, which had just come out when we started our energy modeling, arrived at the perfect time. With the new primary energy renewable factor we were able to calculate within the PHPP the kWh requirement—6,000—and the number of solar panels needed to meet the NZE goal: 12 panels for this 2,000-ft<sup>2</sup> all-electric house. With the addition of just 4 more panels, we are able to power an electric car and achieve a Net

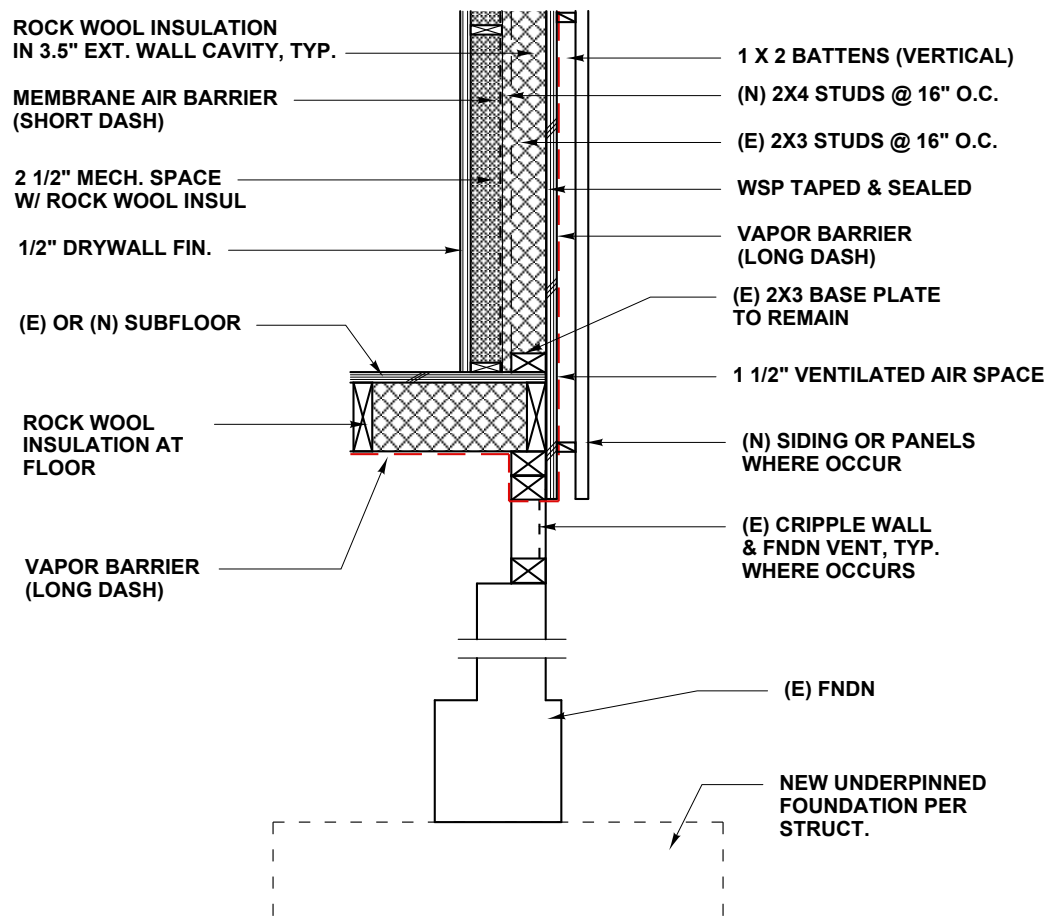


Photo courtesy of Xavier Gaucher

Zero Lifestyle goal. If the house had been designed just to meet California's Title 24 building efficiency standard rather than the more-stringent Passive House standard, the roof would have been too small to fit all the necessary solar panels.

In conclusion, the extra cost to build this Passive House was less than 5%, and I am confident that premium can be reduced. With two completed Passive Houses in Los Angeles by early 2018, our Passive House California Los Angeles Chapter intends to use these examples to inspire local policy makers, developers, architects, contractors, and customers to build many more such projects.

XAVIER GAUCHER is a Certified Passive House Consultant and the owner/builder of the Perlita Passive House.

**Passive House Metrics**

Heating energy	Cooling energy	Total source energy	Total renewable source energy	Air leakage
2.2 kBtu/ft <sup>2</sup> /yr	3.2	23.5	10.5	0.9 ACH <sub>50</sub>
0.7 kWh/ft <sup>2</sup> /yr	0.9	6.9	3.1	
7 kWh/m <sup>2</sup> a	10.0	74.0	33.0	

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Glazing Layer 1	N/A	



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*Photos courtesy of Key Architects*

# PASSIVE TOWN

## Phase Three

**P**assive Town, in Kurobe, Japan, is a multibuilding residential development started in 2010 by YKK, a Japanese conglomerate with multiple lines of business, including fastening products, commercial building facades, machinery, and building products. Kurobe-based YKK started relocating part of its headquarters from Tokyo back to Kurobe after the Great East Japan Earthquake in 2011. Passive Town was designed to provide approximately 250 residential units—in six phases—mainly for the company’s employees but also for the local residents. Three phases of the project have been completed.

The goals of the master plan, developed by both an architect and a landscape designer, included maximizing solar and wind power potential. Each phase was turned over to a separate architectural firm for building design. Yuichiro Kodama of Estec Design designed phase one, and Fumihiko Maki of Maki and Associates designed phase two. For phase three, YKK selected Miwa Mori of Key Architects. Mori is the representative director of Passive House Japan and is one of the driving forces of the Passive House movement in Japan.

Phases one and two were developed as new housing, with basement car parking and a sophisticated biomass boiler plant for phase one. The new housing required demolishing existing four-story apartment buildings that had been used for more than 30 years as YKK employee housing. All the remaining structures, including Buildings J and K, were very similar to the public housing stock found throughout Japan, and the buildings that had been demolished—old, boring, and uncomfortable. However, they had a very simple shape and excellent southern exposure.

Key Architects suggested that YKK keep the existing Buildings J and K and incorporate Passive House features to improve their energy efficiency and comfort. Key also suggested redesigning the façade to give it a more modern look. This renovation approach minimizes the impact on both the local and the global environment, while also promoting a new, modern lifestyle for the residents. Before agreeing to this plan, YKK undertook a structural analysis of the existing buildings to ensure that they would meet Japan’s rigorous seismic code—which they did.

Consequently, in 2015, the phase three refurbishment project was started not only to help solve YKK’s immediate housing needs in Kurobe, but also to find a general solution for improving typical Japanese public housing. These two buildings were designed to Passive House standards. One was picked for PHI EnerPHit certification, and the other for LEED for Homes Platinum certification. Both buildings were certified in 2017.

Before covering the existing structures with 3 inches (150 millimeters) of exterior EPS insulation, the cantilevered concrete balconies of Buildings J and K were demolished to eliminate a significant thermal bridge. The fourth-floor wall of Building K was likewise demolished at balustrade height to create a new roof deck for the residents. These changes reduced the weight of the two buildings significantly so that some further optimizations could be done without risking the strength of the structures. For instance, new floor openings were created to insert small elevators. Also, some units were combined to create two-story units with an upstairs sleeping room. New steel balconies with a ground-based foundation and limited building connection were designed, avoiding unnecessary thermal bridging.

The 37 units, ranging in size from 430 square feet (40 square meters) to 530 square feet (50 square meters), were outfitted with heat pump water heaters, single-head mini-splits for heating and cooling, and triple-pane PVC windows manufactured by YKK’s Architectural Products group. Wall-mounted HRV units provide ventilation for the all-electric apartments.

Like most construction projects, this one presented certain difficulties. However, intense communication between the contractor and Key Architect’s on-site project manager solved most of them. For instance, 5.9 inches (150 millimeters) of external EPS, required to achieve EnerPHit certification, is quite unusual in Japan—it’s still possible to get planning approval for a new building with no insulation. Everyone involved in the project, including the subcontractors, clearly understood the project’s intent, which also helped avoid problems in the field.

Rental property in Japan is often of very poor quality, and tenants are not allowed to change the internal finishes. In phase three, the finish materials were chosen very carefully, aiming for a very high-quality, hotel-like



Photos courtesy of Key Architects

atmosphere for all 37 apartments. Although a bit more expensive, these upgrades were possible because of the savings introduced by recycling the existing structure.

After completion, the thermal comfort of Buildings J and K is significantly improved, hopefully triggering lifestyle changes. Perhaps the occupants will come home from work earlier than before, or invite friends to visit. Because their new homes are cozy, attractive, and energy efficient, their homes and the neighborhood may be used more for social activities. To encourage this type of lifestyle change, Mori designed a small community kitchen in Building K. The kitchen operates using only renewable and local energy, demonstrating how simply our daily lives can be managed using clean energy.

**MIWA MORI** is principal of *Key Architects Co., Ltd.* Steve Mann worked with Miwa Mori on the preparation of this article.

**Passive House Metrics**

Heating energy	Cooling energy	Total source energy	Total renewable source energy	Air leakage
6.3 kBtu/ft <sup>2</sup> /yr	5.1	20.0	2.9	0.2 ACH <sub>50</sub>
1.9 kWh/ft <sup>2</sup> /yr	1.5	5.9	0.8	
20 kWh/m <sup>2</sup> a	16	63.0	9.0	

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Renderings courtesy of Ryall Sheridan Architects

# Bringing Comfort and Efficiency to the DALLAS MARKET

entertaining and affords access to a generous backyard. The master suite and a study complete the first floor, and two smaller bedrooms are upstairs.

Nothing about the home screams energy efficiency, but there are clues. That recessed front door creates an inviting alcove and also limits the sunlight and heat reaching the entry vestibule. The house is clad in gray stucco and wood siding, their light tones chosen with an eye to reducing solar absorption. The front of the house faces north and still has ample glazing.

“It was a fascinating process,” says architect Ted Sheridan, whose Passive House-centric firm is based in New York. “The climate in Dallas is very different, really completely backward, from what we are used to working

**N**ew York, Vancouver, and Dallas? Dallas is not yet a booming Passive House metropolis, but the first Texas house on the PHI certification track is on the market. Fagin Partners, a father and son team consisting of Kyle and Connor Fagin, developed the 3,500-ft<sup>2</sup> house and sees the likely buyer as a young family who care about comfort and the environment.

The contemporary three-bedroom home, designed by Ryall Sheridan Architects, ushers in visitors through a gracious, recessed entryway that opens into a great room with kitchen, living, and dining spaces. A screened-in porch off the great room allows for easy indoor-outdoor

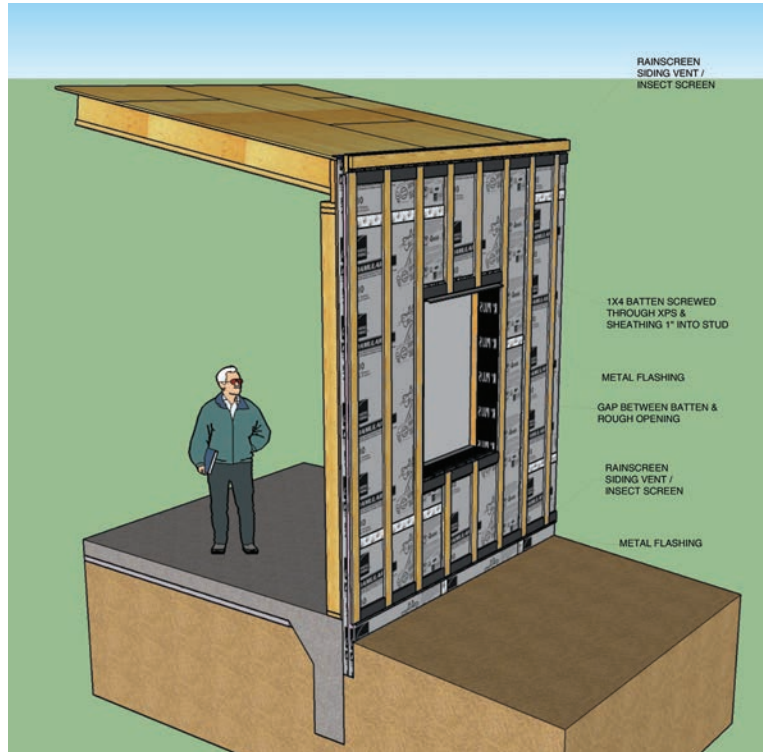
with.” Instead of designing with a focus on keeping heat in a building, Sheridan, his partner Bill Ryall, and associate Will Robinette—all Certified Passive House Consultants—had to shift gears and concentrate predominantly on keeping heat out, although Dallas also has heating loads during its brief winters.

The biggest surprise came early on in the design process. In Dallas, homes are traditionally constructed on a slab-on-grade foundation. Fine, thought Sheridan, we’ll just put a bunch of insulation under it. Or not. In working with the PHPP model, they found they could only meet the Passive House targets when they had no insulation under the slab and the ground could act as a heat sink for the home.

The wall and roof assemblies held fewer surprises. Ryall Sheridan specified a double-wall assembly insulated with cellulose, with an intelligent air and vapor barrier membrane on the interior surface of the stud wall. To avoid risking penetrations of this membrane, Sheridan had the crew fur out an interior false wall for the wiring and plumbing. Triple-pane glazing was required to meet the comfort criteria year-round, so the architects specified an economical, high-performance PVC window.

Shading was an overarching concern, with Sheridan relying primarily on architectural features to avoid the extra cost of exterior blinds. The south-facing windows overlooking the backyard are smaller than would typically be the case in a northeast locale. He positioned some of those windows so that they look through the screened porch and are shaded by it.

In keeping with the home’s contemporary aesthetic, the roof is fairly flat. Its membrane topping is light gray—again to minimize solar absorption. “A black roof would have killed us,” says Sheridan. Below the membrane are 3 inches of polyiso insulation boards, a plywood roof deck, and then about a foot of cellulose insulation. The house is prewired for PV, which the developers plan on implementing before the house is sold.



In addition to heat, Dallas's subtropical climate delivers plenty of humidity. The high-performance HRV, chosen to help meet the heating load, is being supplemented by a central dehumidifier. Ryall Sheridan had heard of Passive Houses in this type of climate becoming uncomfortably humid inside, and he didn't want to take any chances. Heating and cooling are being supplied by a mini-split system.

Ryall Sheridan designed this house to be all electric, avoiding any potential combustion safety issues and the need for gas lines. An electric on-demand tankless water heater will provide the hot water, and an induction cooktop will be used for cooking.

Fagin Partners started promoting this project on social media and the radio toward the end of the construction process. Although the house had not been sold at press time, the home's green features had generated enough interest that the developers are already looking ahead to their next Passive House projects. Says Sheridan, "They are interested in more cost-efficient ways to build Passive Houses and have asked us to design prototypes that could be built with prefab components." Watch out, Vancouver.

—Mary James

### Passive House Metrics

Heating energy	Cooling energy	Total source energy	Total renewable source energy	Air leakage
4.75 kBtu/ft <sup>2</sup> /yr	1.6	29.0	14.0	0.6 ACH <sub>50</sub> (design)
1.4 kWh/ft <sup>2</sup> /yr	0.5	8.5	4.1	
15 kWh/m <sup>2</sup> a	5.0	91.0	44.0	

### Products

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# Old School Meets NEW SCHOOL

**T**he Stone Schoolhouse Passive House is an almost perfect case of the past and present fusing to create a yet more perfect form. Interestingly, the building and the architectural firm undertaking the retrofit have similar roots, with histories that date back to the nineteenth century.

The 800-ft<sup>2</sup> schoolhouse, empty for the last 20 years, was built in 1849 in Fayetteville, New York, a small village on the outskirts of Syracuse. The architectural firm spearheading the building's renovation, King + King, located in Syracuse, has been around almost as long. Founded in 1868, it's one of the oldest architectural practices in the country. King family members have been involved in the practice from nearly the beginning, going back five generations. The firm is known primarily for nonresidential buildings, especially education and health care facilities.

Now Passive House is changing both the building's and the firm's trajectories. The project manager, Tom King, is the son of Jim King, one of the firm's partners. The younger King recently graduated from Stevens Institute of Technology with a master's degree in product architecture and engineering, complementing his undergraduate architecture degree. The focus of King's Stevens curriculum was to prepare an entry for the 2015

U.S. Department of Energy Solar Decathlon competition. One of the courses focused on Passive House principles, enabling King to sit for and pass the certified Passive House designer and tradesperson exams. His team's Passive House-designed SURE HOUSE won the Decathlon in seven out of ten categories, and took the overall prize.

After graduation, King joined King + King, bringing with him his interest in Passive House technologies. The Stone Schoolhouse is the firm's first Passive House project. The firm is pursuing EnerPHit certification, with Low Energy Building certification as a backup plan. The schoolhouse is being converted into a residence for King's parents, who are downsizing from a 3,000-ft<sup>2</sup> home. As the Schoolhouse is completed, King will continue to incorporate Passive House principles into the firm's larger commercial and institutional projects.

The renovation requires that the building retain its historical character, which is defined primarily by the 20-inch-thick structural limestone walls. Insulation and air sealing must be done from the inside. In addition, changes cannot compromise the integrity of the stone walls, which have survived without human improvement for a long time. Like masonry, stone is very susceptible to vapor drive, especially on the south-facing walls. The project team ran extensive hygrothermal analyses of the



*Photo courtesy of King + King Architects*

walls to make sure that once insulated, they will continue to perform.

As stone and masonry walls have more complex vapor movement than stick-framed buildings, Passive House guidelines suggest that, in a climate zone like Fayetteville, stone should generally be less insulated, especially on the interior, than typical Passive Houses. The Schoolhouse walls have a total of 7.5 inches of mineral fiber insulation on the interior (R-31.5), with 3.5 inches against the stone, and another 3.5 inches in a 2 x 4 wall detached from the stone, creating a thermal-bridge-free assembly. The insulated crawl space has 4 inches of fiberboard (R-16) on grade and 7.5 inches on the walls.

In contrast to the walls, the roof assembly relies on exterior insulation. The heavy timber roof framing and interior sheathing are being left exposed for historical accuracy and aesthetics. To allow for a continuous thermal assembly, the roof was raised 7 inches and 500 psi structural insulation was inserted between the roof frame and the top of the stone walls. Exterior to that, another 6.3 inches of phenolic insulating foam (R-53) is layered above the sheathing.

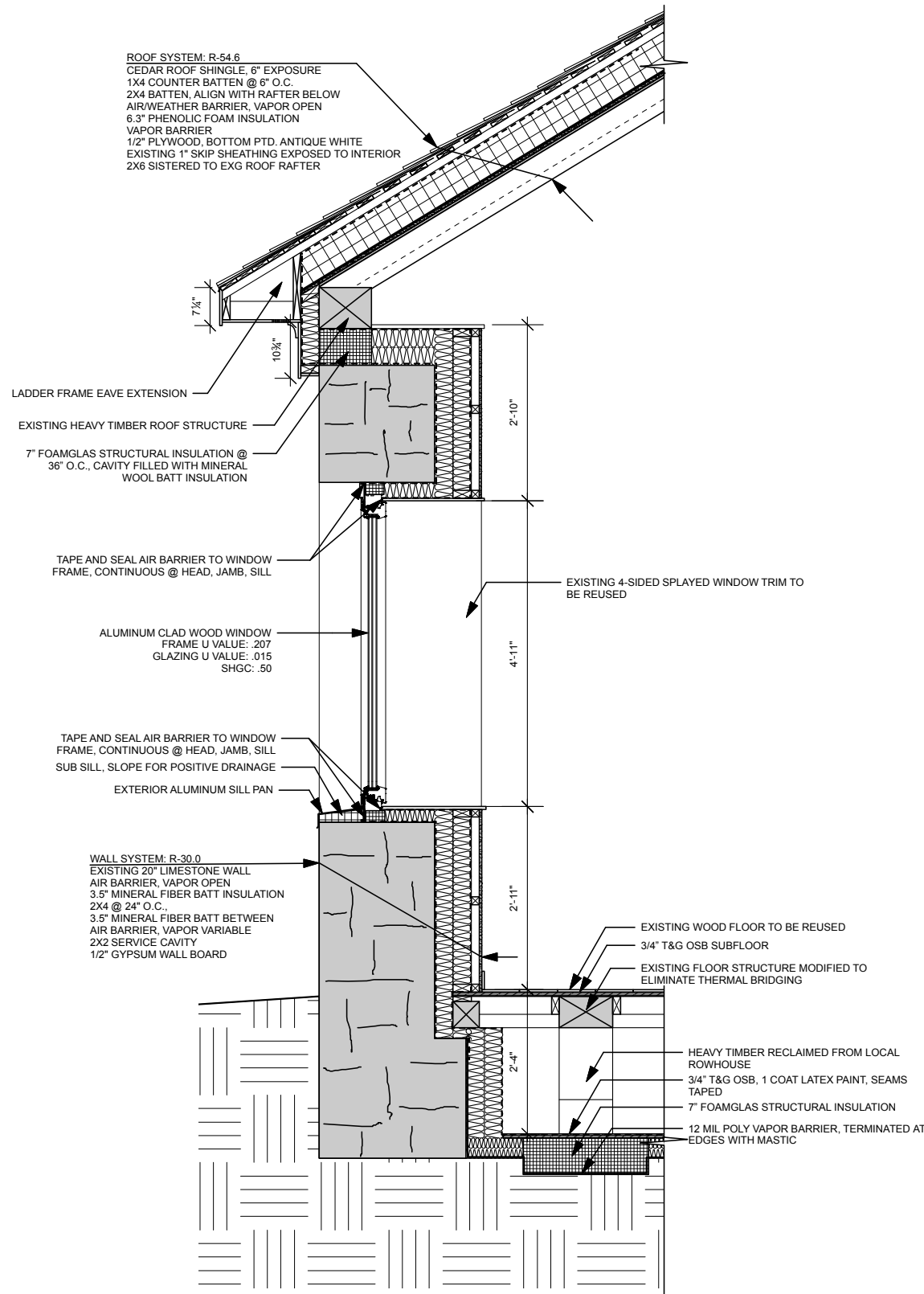
Consequently, the thermal barrier goes from the inside on the crawl space floor and walls to outside on the roof. The air barrier follows the thermal barrier, wrapping from

the crawl space vapor barrier up the interior stone wall surface, over the top of the wall to the outside, and to the roof sheathing under the phenolic foam insulation.

For an old building, the floor plan is remarkably similar to many new live-work lofts. There's a large room with a full-size kitchen and living area, and a smaller adjacent mud room, bathroom, and laundry combination. The ceiling height in the center of the main room is more than 16 feet, providing ample space for a sleeping loft above the kitchen. The triple-pane, aluminum-clad wood windows have a 0.131 U-factor and a solar heat gain coefficient of 0.5.

King states that, because of the stone wall assemblies, humidity control is essential to the project's success. For this reason, an ERV was installed that has an 87% heat recovery and a humidity recovery rated at greater than 40%. When finished in the spring of 2018, the all-electric house also will include an induction cooktop, an electric tankless water heater, and a mini-split heat pump for heating and cooling.

The project team plans to monitor temperature and humidity within the thermal layers for multiple years after occupancy to ensure that the retrofit is not damaging the existing structure. It will also track electric use to size a PV array for a net zero profile. In phase two, the



STONE SCHOOLHOUSE - TYPICAL WALL SECTION

**Passive House Metrics**

Heating energy	Cooling energy	Total renewable source energy	Air leakage
13.5 kBtu/ft <sup>2</sup> /yr	3.5	35.0	0.6 ACH <sub>50</sub>
4 kWh/ft <sup>2</sup> /yr	1.0	10.3	
42.7 kWh/m <sup>2</sup> a	11.0	110.0	

solar hardware will be mounted on a newly constructed, detached, vehicle shed roof. Once the project is finished, the new generation will have successfully picked up the architectural torch from the previous generation, and in return, will have provided them with a comfortable and efficient twenty-first-century home. Seems like a fair exchange.

—Steve Mann

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# KITCHEN *Ventilation*

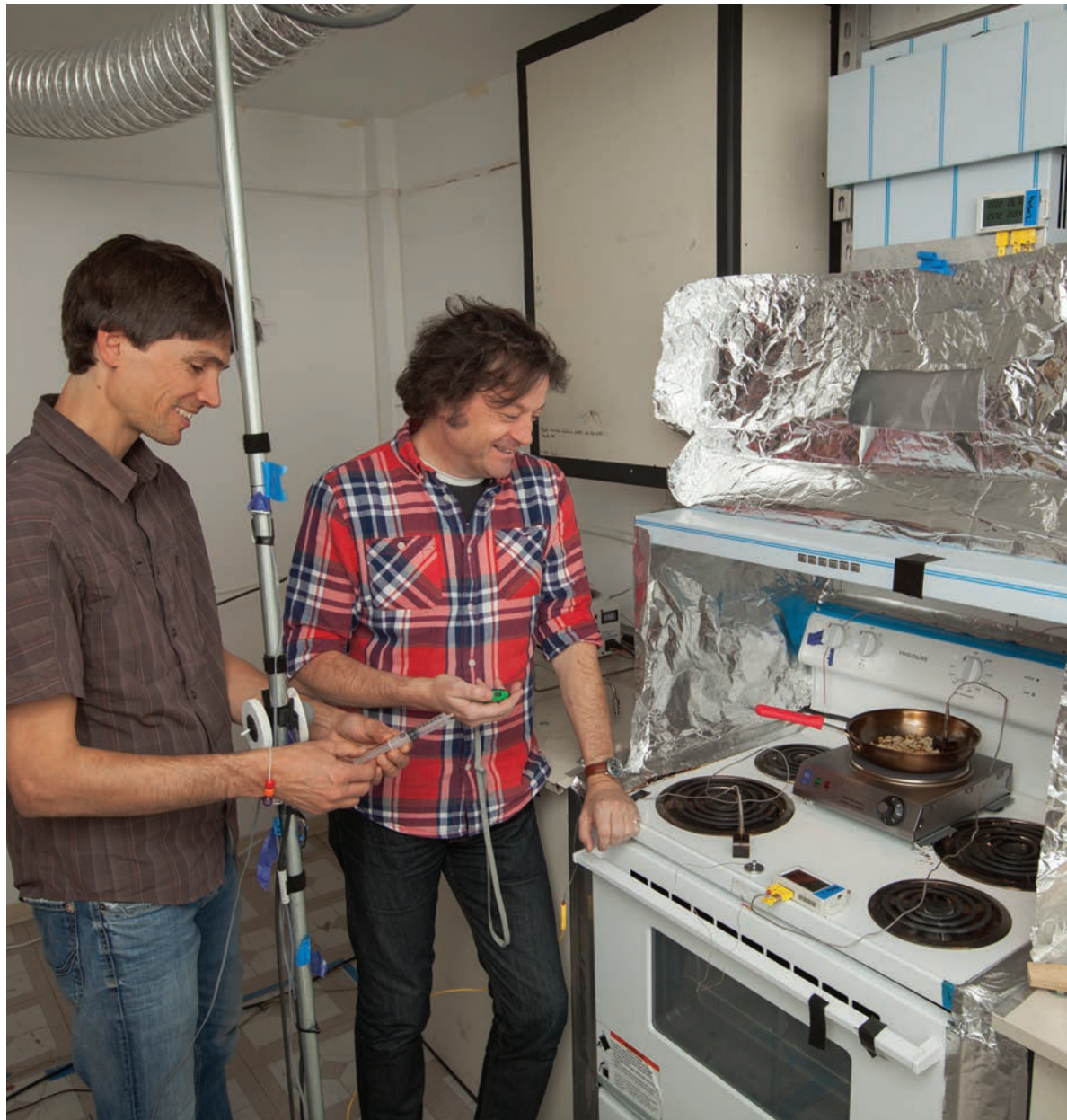


Photo by Joel Bernstein Photography

One of the more controversial topics at last fall's North American Passive House Network (NAPHN) conference was kitchen ventilation. The controversy essentially boils down to two questions. First, recirculating or extraction hood? How do these strategies compare when it comes to effectively removing cooking-generated pollutants, odors, and particulate matter? And second, what is the lowest-energy approach that adequately addresses cooking-related pollutants, especially in a highly energy-efficient Passive House, where a designer may be counting kilowatt-hours in order to meet the heating demand target?

Ongoing research at Lawrence Berkeley National Laboratory (LBNL) by Brett Singer and Iain Walker, among others, is specifically addressing how kitchen ventilation issues play out in high-performance homes, such as Passive Houses. Last year Gabriel Rojas, from the University of Innsbruck in Austria, joined LBNL, and the three coauthored a paper, "Comparing Extracting and Recirculating Residential Kitchen Range Hoods for the Use in High Energy Efficient Housing," for a presentation at the 2017 conference hosted by the Air Infiltration and Ventilation Centre, the International Energy Agency's information center on energy-efficient ventilation. Much of the following information is excerpted from that article. (The full article is available at <http://www.aivc.org/resources/collection-publications/aivc-conference-proceedings>.)

The first question to sort out before addressing ventilation strategies is, how important is removing cooking-generated pollutants? Gas burners can produce all the by-products of any combustion device, including carbon dioxide, carbon monoxide, and water, as well as formaldehyde and nitrogen dioxide (NO<sub>2</sub>). In homes where cooking with gas burners regularly occurs and where kitchen exhaust ventilation is not used, cooking burners are the major source of NO<sub>2</sub> exposure, and concentrations can routinely exceed health-based standards for ambient-air quality.

While electric-powered cooktops generate fewer pollutants than gas ranges do, switching devices does not substitute for adequate ventilation. No matter the heat source, cooking emits ultrafine particles, fine particulate matter (PM<sub>2.5</sub>), volatile organic compounds, and odors. Even boiling water on an electric stove will typically release ultrafine particles. Much research has linked breathing fine particulate matter to respiratory diseases and cardiovascular health effects, and there is great concern and increasing evidence that ultrafine particles pose an even broader health hazard.

"It is very important to note that pollutants from cooking are typically emitted during events that release large quantities in a short amount of time," says Singer.

"For this reason, low-airflow continuous-exhaust ventilation—even when it is in the kitchen—is not adequate to address these emissions."

There is solid evidence that venting or extraction range hoods can very effectively remove pollutants generated by cooking that occurs under the hood. A well-designed and correctly installed hood can remove the majority of pollutants at an airflow of 150 CFM, and if cooking occurs on the back burner, an airflow of 100 CFM is often sufficient. Under some circumstances—such as when the kitchen is an enclosed room—high-airflow exhaust ventilation fans located on the kitchen ceiling can provide effective performance at airflows of 200–300 CFM.

For low-energy housing, such as Passive Houses, there are several problematic issues associated with extraction hoods. First, their required airflow openings are penetrations through the building envelope, creating



Photo by Joel Bernstein Photography

thermal bridges and potential air leakage sites. Second, when operating, these range hoods usually run at a flow of around 100–300 CFM, which can contribute to additional home heating and cooling loads. At higher airflows, there is also the possibility that the resulting increase in envelope pressures may reduce the airflow through exhaust air systems in other rooms, such as bathrooms.

Therefore, the use of recirculation range hoods has become standard in central Europe for highly energy-efficient housing that has mechanical ventilation with heat recovery. Recirculation hoods do not expel the extracted air to the outdoors. Instead, they pull air through a filtration system and then release the filtered air back into the kitchen. The most commonly installed recirculation range hoods include some technology for removing grease from the airstream and typically also include an activated carbon filter for odors.

Open questions remain regarding recirculation hoods' capture and filtration efficiency as a function of filter age,

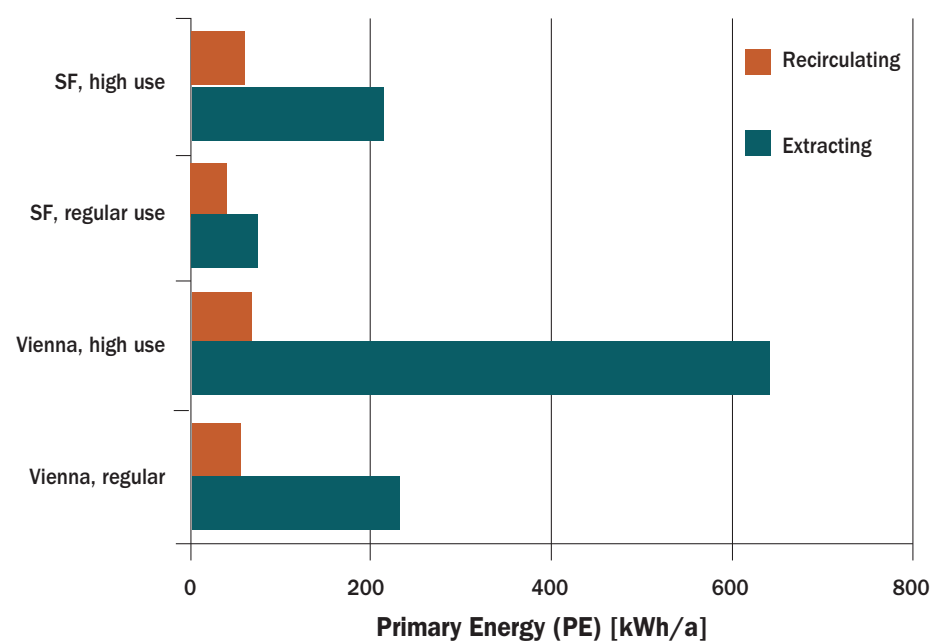


FIGURE 1.

especially for PM and odors. They also don't adequately address moisture removal, which can be a problem in humid climates. The amount of carbon and thus the capacity for odor removal varies from almost nothing to some devices that appear to have substantial capacity. One speaker at the NAPHN session was aware of only one commercially available hood that includes a filter for fine particles. This hood also includes a very large bed of activated carbon. However, the cost for this hood is on the order of \$3,000, so it is likely not an option for most homeowners.

The effectiveness of a kitchen range hood at removing pollutants can be quantified by its capture efficiency (CE), defined as the fraction of the cooking pollutants that are removed and not allowed to mix with the air in the kitchen. Besides obvious parameters like flow rate, hood design, and position, there are less-obvious influencing variables like the air currents in the room and the cooking-generated thermal plume, which in turn depends on the heat input, the type of cooking, etc.

CE is being used in a new ASTM (ASTM 2017) test method based on exhausting the pollutants to outside, but could also be used for recirculating hoods to represent the fraction of pollutants removed by the hood before the air returns to the kitchen. Now that there is a test method for range hood capture efficiency, look for future

changes to standards—such as ASHRAE 62.2 and Title 24 in California—requiring that minimum CE levels and ratings be published in manufacturers' literature and by organizations such as the Home Ventilating Institute.

A thorough review of the existing literature using the phrases “range hood,” “kitchen ventilation,” and “cooking exhaust” was performed within Web of Science. The main results of these studies are in good agreement and confirm what one would intuitively expect: higher CE for back burner use, for higher flow rates, and for hoods with a big sump. These studies also show that CE, in particular for front burner use, can vary drastically for different designs, and that the removal efficiency of particles and gaseous contaminants can differ.

Unfortunately, no scientific study was found that investigated the performance of recirculating range hoods. However, the leading German consumer magazine, *Stiftung Warentest*, recently tested 21 different range hoods in their extracting and recirculating configurations. Besides evaluating functionality, which included grease and odor removal performance tests based on ISO 61591 (and humidity removal in extracting modes), the assessment encompassed test criteria for sound, handling, energy consumption, versatility, and safety. The results of the tests are categorized in five levels, ranging from “very good” to “insufficient.” The results for grease removal in



Photo by Joel Bernstein Photography

recirculation mode were either the same or dropped by one level compared to the extraction mode. However, the odor removal performance rating ranged mostly from “medium” to “insufficient” for recirculation, with only one model rated as “very good” and another model as “good.” In comparison, all models in the extraction mode were rated “very good” for odor removal.

A number of other surveys have been performed that give insights into the characteristics of residential kitchen range hoods and their perceived performance. In one in which 85% of the respondents used an extracting device, the data show a clear trend toward less usage for households with recirculating devices. While both groups most frequently cite “not needed” as the reason for not using the hood, “doesn't work” was cited by only 5% of respondents with an extracting device but by 17% of respondents with a recirculating device. In another survey, only 6% of the households with extracting devices, but 58% of the group using a recirculating range hood, chose “not effective” as an answer to a question about their kitchen fan's effectiveness. If a fan is perceived as not effective and is therefore not used, its effectiveness falls off a cliff.

So what is the energetic benefit of installing a recirculating range hood in comparison to an extracting device? To answer that question, a set of simple

calculations were performed to estimate the difference in primary energy use for each of these two systems. The details of how the calculations were performed can be found in the original paper. The researchers conclude that for households with average use of a range hood, and in climates with moderate heating demand, there is no reason to install a recirculating range hood from an energetic point of view. For colder climates, and in particular for high-use scenarios, the reduction in heating demand due to a recirculating device could be substantial for low-energy housing (see Figure 1).

Clearly, it would be helpful if we didn't have to weigh the energy penalty of an extract hood against effective pollutant removal. There's an engineering challenge embedded in this research, according to Singer: Is reducing the energy penalty of an extract hood or creating an effective air-cleaning recirculation hood more readily achievable? And how will the costs compare? Until we have those answers, please consider participating in an ongoing study by taking a survey on kitchen ventilation at <http://kitchen-ventilation.lbl.gov/>.

**GABRIEL ROJAS, IAIN WALKER, and BRETT SINGER** are researchers at LBNL. **MARY JAMES** worked with the authors on the preparation of this article.



# COOLING *and* DEHUMIDIFICATION *Using Ventilation Supply Air*



Photos courtesy of Key Architects

The PHI's humidity threshold in a Passive House is a rigorous 12 grams of water per kilogram of air at 25°C (77°F), or .012 pounds of water per pound of air. This limit can be tough to maintain in certain high-humidity climates zones. Ishioka, a city located in Japan's Ibaraki Prefecture, northeast of Tokyo, is one such climate zone. July temperatures are consistently about 30°C (86°F), with outdoor humidity levels above the Passive House criterion, as high as 20 grams per kilogram.

Key Architects of Kamakura, Japan, tackled this problem head-on when it designed a Passive House in Ishioka. The residential structure is 150 square meters (1,615 square feet) of treated floor area occupied by six people. Initial load calculations showed a peak heating load of 1,620 watts, and a peak cooling load, including dehumidification, of 2,200 watts.

These loads were supposed to be satisfied by a 3.8-kW air-to-water heat pump installed in-line with the ERV's supply ductwork. Unfortunately, because it was restricted

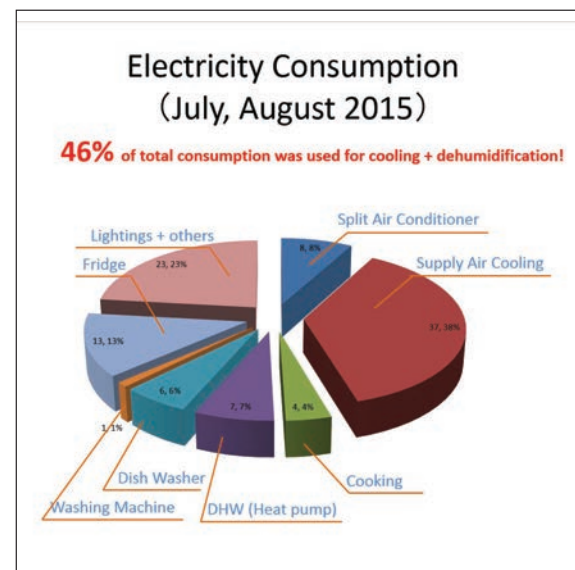


FIGURE 1.

by the ERV's airflow of 150 cubic meters per hour (88 ft<sup>3</sup> per minute), this system could only deliver 1.5 kW of sensible cooling capacity. In addition, the heat pump cycled on and off, never reaching peak efficiency, and produced higher than expected electricity bills.

Concerned about the utility costs, the owner installed an efficient ductless mini-split in the master bedroom. Fortunately, Key Architects had installed monitoring equipment in the house from the project's beginning, so the HVAC performance could be accurately monitored. The measured results for July 2015 were quite revealing.

The interior temperatures in the living space and one of the children's bedrooms exceeded 25°C (77°F), the Passive House upper threshold for summer comfort, almost half the month. The humidity levels were even worse—they exceeded 12g/kg for three weeks of that month. In addition, 46% of July's household electricity was used for cooling and dehumidification, with the ERV and heat pump consuming about 37%, and the secondary

mini-split the remaining 9% (see Figure 1). Not only was the comfort compromised, electricity consumption was too high.

In 2016, Miwa Mori, Key Architect's founder, approached a leading Japanese heat pump manufacturer to discuss a possible solution—a heat pump that could deliver gas refrigerant directly into the ERV system, but satisfy higher cooling loads as efficiently as the best Japanese equipment. The air-to-water heat pump was replaced with a proprietary, dual compressor, air-to-air heat pump that uses R410A refrigerant (see Figures 2 and 3). Rated at 2.2 kW, it was sized correctly for the cooling coil to eliminate cycling. It also has a higher coefficient of performance (COP) than the previous heat pump, 4.88 compared to 3.45, to reduce the operating costs.

The mini-split in the master bedroom was removed; the team realized that one mini-split head was not a successful way to distribute cool air throughout a house. Once again temperature and humidity levels were

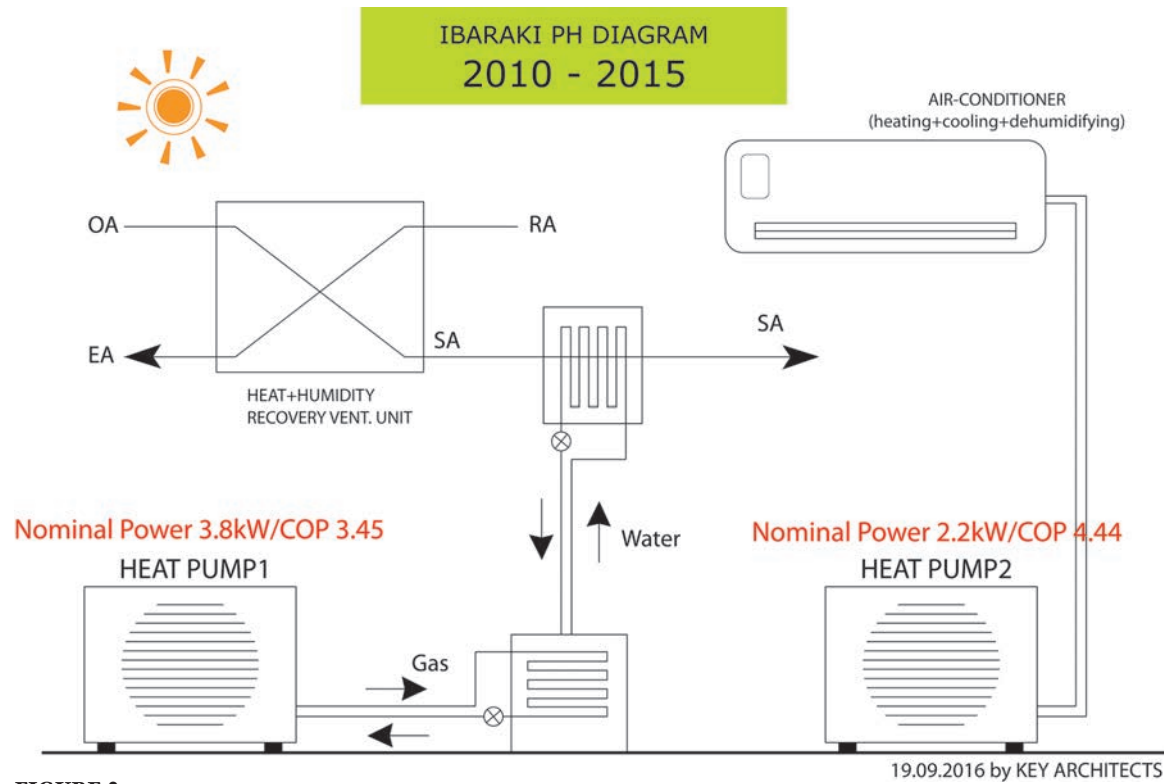


FIGURE 2.



Photos and graphics courtesy of Key Architects

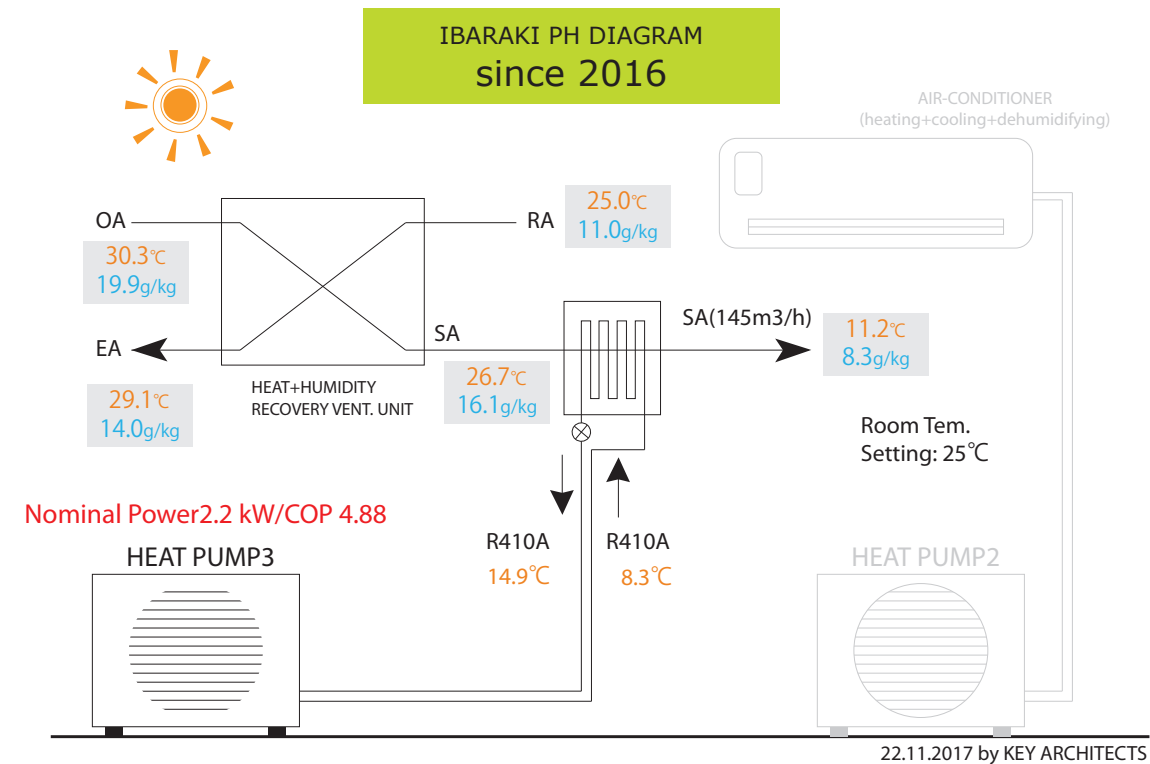


FIGURE 5.



monitored in July. The outdoor conditions were similar to the previous year.

The results were much more satisfactory. Room temperatures throughout the house stayed below 25°C for the entire month. Likewise, humidity was always below 12 g/kg. With all cooling being supplied by the ERV system, distribution was much more even. The summer sensible heat ratio (SHR) of the new system was measured at 0.50, compared to 0.73 for the first system. This means that 50%, instead of 27%, of the cooling capacity was used for dehumidification. PHI calculated the summer seasonal performance factor (SPF) as 4.62, meaning each watt of electricity consumed delivered 4.62 watts of cooling. Finally, household summer electricity consumption for cooling and dehumidification dropped from 46% to 33%.

Mori says that a few Japanese manufacturers are investigating transforming this supply-air cooling system into commercial products. She is confident that this solution—using just ventilation air to supply cooling and dehumidification—is an excellent one for Passive Houses that have high cooling and dehumidification demands.

—Steve Mann



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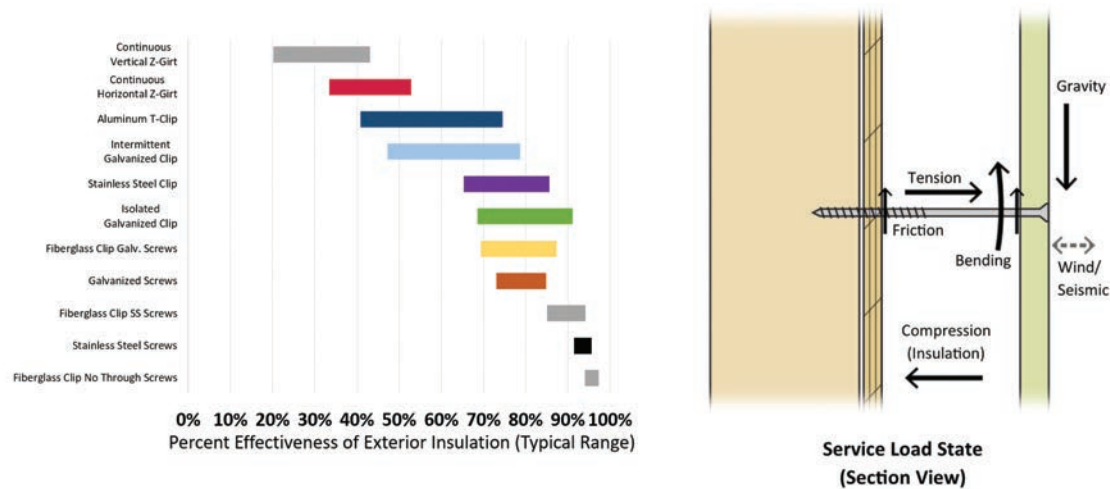
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# Getting CLADDING ATTACHMENT *Right*



FIGURES 1 AND 2. Courtesy of RDH Building Science

The Passive House standard is driving change toward installing higher R-value wall assemblies and simultaneously paving the way for products that reduce thermal bridging. As the building industry responds by using thicker layers of exterior insulation, selecting the right attachment materials becomes more important (see Figure 1). There are plenty of cladding attachment techniques currently on the market, but long screws through exterior insulation is beginning to rise above the rest for use in wood frame construction.

Although long screws have been on the market for several years now, there is still uncertainty about the method. Frequent questions that arise include “How do we install it?” “What are the allowable cladding

loads?” “What fastener type should we use?” and most commonly, “How much deflection is OK?” The results of studies conducted by RDH Building Science demonstrate that using long screws to structurally attach rain screen furring over exterior insulation is a viable and warrantable technique for attaching the most common cladding types.

## DESIGN AND FORCES

To understand why, consider the combination of forces acting on long screws. The most obvious force is the gravity load of cladding working against the bending resistance of the fastener when the load is applied to rain screen furring. Introducing exterior insulation between the rain screen furring and the backup wall creates the



Bella Bella Passive House under construction in factory. Photo courtesy of Monte Paulsen, RDH Building Science

formation of a truss. This system relies on tension of the screw and compression of the insulation by the strapping to resist the cladding load (see Figure 2). In addition, some load is also resisted by the force of friction between the insulation and the sheathing membrane. With this in mind, it can be difficult to determine exactly which forces to rely on, when aiming to create the optimal design. This is where testing comes in.

## TESTING

Testing completed by Building Science Corporation in 2013 looked at insulation in the 2- to 4-inch range and combinations of mineral wool, EPS, and XPS insulations paired with cladding such as adhered stone veneers,

stucco, fiber cement siding, wood siding, and vinyl/metal siding (Baker, 2013/2014). Using a hydraulic ram to apply load, the team found that the heaviest material, stone veneer, created up to 1/8 inch of deflection—not a significant amount.

RDH built upon this study, testing insulation assemblies with thicknesses of 3, 6, 9, and 12 inches. We also looked at different insulation types with different compressive strengths. Lastly, we compared different fastener angles (arrangements). The results for the 6-inch insulation board showed that once the load on a fastener exceeded 200 pounds, 1 inch of deflection was recorded. However, this is not bad news. Two hundred pounds is very heavy, and typical claddings weigh less than 5

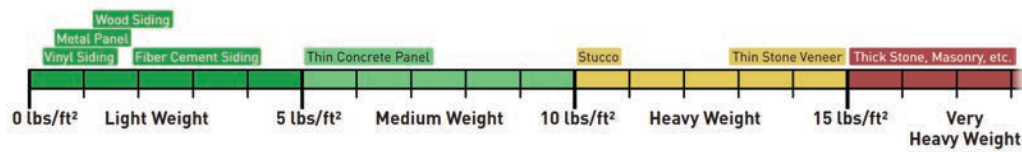
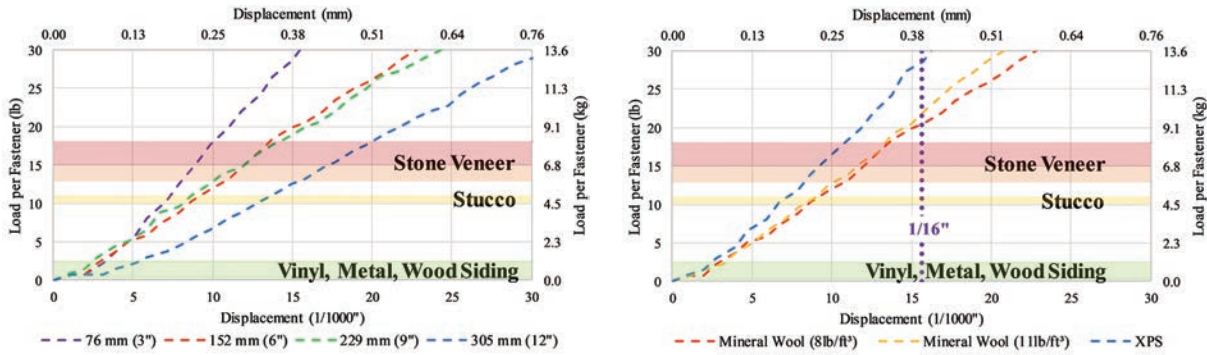
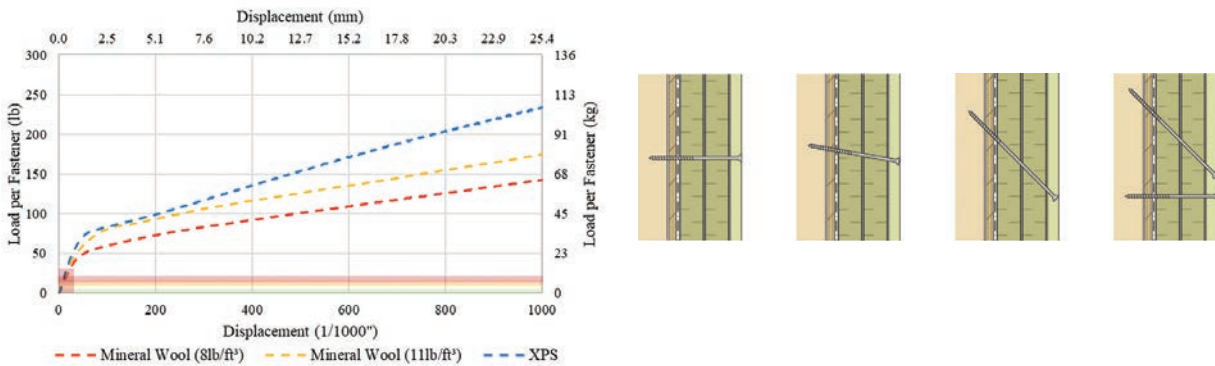


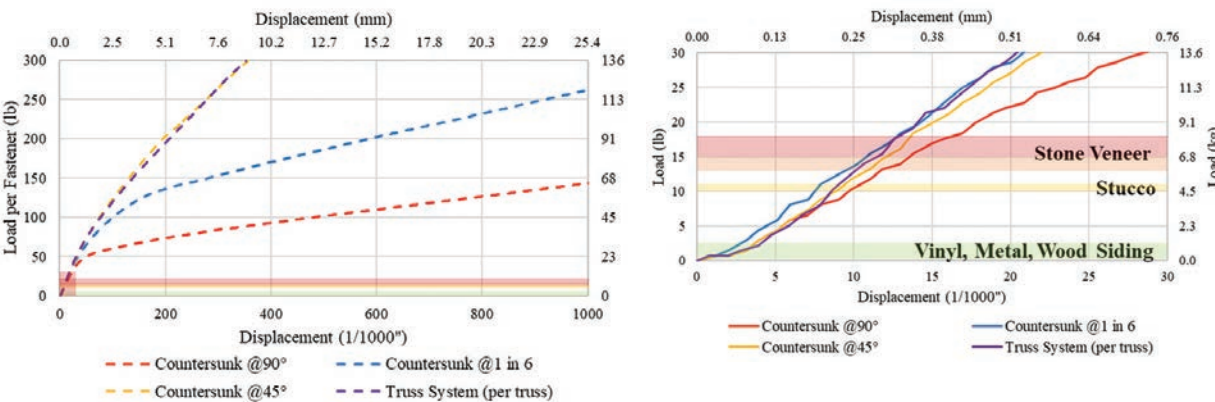
FIGURE 3. Courtesy of RDH Building Science



FIGURES 4 AND 5. Courtesy of RDH Building Science



FIGURES 6 AND 7. Courtesy of RDH Building Science



FIGURES 8 AND 9. Courtesy of RDH Building Science



Bella Bella Passive House. Photo courtesy of Monte Paulsen, RDH Building Science

pounds per square foot, with heavier claddings weighing 10–12 lb/ft<sup>2</sup> (see Figure 3). Looking at how typical loads will actually perform, the maximum deflection reached would be 1/64 inch even for the heaviest cladding types (see Figures 4, 5, and 6).

To counter deflection, many European designers have suggested building a truss system with the fasteners, with one fastener at a 90° angle from the sheathing, and another at a 45° downward angle. Our team tested this system along with more-standard fastener arrangements at 90°, 80.5° (1:6), and 45° (see Figure 7). The results showed that the truss system method and countersunk at 45° were the stiffest compared to other arrangements. Again, when examined closely at typical cladding loads, the load displacement result lines are all very similar, as shown in Figures 8 and 9.

### ACCEPTABLE DEFLECTION?

Although it is difficult to define the precise limit of how much deflection would be acceptable, many claddings can easily accommodate up to 1/8 inch of deflection. To put this level of deflection in perspective, we compared it to wood shrinkage due to drying. For a typical wood-framed, single-story building, shrinkage of approximately

3/8 inch could be expected—10 times the amount of the measured deflection noted in our testing.

### BELLA BELLA PASSIVE HOUSE

This Passive House project was built in 12 modular parts in a factory before being shipped to a remote location on the British Columbia coast, where the parts were assembled on-site. The modules' assemblies included 6 inches of mineral wool insulation on the exterior with vertical strapping and long screws, as well as metal cladding. Investigation on-site revealed no sign of cladding movement during the modules' journey from the factory to the site.

**MICHAEL AOKI-KRAMER** is a managing principal and **LORNE RICKETTS** is a building science engineer at RDH Building Science, Incorporated.

**MORE DETAILS ABOUT THIS RESEARCH** can be found in *Tatara, J., and L. Ricketts. Structural Testing of Screws through Thick Exterior Insulation. 2017. To view this report, go to <https://buildingsciencelabs.com/wp-content/uploads/2017/11/CCBST-2017-Structural-Testing-Screws-through-Thick-Exterior-Insulation.pdf>.*

# PHPP ILLUSTRATED, Second Edition

**P**HPP is a powerful design tool for creating high-performance buildings, because it calculates the energy balance transparently and accurately.

And *PHPP Illustrated* is an essential companion.

This resource helps anyone learning to use PHPP or mastering it. Even expert users will want a copy to confirm their understanding—and to help them quickly guide less-experienced users with clear textual explanations and beautiful illustrations.

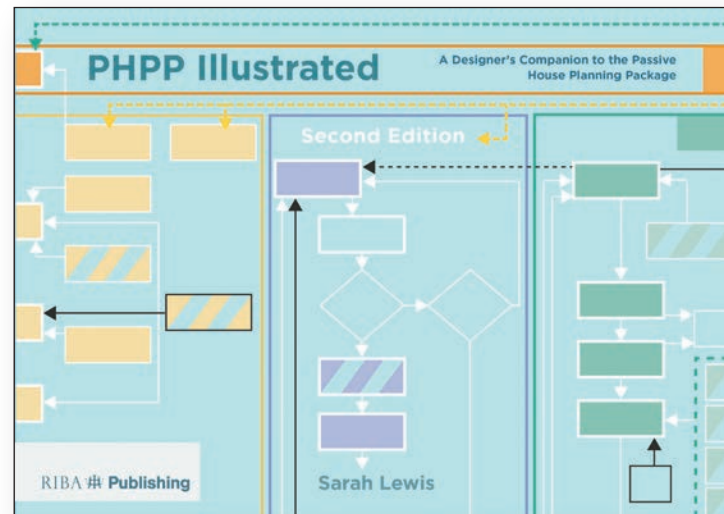
Like the popular first edition (2014), Lewis's second edition begins with a succinct explanation of the design principles for Passive House buildings. As with all the other topics, this one is richly illustrated. My favorite section in the introduction is Lewis's explanation of the form factor, and the illustrations of varying shapes where the envelope surface varies substantially even with the same usable floor area.

Chapter 2 covers PHPP basics, and here is substantial new material, including a clear and complete explanation of the Primary Energy Renewable (PER) metric and PHI's new standards incorporating higher levels of efficiency and renewable-energy production. Additionally, Lewis carefully delineates the thermal performance and component pathways for EnerPHit certifications.

Chapter 3 follows the first edition in covering the heating demand basics—what I call the architectural sheets of PHPP (as opposed to the energetic equipment, appliance, and lighting sheets). For readers who already own the first edition, you'll be happy to know that the second edition uses a new case study home to illustrate PHPP.

Chapter 6 is a brand-new introduction to *designPH* by David Edwards, one of its creators at PHI. This chapter includes not only clear, well-organized descriptions, but illustrations of the same case study building in the other chapters, as well as frequent tips to users.

Chapter 8 is another brand-new chapter, introducing the additional functions incorporated in PHPP Version



9 to compare multiple assemblies in the same building as well as to compare multiple buildings that are slightly different, such as row houses. These tools even offer cost, payback, and value comparisons, and are especially useful when planning a retrofit.

As a person who learns best by example, I find the screen shots of PHPP showing exactly how the details of the example building are entered to be the most valuable feature of both editions. Having two sample PHPPs is easily worth the cost of these books. In addition, Lewis covers new features of PHPP Version 9, including the new Check Sheet, an extremely helpful set of cautions and error detectors for each sheet.

When I am working in PHPP, Lewis's books are always at my elbow. And when consultants or designers call with a question about PHPP, I usually refer them directly to a page that will answer their questions.

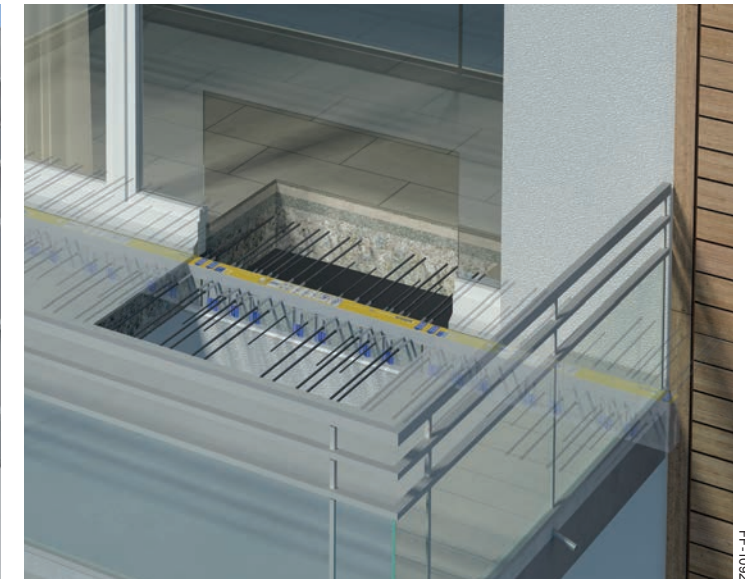
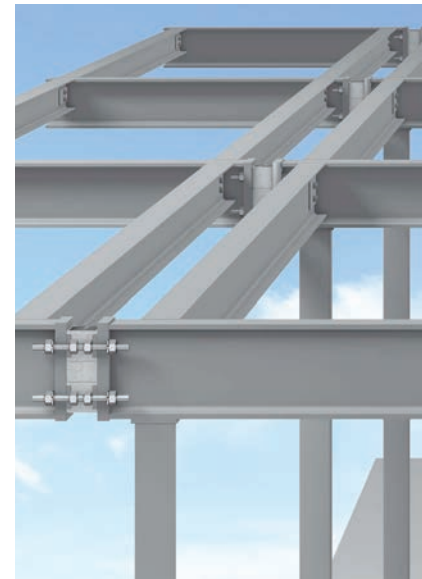
—Tad Everhart

*THIS ARTICLE originally appeared in the Passive House Northwest newsletter.*

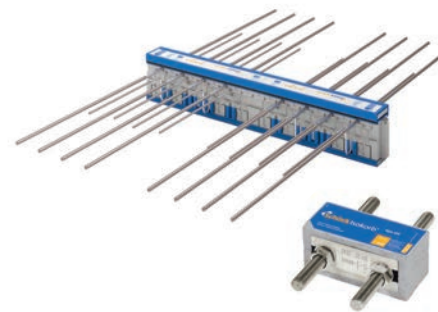
**LEWIS, SARAH.** *PHPP Illustrated: A designer's companion to the Passivhaus Planning Package.* RIBA Publishing, 2017.

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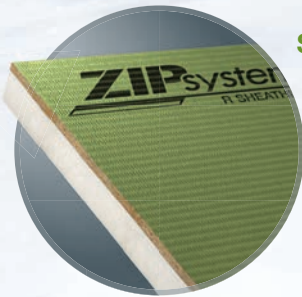
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