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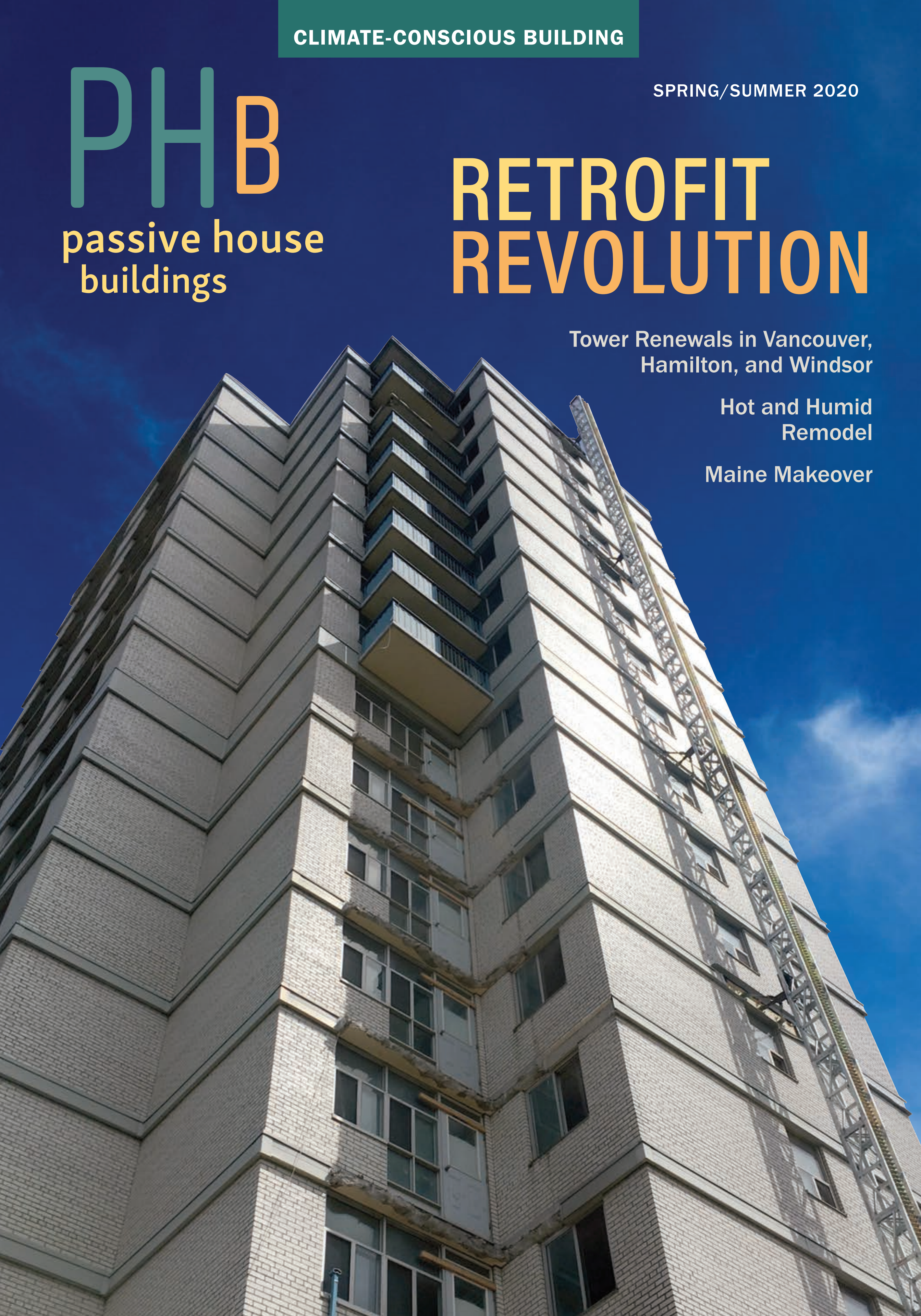
SPRING/SUMMER 2020

RETROFIT REVOLUTION

Tower Renewals in Vancouver, Hamilton, and Windsor

Hot and Humid Remodel

Maine Makeover



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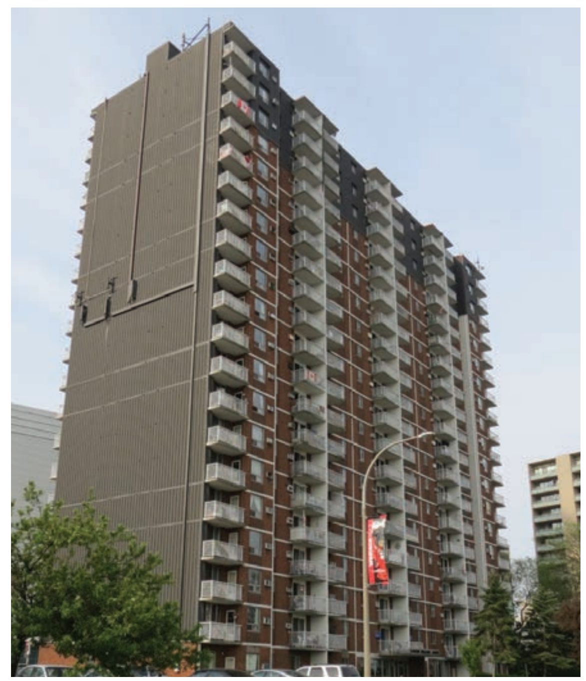

Index of SPONSORS

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EDITORIAL

In late December my heating system broke down, and it took six days to get the problem repaired well enough that I could get any heat. Fortunately, the indoor temperatures only dropped into the low 60s, because I started off with two advantages. I live in Northern California, so the outdoor temperatures dipped down into the high 30s at night but were up in the high 50s during the day. The other huge plus was that ten years ago I abandoned my previously unsuccessful Band-Aid attempts at making my poorly constructed house comfortable and undertook a phased retrofit toward the EnerPHit standard. In 2009 the Passivhaus Institut's research was instrumental in helping me identify renovation strategies that effectively improved the durability and comfort of my home.

Existing buildings simultaneously pose a huge problem in terms of carbon emissions from the built environment, and provide a very large market opportunity—which is why the bulk of this issue's articles are devoted to deep energy retrofits. Although renovations of single-family dwellings can be straightforward, they rarely are. In a comment that will be all too familiar to many readers, Jesper Kruse said of his own Passive House retrofit (p.38), "Everything is a big project."

Scaling up a deep energy retrofit to the size of a multifamily building greatly amplifies a project's challenges, and yet these projects must be, and are being, tackled. This issue features three EnerPHits of tall towers: one in Vancouver, British Columbia (p. 16); one in Hamilton, Ontario (p. 20); and one in Windsor, Ontario (p. 26). Go Canada! South of the Canadian border two programs modeled on the Dutch Energiesprong approach, one led by NYSERDA and one by the Rocky Mountain Institute with assistance from PHIUS, are paving the way for industrializing retrofits of multifamily buildings (pp. 4 and 10).

Exemplary and ambitious as deep energy retrofits are, reducing emissions from the built environment requires considering both embodied and operational carbon emissions. To say that trying to figure out the overall impacts in any given project is a complex task is a gross understatement, and yet our changing climate demands that we not shy away from it. In "Can Buildings Be Leveraged to Help Reverse Climate Change?" Philippe St-Jean thoughtfully addresses this topic, reporting on several tools that simplify the required calculations (p. 74).

In all these projects, the appropriate products are key to creating very low-energy and net positive buildings. The extremely heartening news in 2020 is the growth in availability of these key products. As always, a big thank you goes out to our sponsors, whose support is essential to our publications and to the completion of so many Passive House projects.

Of course, the North American market is still lacking certain critical products—a compact, integrated mechanical system, for example—that are available elsewhere, such as Europe and now China. Fortunately, positive developments are in the pipeline. Stay informed about innovative products and cutting-edge projects by regularly visiting passivehousebuildings.com.

—Mary James
Editor and Publisher

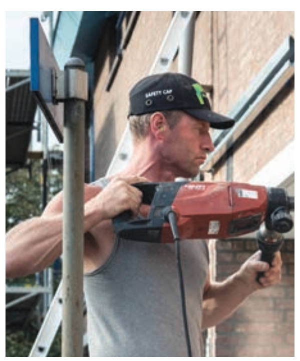
RetrofitNY *Enters* Second Phase

Photos courtesy of Rocky Mountain Institute

RetrofitNY, NYSERDA's (New York State Energy and Research Development Authority's) initiative to scale up deep energy retrofits of multifamily buildings, is moving forward with a refined set of goals for phase 2 of the initiative. RetrofitNY is an adaptation of the Energiesprong approach to industrializing retrofits that was first developed in the Netherlands, has since spread to France, Germany, Italy, and the UK, and has now gotten a foothold in North America. (For more on the Retrofit-NY initiative, see passivehousebuildings.com/magazine/spring-2019/industrializing-deep-energy-retrofits/.)

The initial phase of this effort saw the creation of six teams with extensive building science experience who undertook proof-of-concept retrofit pilots in low and midrise residential buildings. Assembling those teams was one of the key phase 1 objectives, according to Christopher Mahase, senior project manager in NYSERDA's Multifamily Residential program. Mahase is charged with overseeing the RetrofitNY initiative. All six teams produced reports on their progress this past August, which can be found on NYSERDA's website.

While team building is still a critical aspect of phase 2, says Mahase, lessons learned from phase 1 have informed phase 2 goals. "We've added a dedicated emphasis on manufacturing," he says. "One of the keys going forward is making sure we have manufacturers that have viable products."



The Energiesprong program in the Netherlands has been succeeding in part because there existed a base of building component manufacturers who responded to the program's aggregated demand for retrofits by adding to or adapting their product lines. Analyses of Dutch projects show that the cost of essential industrialized retrofit elements has been dropping since 2010—by 37% for prefabricated envelope systems and by 73% for integrated mechanical systems.

Panels in factory lined up and ready to be installed in an Energiesprong retrofit in the Netherlands.

In New York the lack of access to specialty retrofit products has been a source of frustration. To quote from a report produced by one of the RetrofitNY teams, which was led by the International Center for Appropriate and Sustainable Technology: "It was NYSERDA's goal to find or create a market for panel manufacturers similar to those present in Europe, but our extensive efforts failed to identify a single U.S. manufacturer who actually makes retrofit panels."

Although panels exist for the new-construction market, these panels have a load-bearing capacity that is unnecessary—and therefore not cost-effective—for a retrofit project. A comprehensive, compact mechanical system is another crucial product that so far is missing in action in the U.S. market.

To fill these product gaps, NYSERDA is stimulating the emerging market for comprehensive integrated retrofit components, using a multipronged approach. The agency is working to accurately quantify the market opportunity by such means as updating its multifamily residential baseline study and commissioning more detailed architectural studies of the New York State building stock. Simultaneously NYSERDA is issuing solicitations supporting suppliers. Last October NYSERDA issued a solicitation to design and manufacture what it is calling an energy pod: "An energy pod will meet a dwelling unit's heating, cooling, ventilation, dehumidification, and domestic hot water needs on a distributed basis in one cost-effective, compact unit." A separate solicitation is targeting manufacturers of building envelope components to address the need for retrofit panels.

With greater engagement from manufacturers, retrofit costs could become more reasonable, enabling more building owners to undertake the goal of achieving net zero performance in existing buildings. In the first pilots, Mahase was quite surprised at the gap between projected and actual incremental costs. "The incremental costs to achieve an all-electric net zero building averaged $70,000 per dwelling unit," he says. To facilitate construction, NYSERDA relaxed the prescribed energy use intensity performance targets for the retrofit pilots to 27 kBtu/ft^2 per year and is providing subsidy of $30,000–$40,000 per unit to make this achievement more realistic.

The other concession made concerned the agency's goal of achieving all-electric buildings, in keeping with New York State's climate goals; at this point all-electric water heating was not feasible for some of the building owners. However, Mahase says that he expects this issue to be solved in the not-too-distant future. In the meantime, the RetrofitNY program is working to leverage all the benefits of electrification, including the potential insurance savings associated with no on-site fossil fuel consumption, because of the reduced risk of fires and carbon monoxide emissions.

Phase 2 of the RetrofitNY program, including the piloting of new technologies and creating a production ramp for engaged manufacturers, is set to kick off in late 2020 or early 2021. Another solicitation will be issued in support of innovative business models in the construction space—ones that can scale up sufficiently to meet the demand for renovating multifamily buildings so that they use at least 70% less energy than previously, and that will move this sector toward meeting the state's ambitious climate goals.

—Mary James

Passive House Pilots Completed in MEXICO

Photos courtesy of Passive House Institute

Thirty low-income families in Mexico are now experiencing the benefits of Passive House residences thanks to a pilot program funded in part by the European Union's Latin America Investment Facility (LAIF) Component of the EcoCasa Program. These Passive Houses constitute a small part of the EcoCasa Program, which is helping to pay for the construction of more than 27,000 low-carbon homes throughout Mexico.

Mexico's residential housing sector is responsible for 16% of the country's total energy use and 26% of its electricity use. The Passive House component of the EcoCasa Program, managed by Sociedad Hipotecaria Federal, grants credits for the construction of energy-efficient houses that achieve at least a 20% reduction in greenhouse gas emissions. In hot climates like Monterrey and Nogales, the Passive Houses achieved an 80% reduction of CO_2 emissions solely by saving energy. The Consortium GOPA | Passivhaus Institut, with the collaboration of IzN, provided technical support, working with local advisors to guarantee that all projects achieved the Passive House standard and were built according to plan.

The five row houses in Morelia, which is situated at 2,000 meters above sea level, were among the first to be completed. In this temperate climate, with only a few improvements to the thermal envelope, it was found that a small electric heater was sufficient to ensure that the homes remained comfortable. The ten row houses in Guadalajara, a little southeast of Morelia, did not require mechanical cooling or heat recovery ventilation either. In such temperate areas as Morelia and Guadalajara, PV panels generated sufficient electricity to reduce CO_2 emissions by 80%.

Farther north in Nogales, which is just south of the U.S. border, ten duplex homes were constructed. This location is much closer to the desert, so the building envelope required 5 inches of insulation and triple-glazed Passive House-certified windows. Only two small mini-split units are providing the heating and cooling needed in each home. As in Morelia, heat recovery ventilation was not required.

In Monterrey, a city south of Texas with a hot semihumid climate, five row houses were built. These homes required mechanical ventilation with heat recovery, making Monterrey the only pilot site to require comfort ventilation.

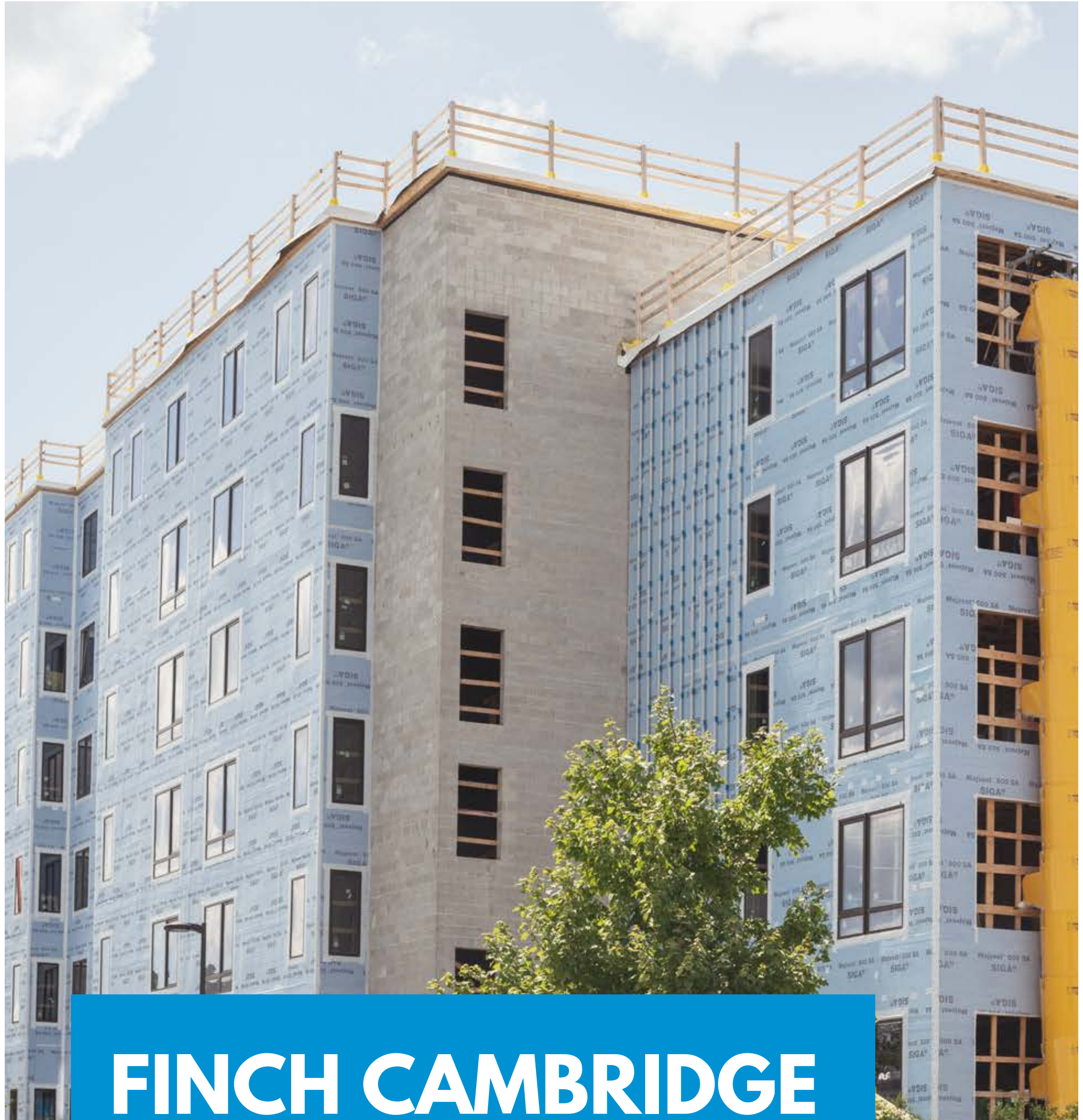
At each of these sites, for a project plan to be approved, an economic analysis had to show that the additional investment costs would be completely offset by the savings realized on electricity and gas bills. In other words, these first new-built houses to achieve the Passive House standard in Mexico and Latin America are great examples of cost-effective solutions to create very high-performing homes in this region.

These homes provide a path for residents to adapt to the impact of climate change, and to help move Mexico toward a 50% reduction in carbon levels by 2050. The project is expected to reduce one million tons of CO_2 in its first seven years. On the horizon there may be a second phase of the LAIF component where developers can choose to use Passive House designs.

For more background on this project, see "Applying the Passive House Standard in Mexico" in the 2017 issue of *Passive House Buildings*.

—**Sydney Gladu**

SYDNEY GLADU *is a freelance journalist based in Seattle, Washington.*



FINCH CAMBRIDGE

New England's largest multi-family, Passive House project

Finch Cambridge, formerly known as Concord Highlands, is a 6-story residential building which is expected to be Cambridge's largest new-construction, 100% affordable housing development in over 40 years. Not only is the building set to provide affordable housing to the market, but it's also expected to be New England's largest multi-family, Passive House building with 98 affordable apartments.

"I fought hard to keep a different WRB on this project. I'm glad I lost that fight."

- Matt Smyka, NEI General Contracting

Majvest 500 SA

Majvest 500 SA is the air and weather barrier on the project. It enabled the installers to use the same product on 3 different substrates (DensGlass, plywood and CMU) without requiring primer.

Wigluv

Wigluv 60, 100, 150 and 230 were used to seal the overlap seams of Majvest 500 SA and flash the windows to create an airtight building envelope.

Fentrim IS 20

The pre-folded adhesive tape was used on the interior of the windows to create an airtight connection.

SIGA 1966

Skip the primer.
Email americas@siga.swiss about the Majvest 500 SA.

Catalyzing ZERO-CARBON Retrofits

Photo courtesy of REALIZE Project Team

REALIZE, a Rocky Mountain Institute (RMI) initiative, aims to catalyze a zero-carbon retrofit revolution. Inspired by Energiesprong, an innovative industrialized zero-energy retrofit approach developed in the Netherlands, REALIZE is combining demand aggregation and supply chain coordination to deploy prefabricated retrofit systems that are easy and fast to install and can ultimately be financed through utility cost savings. Through awards from the U.S. Department of Energy (DOE) and the California Energy Commission, REALIZE is launching several pilots to demonstrate Energiesprong-like retrofit packages in the affordable multifamily housing market.

The goal of REALIZE's DOE project is to develop a standardized, climate zone specific net zero energy ready retrofit system, designed to achieve at least a 50% lower energy use intensity (EUI) relative to the measured baseline energy performance. This retrofit package is to be demonstrated and validated on one or two multifamily buildings of 30+ units each. RMI is working with PHIUS, Staengl Engineering, Re:Vision Architecture, and The Levy Partnership to deliver the project.

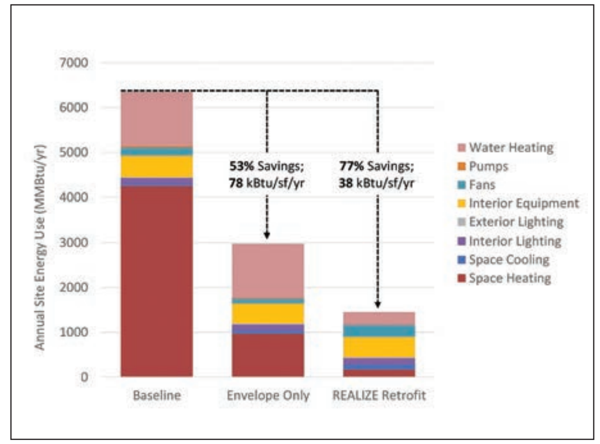
To make sure the systems developed in the DOE project are scalable across the pilot building region, RMI undertook a study to identify the most common building typologies and HVAC systems in ASHRAE climate zones 4 and 5 for 30+ unit multifamily buildings. Based on the American Housing Survey and the Residential Energy Consumption Survey (RECS) 2015, RMI determined that 5- to 19-unit buildings (low rise) and 50+ unit buildings (midrise) with the three HVAC bundles listed in Table 1 are the most common typologies.

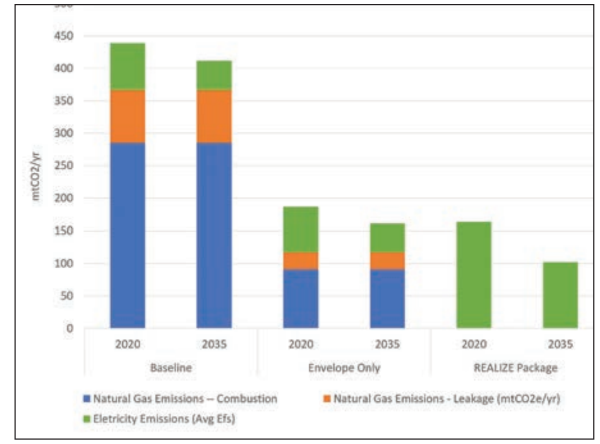
Based on the typology study, REALIZE issued a request for proposals for a pilot building and selected Eva White Apartments, a multifamily property consisting of two separate seven-story buildings located in Boston, Massachusetts. Ultimately REALIZE chose to limit the pilot to one 38,349-ft^2, 53-unit building. Eva White, which was submitted for consideration by WinnDevelopment, is currently owned by the Boston Housing Authority (BHA), who is working with WinnDevelopment and Castle Square Tenant Organization (CSTO) on the property's anticipated Rental Assistance Demonstration (RAD) program conversion and low-income housing tax credit rehabilitation project.

Originally constructed in 1967, Eva White fits within the first HVAC typology described in Table 1, with central natural gas boilers and hydronic baseboard distribution supplying space heating, while window air conditioners installed by tenants provide cooling in some apartments. The property's energy audit and subsequent modeling exercise revealed the prevalence of electric space heating to supplement the building's central gas fired boiler plant. Central, high efficiency condensing water heaters and storage tanks provide domestic hot water for the building. As a concrete building with brick veneer, Eva White's building envelope is extremely inefficient, with uninsulated walls (R-1), single-pane windows, and a minimally insulated roof (R-9) and exposed floor (R-7.9). Given the building's location, envelope construction, and existing HVAC systems, Eva White fits the criteria of the common typologies identified by REALIZE and represents a significant opportunity for substantial energy savings.

TABLE 1. Top HVAC Bundles for ASHRAE CZ 4 and 5 from RECS 2015

	HVAC Bundle 1	HVAC Bundle 2	HVAC Bundle 3
Heating system	Steam or hot water system with radiators or pipes	Central furnace	Electric furnace or baseboards
Heating fuel	Piped natural gas	Piped natural gas	Electricity
Air-conditioning	Room	Central	Central
Number of units represented	1,582,364	1,289,997	1,179,079
Percentage of total multifamily units	17.4%	14.2%	13%





(left) Figure 1. Modeled annual site energy use (right) (Source: REALIZE Team Analysis) Figure 2. Annual CO_2 emissions. Key assumptions: average electricity emissions factors; Massachusetts reaches its Renewable Portfolio Standard goal of 50% renewable electricity by 2035; 2.3% natural-gas leakage rate. (Source: REALIZE Team Analysis)

The building has a baseline annual energy use intensity (EUI) of 166 kBtu per square foot, with space heating accounting for more than 60% of the building energy use. Given the low insulation values of the envelope, improving the building's shell alone presents a large opportunity for heating load reductions and annual energy savings, along with improved comfort for residents and durability. The REALIZE team identified a standardized retrofit specification based in large part on PHIUS guidelines for climate zones 4 and 5 and the 50% EUI reduction goal. The proposed REALIZE retrofit package includes improvements to the exterior envelope, HVAC system, and domestic hot water system. The proposed package also seeks to completely electrify the building. The REALIZE team, along with WinnDevelopment's design team and engineers of record, are currently in the process of reviewing conceptual designs, which must be considered and evaluated for cost, impact (carbon and cost), replicability, durability, and constructability.

BUILDING ENVELOPE: The REALIZE retrofit package specifies an R-32 exterior wall and R-40 roof insulation to reduce the thermal load of the building. The project is considering a light-weight insulated exterior panel product that will bring the total effective R-value of the walls and roof to R-33 and R-41 respectively. The new integrated wall panel—including a weather barrier, insulation, high-performance windows (U-0.26), and cladding—will drastically reduce air infiltration and thermal bridging and is designed to be installed quickly with minimal disruption to building residents.

HVAC AND PLUMBING: Heating, cooling and ventilation will be provided by a rooftop central plant with in-unit "mechanical pods". The in-unit pod is expected to include an ERV, a fan coil unit, and monitoring and controls equipment. REALIZE is considering two different central plant options, either a VRF system or air-to-water heat pumps. REALIZE expects either system to require new refrigerant or hydronic pipes, which will be mounted vertically along the exterior of the building between the new retrofit panels and the existing façade. Either system will provide central cooling to all apartments, an upgrade the residents and owner wish to achieve. REALIZE is also evaluating an all-electric solution for domestic hot water production, which will be heated primarily by waste heat from the air-to-water heat pump or VRF system and delivered through existing DHW piping. Back-up electric resistance may be required to satisfy the building's domestic hot water demand on certain design days.

In addition to the envelope and mechanical system upgrades, the project will include upgrading appliances, lighting, and cooktops to help reduce internal equipment loads in the building.

The anticipated REALIZE scope of work is projected to reduce Eva White's current EUI of 166 kBtu per square foot per year to an EUI of 38, representing a 77% reduction, significantly exceeding the program's 50% goal (see Figure 1). The REALIZE package is also estimated to reduce Eva White's carbon emissions by 80% by 2035 compared to baseline values (Figure 2). This emissions reduction impact is expected to grow with time as Massachusetts advances its carbon neutral goals through renewable energy deployment and energy efficiency investments. Due to Eva White's limited open roof area, the project is not ideal for onsite PV, which has not been included in the preceding carbon emissions projections. A rooftop PV array has been estimated to offset approximately 12% of post-retrofit electricity use.

NEXT STEPS: To reach scale and revolutionize how existing buildings are renovated, REALIZE must first implement thoughtful, and successful, demonstration

Q&A with Chris BALLARD

Sydney Gladu spoke with Chris Ballard about his new position as Executive Director of Passive House Canada.

Photo by Greg King

Sydney Gladu: What motivated you to switch from Ontario's minister of Environment and Climate Change to Passive House Canada?

Chris Ballard: I left politics in 2018, but I was still very passionate about the need to find some concrete solutions to the growing climate crisis. And it didn't take me very long to see that this position is a phenomenal opportunity to make real change in how we address the climate crisis in Canada. The climate crisis is top of mind here in Canada. When individuals learn about Passive House, they are excited about how it works.

SG: Passive House Canada has been key to the inclusion of Passive House in building codes there. How will you build on those efforts?

CB: We need to make sure other provinces across Canada are adopting the Passive House standard in their building codes, and we can't wait for 2030 or 2050, when the national building codes start to change. We need it sooner. We have to push toward government regulation for Passive House standards; we have to get the professional community on board; and we have to do the same for tradespeople. Those are the three groups I'll be focusing on.

SG: What benefit do you see to working in the nonprofit sector as compared to a provincial government when it comes to climate change?

CB: It is another way of achieving a goal. As Ontario's minister of Environment and Climate Change, my focus was on regulatory solutions—solutions to help the province crack down on greenhouse gas pollution—and educating the public in Ontario. Working with Passive House Canada we are not regulators, but we are educators and we have solutions. This is an opportunity to work closer to the ground and offer real solutions to the ministers and the leadership across the country. They are looking for solutions, and yet too many of them do not know about Passive House standards. Passive House Canada is a solution-based organization, and that is kind of fun to work with.

SG: What does building sustainable communities in Canada look like to you, and how is Passive House a part of that vision?

CB: I have a very simple definition that it is a place that people want to live, work, and play in. When I look at Passive House standards, I see homes and buildings that are wonderfully comfortable to live, work, and play in and are gentler on the environment. Passive House is a foundation for a sustainable community right across the country. Given the weather and climates we have, Canada is poised to be a Passive House leader around the world and export our knowledge and products around the world.

—**Sydney Gladu**

SYDNEY GLADU *is a freelance journalist based in Seattle, Washington. This interview has been edited for clarity.*

"Catalyzing Zero-Carbon Retrofits" continued from p. 9

projects. REALIZE must advance this early concept for Eva White through design development as well as pricing exercises, all of which must be coordinated with Eva White's upcoming RAD conversion, which presents a critical opportunity to leverage a major recapitalization event and financial transaction typical of affordable housing developments. The project team anticipates additional financial resources will be needed to support the project's added costs, which are expected to be approximately $40,000/unit, and is actively engaging potential sources interested in electrification and carbon savings. When the package is standardized and more broadly adopted, REALIZE expects the cost premium to decline drastically, as it did under the Energiesprong model, which will be critical for total market transformation.

There are tens of thousands of large multifamily buildings like Eva White that must reduce their dependence on fossil fuels, while improving their resiliency in a changing climate. The REALIZE team, along with WinnDevelopment and CSTO, are committed to developing and delivering an innovative deep energy retrofit solution, including an integrated panel and mechanical pod component, that can be demonstrated in Boston and scaled across major metropolitan areas rapidly, responsibly, and cost effectively.

—**Maggie Huang and Christina McPike**

MAGGIE HUANG *is an associate in Rocky Mountain Institute's Buildings Practice.*

CHRISTINA McPIKE *is director of energy and sustainability at Winn Companies.*

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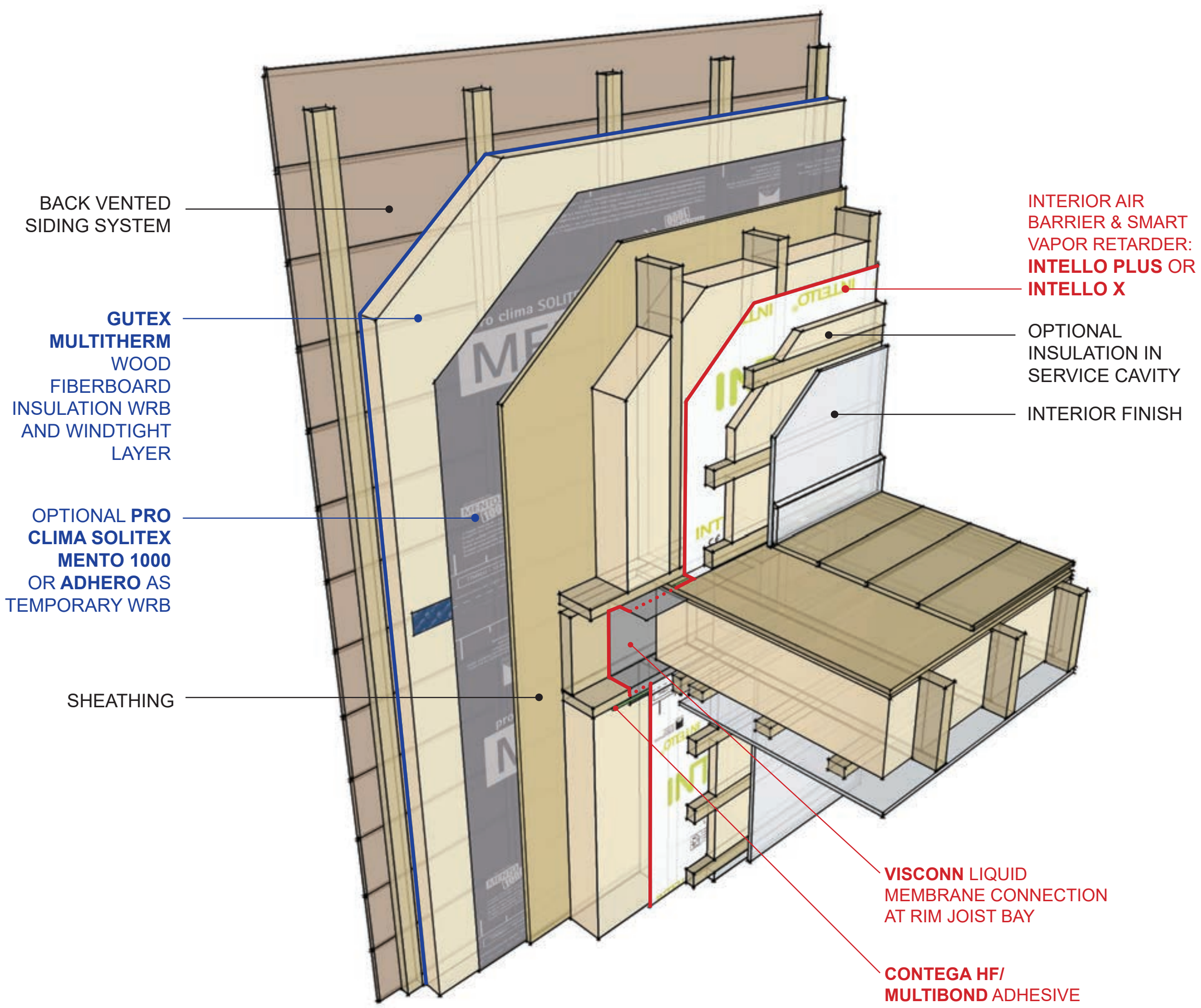

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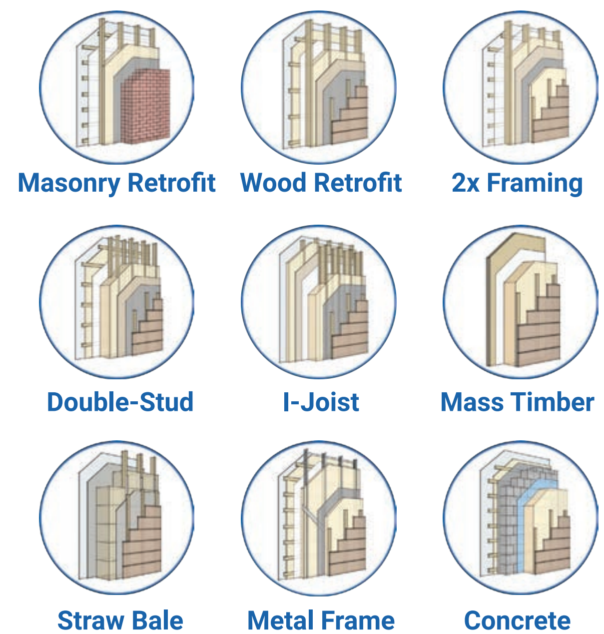

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PHASED *Twin Towers* EnerPHit

Photos by Zaina Abdul, Impact Engineering

For more than 40 years, two concrete high-rise towers in North Vancouver owned by Affordable Housing have been providing high-quality affordable housing, but decades of use have led to the need for a serious overhaul. Just from a mechanical perspective, the boilers were original equipment, as were the ventilation units, most of which are failing. Affordable Housing hired Impact Engineering, then known as HiH Energy, to update and optimize the mechanical systems.

Both towers feature a mix of commercial and residential spaces. The south tower has a ground-floor commercial space and 15 residential stories with 122 units. The north tower's commercial podium takes up 2 stories; its additional 10 stories contain 90 dwelling units. Most of the suites in this social-housing complex are single occupancy, and the population tends to be older.

When Ben Mills, principal and founder of Impact Engineering, heard that Affordable Housing was simultaneously exploring envelope measures, he got excited. If he could bring the teams together, they could work with each other and develop a more substantial and comprehensive building overhaul. "I pitched an EnerPHit feasibility study," says Mills, whose proposal was ultimately accepted. "It was a deep lesson in truly collaborating, which turned an unambitious project into a great one."

The feasibility study has turned into a full-fledged plan to proceed with a renovation that is targeting EnerPHit-level energy criteria for the residential portions of the buildings. Both buildings' mechanical systems will be fully decarbonized, and the building envelopes will undergo major retrofits, bumping up the walls' effective R-value substantially.

Mills says the project may not quite meet all the EnerPHit targets because of the challenges of renovating a mixed-use building. "In order to make the air-sealing target, we would have to add doors and air-sealing details in the commercial spaces that wouldn't make practical sense," Mills explains. "What we will achieve is a high-performing resilient envelope, a decarbonized building, and reduced operating costs."

The projected cost for all of these achievements was shockingly reasonable, according to Mills. As part of the feasibility study, his firm collaborated with a cost consultant to estimate the cost of replacing like for like and then compared that to implementing the mechanical and electrical portion of the EnerPHit proposal. "The delta between like for like and Passive House was a 25% uptick, which was mind blowing," says Mills. The EnerPHit building will be far superior in terms of durability, reduced liability, occupant comfort, and resilience. For the first time the mechanical system will be able to actively cool the suites—a safeguard against future potential heat waves. "Financially, this project makes a really strong case for fully decarbonized buildings," Mills points out.

Having moved from feasibility study to schematic design at press time, the project is slated to proceed through detailed design in the first half of 2020, with the construction start planned for fall 2020. The retrofit strategy is to work on a floor-by-floor basis, with Affordable Housing keeping enough vacancies in the building that the residents from one floor can be temporarily moved to another floor to accommodate the construction work.

The HVAC equipment will consist of Passive House-quality rooftop HRV units with a heat pump to supply some heating and cooling, along with supplemental electric baseboard heating. Each suite will incorporate up to two small baseboards with hard-wired wall-mounted thermostats. Domestic hot water will be provided by heat pump water heaters on each floor, thus shortening hot water runs and creating some water heating redundancy as compared to a centralized system, which when it needs servicing interrupts the hot water supply for the whole building. As an additional benefit, the heat pump hot water tanks on each floor will provide cooling to common corridors. The all-electric mechanical system will reduce the buildings' carbon emissions by approximately 450 tons annually, with 9,000 tons of carbon reduced over 20 years of system life for the towers' residential portions, according to Mills.

All envelope upgrades are focusing on exterior solutions to minimize disturbances to the building residents. The proposed envelope refurbishment will start with the removal of the existing stucco walls and the installation of a new exterior sheathing over the existing insulated steel stud wall and the existing concrete walls. The renovated wall assemblies will include a new air barrier membrane, 6 inches of exterior insulation,

thermal clips, an aluminum rail, and composite metal cladding panels. Additional membrane detailing will be required around the new mechanical unit curbs, around the parapets, and at the doorsills. The glazing, including the patio doors, will most likely be replaced with thermally broken aluminum-framed high-performance windows. A solar heat gain coefficient of 0.3 will be specified to reduce overheating risks. The airtightness target post renovation has been set at 1.0 ACH_{50} for the residential portions, in keeping with EnerPHit performance specifications.

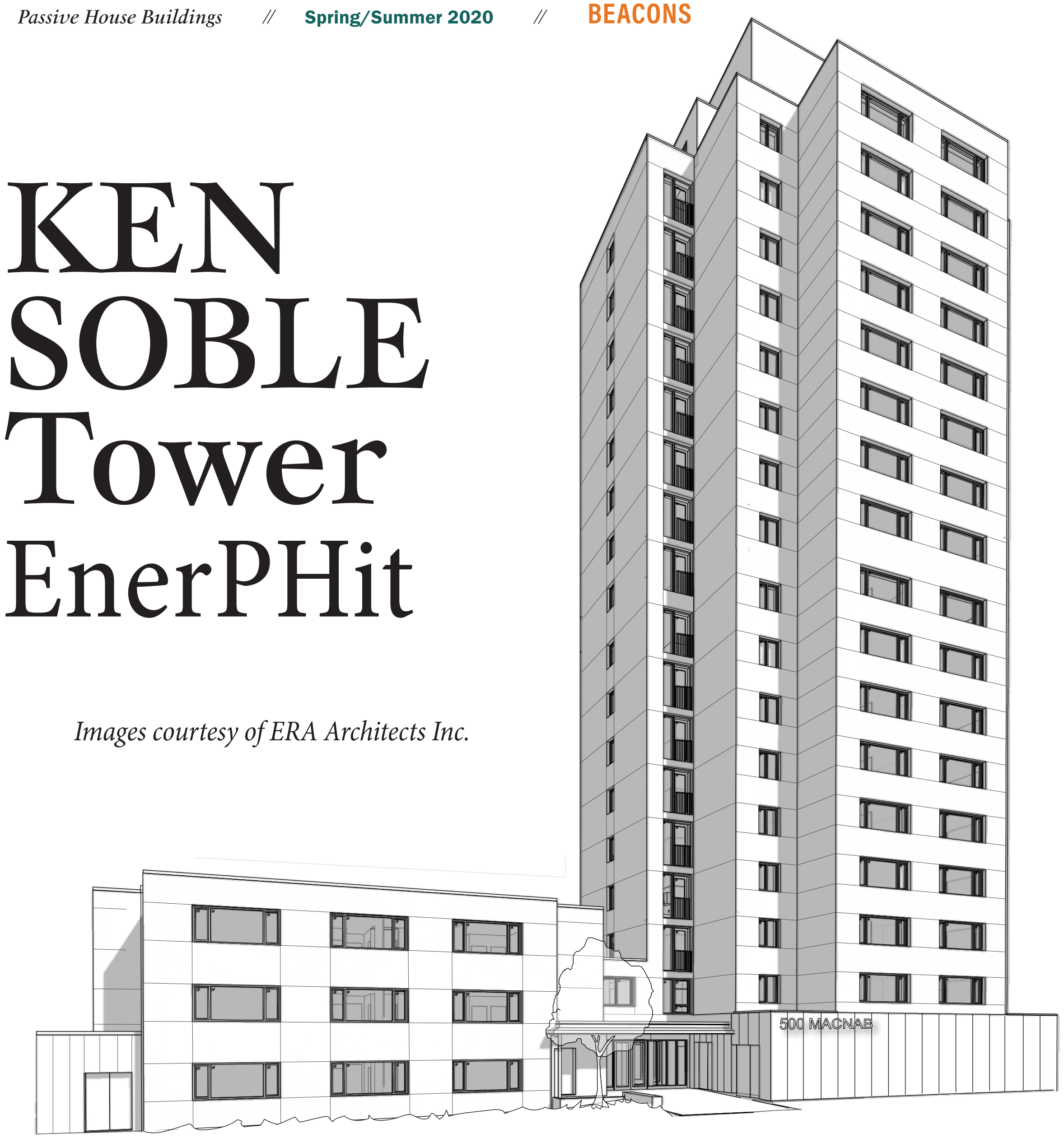
Impact Engineering points out that the vast majority of rental buildings in Canada—76% according to a recent study—are of similar vintage to these twin towers. How these buildings get renovated can translate into modest greenhouse gas reductions or a more ambitious transition to existing buildings attaining near zero emissions—and Impact Engineering is doing what it can to make that latter goal a reality.

—Mary James

PRODUCTS

Ventilation
Swegon GOLD RX

KEN SOBLE Tower EnerPHit

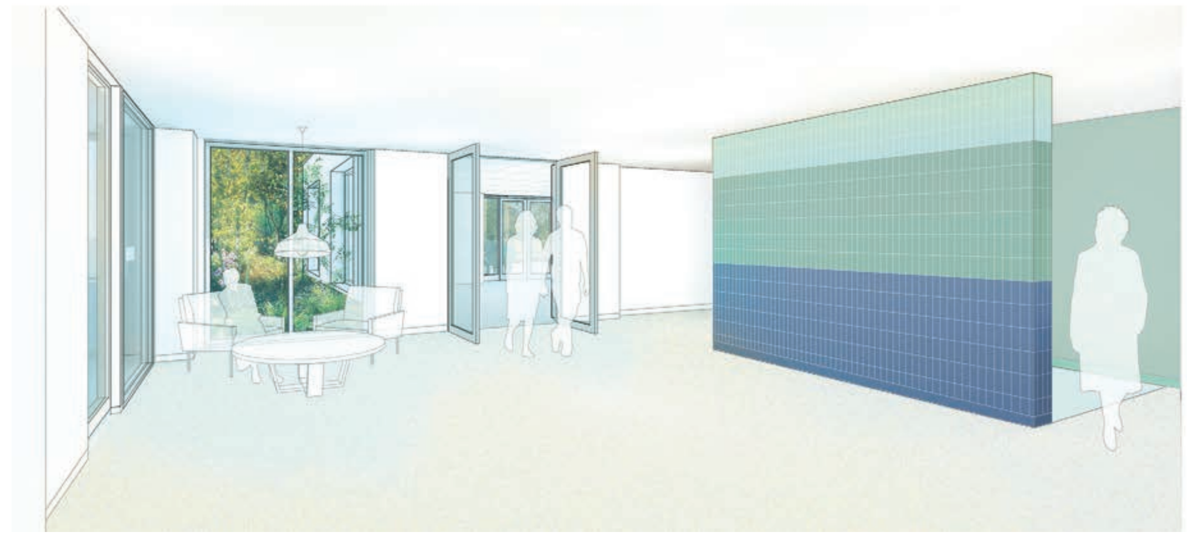


Images courtesy of ERA Architects Inc.

Built in 1967, the Ken Soble Tower is the oldest high-rise multifamily building in the portfolio of CityHousing Hamilton, the housing corporation run by the city of Hamilton in Ontario. Having been in decline for several years, the 18-story building is now on track to be the first residential high-rise EnerPHit in North America. With more than 730,000 units in many thousand similarly constructed concrete towers in Canada alone, this retrofit serves as a groundbreaking model for how to rehabilitate this aging—and yet still vitally important—housing stock.

Before choosing to retrofit Ken Soble, CityHousing Hamilton had examined various options for dealing with the property, including sale, rebuild, and capital repair. It was determined that making significant improvements would cost substantially less than demolition and a new build. In addition, extending the life of the concrete structure, and its associated embodied energy, greatly reduces the overall carbon footprint of the project.

The building's rehabilitation will modernize 146 units of affordable senior housing, while reinvigorating community spaces and outdoor gathering areas; planning for aging-in-place and barrier-free living; and providing high-quality, safe, and healthy housing for another generation. Although this modernization process will



achieve important Passive House objectives, the building had been scheduled already for a major overhaul, reducing the cost premium associated with the EnerPHit process.

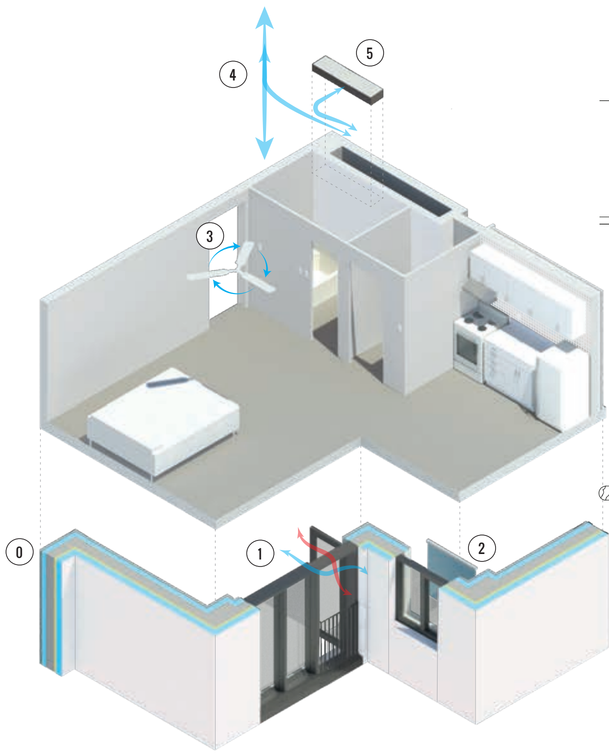
ERA Architects Incorporated, the project's lead architect, has been spearheading Tower Renewal research since 2009. The firm first completed a feasibility study for CityHousing Hamilton in 2017 and then supported the search for funding. Design started in July 2018, and the tender process occupied much of spring 2019.

Graeme Stewart, principal at ERA Architects, explains that innovative projects bring inherent challenges, saying, "Retrofits for Passive House construction of this type are at a very early stage, and there's a gap in the market." The Ontario industry for housing retrofits will benefit from demonstration projects like this one, with its associated trades training and quality-control site measures; these include having an air boss on-site, who is responsible for maintaining the integrity of the airtightness layer throughout the building.

ERA Architects brought its extensive experience in historic retrofits to this project, teaming up with Transsolar, JMV Consulting, and Reinbold Engineering for additional expertise. Existing buildings present many challenges that don't arise with new builds, including thermal bridging that ranges from the obvious—those that stick out like sore thumbs—to the more subtle. One of the first recommendations was to remove the balconies, which Stewart describes as the biggest Achilles heel from an energy standpoint. In Europe, prefab balcony enclosures are available that reduce thermal losses, but those products don't exist on the North American market, and creating custom enclosures is not cost-effective. Additionally, Ken Soble is a senior housing complex, necessitating barrier-free balconies—a standard that the existing balconies did not meet.

The balconies are being replaced with Juliet balconies and full door-sized casement windows that open inward, allowing for cross ventilation during the shoulder seasons. An alternative solution was submitted to the local building authority to permit the use of fiberglass-framed windows, typically prohibited in noncombustible, high-rise applications. The successful submission, which references the upcoming changes to the National Building Code of Canada, will allow their use in this application for one of the first times in Ontario.

The concrete slab the building rests on is another large thermal bridge that can be addressed only by surrounding the foundation with a continuous layer of concrete-board-faced XPS. Other less-obvious thermal bridges include the roof drainage, sanitary stacks, and

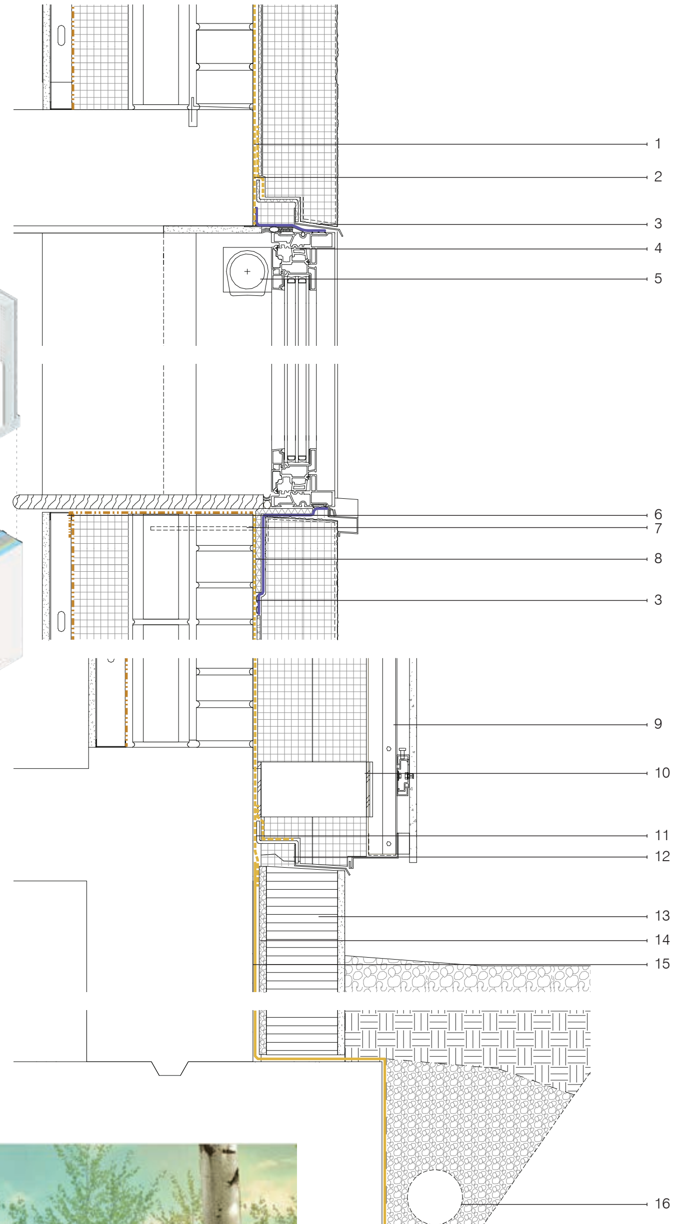


DYNAMIC THERMAL COMFORT THROUGH COOLING

0 1 2 3 4 5

Passive — *Active*

0. R38 Effective Envelope
1. Glazing with a low Solar Heat Gain Coefficient
2. Low emissivity interior shades
3. Ceiling fans to circulate air within units
4. Lightly tempered air delivered through a centralized ventilation system
5. Decentralized cooling 'boost' through a Variable Air Volume Unit activated by in-suite controls



1. AWB Flashing
2. Polyurethane Z-Girt
3. Silicone Transition Strip
4. Fiberglass Window
5. Roller Shade
6. Vapour Barrier
7. Helical Tie
8. Fiberglass Angle
9. Galvanized Steel Girt
10. Fibreglass Cladding Clips
11. AWB Flashing
12. Polyurethane Thermal Break Z-Girt
13. Concrete-Board Faced XPS Insulation
14. Drainage Plane
15. Fluid Applied Bituminous Waterproofing
16. Weeping Tile

garbage chutes. Dealing with the thermal loss from the sanitary stacks required approval for another alternative solution: an air admittance valve (AAV). An AAV is a negative-pressure-activated vent that closes automatically when the plumbing is not in use, eliminating the need for vent pipes through the roof. Stewart praises the Hamilton building department for undertaking staff training on the Passive House approach, leading to the approval of this alternative solution.

The initial plan for retrofitting the wall assembly involved attaching an exterior insulation and finish system (EIFS) that includes mineral wool insulation, but the discovery of mold embedded in the interior wall assemblies meant that plans changed. A slimmer version of the EIFS product that includes 6 inches of rigid mineral wool is still being applied to the exterior. This noncombustible cladding system, which was chosen in part for its lower embodied energy compared to petroleum-based insulation systems, is commonly used in housing developments throughout Europe but is still not widely used in North America. After drywall removal, another 4 inches of mineral wool are being added to the interior of the exterior walls.

Extensive dynamic thermal simulations were conducted to ensure occupant comfort year-round now and during the temperatures projected to occur over the next several decades. Although Hamilton is in a heating-dominated climate, in a building this dense, once the retrofit is complete, the heat loads will be quite small; cooling and dehumidification become larger concerns. In large multifamily Passive House buildings, overheating is a known issue, so the simulations were used to help the team identify which units might be particularly susceptible to the risk of overheating during summer or shoulder seasons and how specific cooling measures could improve comfort in these units.

A centralized heat pump is being used both to meet the heating needs and to supply a small amount of cooling. Other measures designed to preserve comfortable interior temperatures include ceiling fans to increase air movement and comfort in the suites, the option to boost the supply of conditioned air within each suite on a short-term basis, and using glazing with an SHGC (solar heat gain coefficient) of .378 on the south, west, and east façades. Exterior operable shading was considered but is still not readily available in most North American markets. Instead, all windows are being fitted with low-emissivity interior shades. The provision of dehumidified tempered air, delivered directly to suites, will help with humidity control.

A centralized ventilation system was chosen for its cost-effectiveness compared to a unitized system. The

preexisting ventilation system supplied air only to the corridors, depending on pressure differences to push fresh air into the apartments. The existing ductwork is being refurbished, with new ducts being added to bring fresh air directly into the suites. The ERV units are located in the basement and in a mechanical penthouse on the roof.

"A complex retrofit with this kind of performance target requires a holistic approach," says Yaël Santopinto, ERA Architects' project lead, in discussing the big takeaway lessons from this retrofit. "Everyone involved in the project has to understand the constraints and targets, including every trade to various degrees." Santopinto notes that it is also important for the owner and the operations team to understand how a Passive House building operates compared to the other buildings in the owner's portfolio.

CityHousing Hamilton should be able to bring residents into the newly remodeled building by early 2021. This ambitious social-housing transformation will provide residents with improved comfort and control of their indoor environment, along with the ability to withstand extreme climate events—in a building whose greenhouse gas emissions have been projected to drop by 94%.

—Mary James

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	7.97	0.64	41.77	0.6 ACH_{50} (design)
kWh/ft²/yr	2.34	0.19	12.24	
kWh/m²/yr	25.00	2.00	131.00	

STEPWISE Tower Retrofit

Images courtesy Pretium Engineering

The Raymond Desmarais Manor tower (the Manor) at 255 Riverside Drive East in Windsor, Ontario, is undergoing a rare transformation in North America: a stepwise retrofit of a tall multifamily building to the EnerPHit standard.

The owner, Windsor Essex Community Housing Corporation (CHC), spends an incredible half of its operating budget on energy, much of which is consumed by electrically provided space heating. Being a social housing organization, CHC sees providing affordability and occupant comfort as key factors in its decision-making process, so it looks for ways to reduce the occupants' energy costs. While winter weather creates comfort issues, so do summer conditions. The hot and humid weather experienced in Windsor during peak summer poses challenges to passive cooling strategies. Many existing towers in the region do not include active cooling. The consequences are either the installation of low-efficiency windows or through-wall air-conditioning units, or residents must endure uncomfortable—and potentially unhealthy—conditions.

The Manor is not the only tower attempting to achieve the EnerPHit standard. Another project, the Ken Soble Tower retrofit down the long road in Hamilton, Ontario, is also pursuing EnerPHit.

However, there are three characteristics that make the Manor unique:

- The first is tenancy during construction. Whereas the Ken Soble Tower has been vacant for some time, the Manor is occupied and remains so during construction work. This is problematic for a variety of reasons, including that the HVAC installation in corridors and suites will disrupt tenants and testing the airtightness of the whole building becomes much more complicated.
- The second is the existing balconies. The Ken Soble Tower renovation includes removing the balconies. At the Manor, they are being kept per client request, as the tenants use them regularly.
- The third is the stepwise approach. Funding constraints made it impossible for CHC to implement all the required works in a single phase.

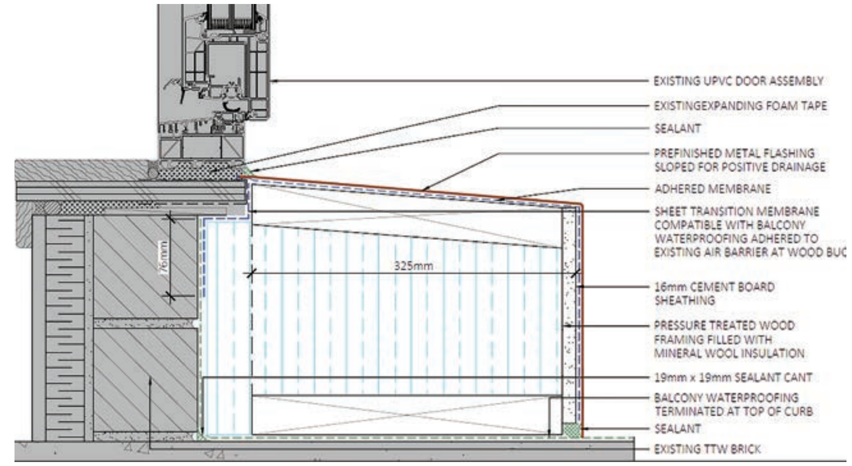


Figure 1. Insulated step at the balcony door threshold. (Courtesy of © Pretium Engineering)

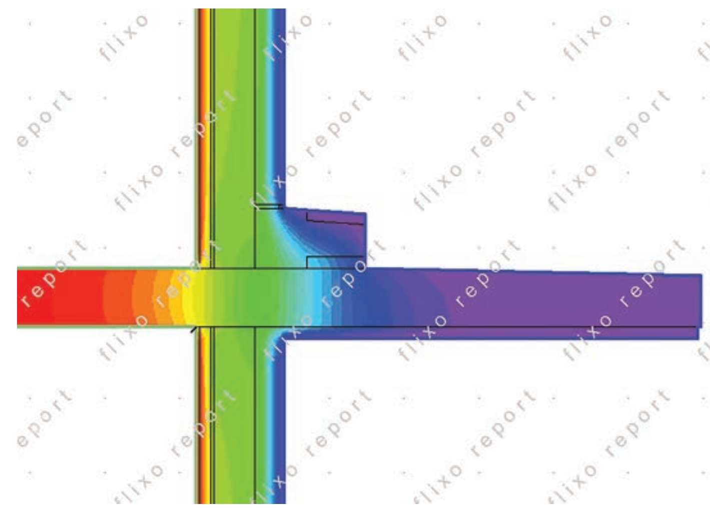


Figure 2. The temperature factor at balcony door threshold is well above 0.7, indicating a safe solution. (Courtesy of © Peel Passive House Consulting)

Standing 20 stories high, the 300-unit tower was built in 1974 as part of the government's massive build-out of affordable apartment buildings. The existing building has a concrete structure and an exterior wall construction consisting of through-the-wall brick masonry, 1.5-inch interior EPS insulation, and parging. The parged brick wall acts as the air-and-vapor control layer. Three inches of roof insulation was added as part of a roof upgrade over a decade ago. Windows are original aluminum frame with single-pane glazing. The HVAC system comprises a gas-fired makeup air unit pressurizing the corridors, local exhaust fans in the kitchen and bathroom, and electric baseboard heaters below the patio doors and living room windows. New gas boilers for domestic hot water (DHW) were installed about ten years ago, although the circulation piping is original and due for replacement. The elevators are also due for upgrades.

During the retrofit process, the building will be upgraded in four phases. The first phase, which is now complete, involved the replacement of all balcony doors and ground floor windows (see Figures 1 and 2). This phase was implemented without planning the subsequent measures, due to the funding timelines. The second phase involves HVAC upgrades, followed by envelope upgrades, and finally DHW piping and elevator upgrades. The team working on this project includes Pretium Engineering, Peel Passive House Consulting, CK Engineers, Zephir, and the Titan Group.

ENVELOPE

The building will be clad in a mixture of mineral wool and an EPS exterior insulation and finish system (EIFS). For cost reasons, CHC would have preferred to use EPS for the whole building, but the choice of PVC windows (also due to cost) forced the use of mineral wool on the suite façades, due to fire code requirements. As mineral wool EIFS are currently only fully tested to 4 inches, this choice limited the thickness of the mineral wool to 4 inches. EPS was permitted on the windowless sidewalls, so the insulation on those walls was increased to 6 inches.

The insulation continues below grade along the basement wall to reduce thermal bridging and mitigate condensation and mold risk. Basement ceiling insulation was also required to meet the space heating demand target. The roof was upgraded recently and is covered by telecommunications equipment, so will remain as is. A continuous air barrier membrane will be installed against the existing brick wall and tied into the roof membrane. Verifying airtightness is a challenge with live-in tenants, as they enter and exit the building frequently. As of this writing, it had not been established how the whole building's airtightness will be verified.

For the balconies, finding the right balance between cost, technical feasibility, impact on tenant space, thermal performance, and moisture risk was a challenge. After numerous iterations, the chosen solution was to insulate the entire soffit and create an insulated step on the top side. This approach mitigates current and future moisture risk.

HVAC

Numerous physical constraints severely limited viable options for providing dedicated supply and extract ventilation into each suite. There was insufficient space within the building to accommodate the dimensions of the vertical shaft ducts required for roof-mounted ERVs, and the roof space is limited, due to the various third-party communications equipment, which will remain in place as it provides a source of rental revenue for CHC. Running the supply and extract ducts along the suite-facing façades (north and south) was considered and rejected, due to the required length of ducting and number of penetrations. It was determined that ducts could feasibly be run down the side façades (east and west). However, the drop in ceiling height required to accommodate horizontal ducting would conflict with the building code mandated minimum of 7 feet. A fully decentralized system was not acceptable to the client on account of the required maintenance.

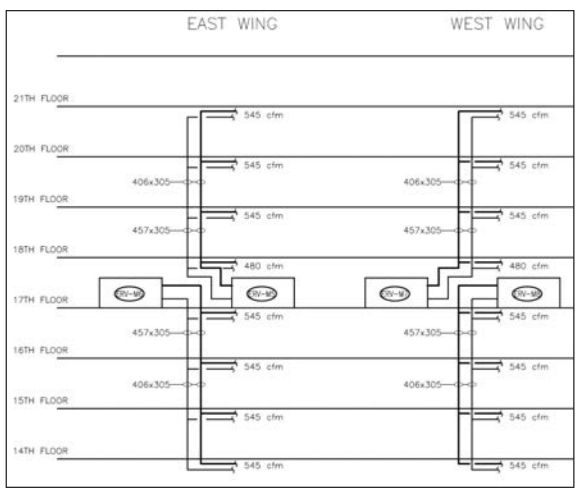


Figure 3. Vertical ventilation distribution strategy. (Courtesy of © CK Engineering)

After further exploration, a viable solution was found: Install semicentral ERVs in a handful of existing suites on floors 6 and 17. Each ERV would serve one side of the building and five floors, either up or down (see Figure 3). CHC was initially hesitant to sacrifice the rental income from the four suites that would be converted to mechanical rooms, but the alternative of a fully decentralized system was less attractive, and so the strategy was approved. The entire building except for two floors is incorporated into this strategy, due to the DHW circulation return piping concealed in the suspended ceiling. For the corresponding suites that are not incorporated, decentralized ERVs were installed. Common areas are similarly ventilated to keep them separate from the suites.

The semicentralized ventilation presented the opportunity to supply all the heating and cooling needs of the suites via the ventilation air. Analysis revealed, however, that this air would not meet the peak loads of the building. A variable refrigerant flow (VRF) system was then proposed as an alternative. Initial estimates established that this system was going to increase the total construction costs by about 30%, which CHC's budget could not accommodate. A novel third option was then proposed: installing a Passive House window in front of the existing air conditioner hole and replacing the air-conditioning unit with a high-efficiency model (see Figure 4). The design enables the tenant to use the air-conditioning unit during the summer by opening the window and plugging in the unit, while enabling CHC to lock the window in the winter to minimize heat loss. The cost savings of 80% over the VRF system were sufficiently compelling to convince the client to move forward with this first of its kind, higher-risk solution.

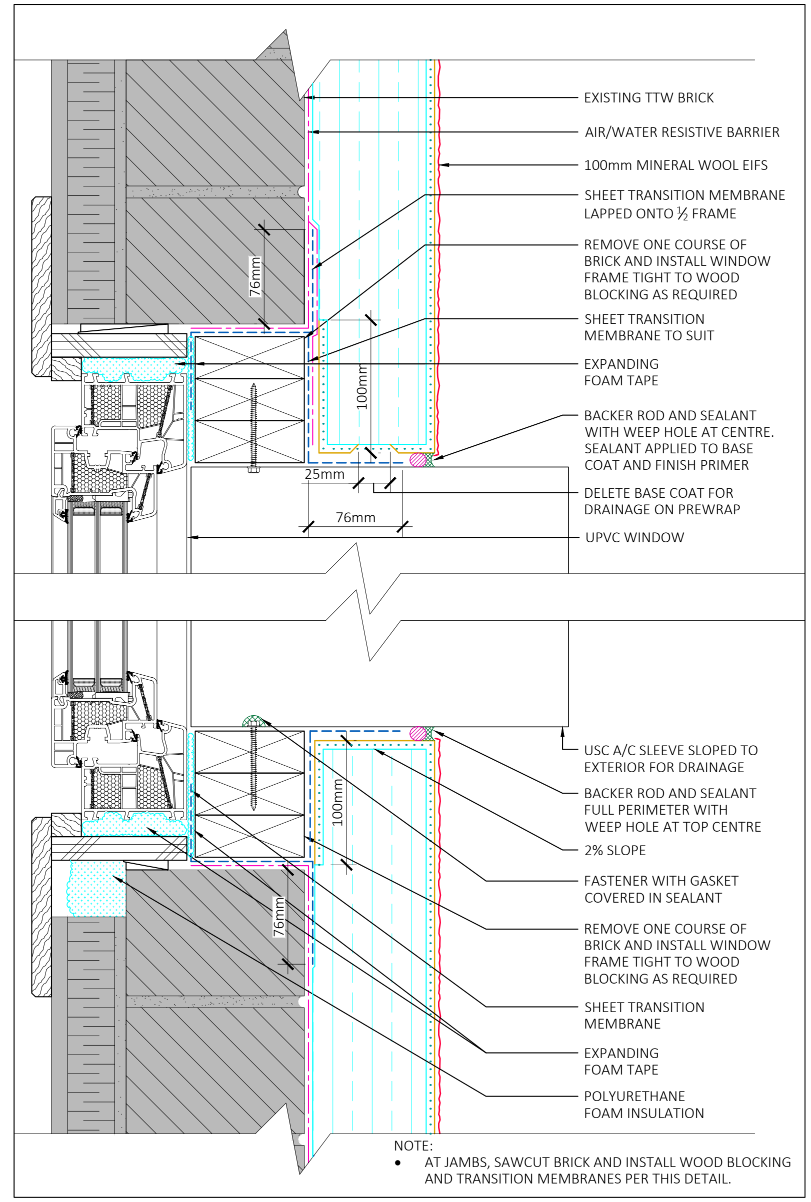
The building also contains a climate control system connected to the heating and cooling systems. This enables CHC to manage the heating and cooling to ensure that conditioned air will not be lost to the outside environment on a continual basis. For example, the system normally supplies sufficient energy to adequately heat or cool each unit independently. If, however, the windows are continually left open, the temperature in the unit will be either hotter or cooler than the setpoint (depending on the season), encouraging the tenants to close the windows or balcony doors.

The remaining mechanical and electrical upgrades include corridor lighting, replacement and insulation of the DHW recirculation pipes, and elevator equipment. Funding is not yet in place for these upgrades, so a time line has not been established.

An interesting discovery is the large discrepancy between the PHPP calculated occupancy (420 occupants) and the actual occupancy (320 occupants). This difference, combined with large corridor lighting and elevator loads, leads to a total primary-energy demand that exceeds the target. A project-specific primary-energy relaxation is being discussed with the Passive House Institute.

—Andrew Peel

Andrew Peel *is founder and principal of Peel Passive House Consulting.*



1 A411 A/C SLEEVE SECTION

Passive House METRICS

	Heating energy	Total source energy	Air leakage
kBtu/ft²/yr	7.97	56.76	1 ACH_{50} (design)
kWh/ft²/yr	2.34	16.64	
kWh/m²/yr	25.00	178.00	

PRODUCTS

Ventilation
Swegon GOLD RX

The Evolving Practice of ONION FLATS

Images courtesy of Onion Flats

Tim McDonald, architect and principal at Onion Flats in Philadelphia, is an innovator who isn't hesitant to share his expertise and his opinions, good and bad, about his own decisions. The firm has designed and built a series of multifamily Passive House developments in Philadelphia. Each development embodies Onion Flats' then-current best practices, and usually a series of lessons learned from its previous ones.

Take as an example the 28-unit Bank Flats, which just opened last November in Philadelphia. The rental apartments are mostly 450-ft^2 one-bedrooms and 300-ft^2 studios. Bank Flats was built with essentially the same superinsulated panels used on Onion Flats' previous 25-unit Capital Flats^2-The Battery project. The same air barrier caulk was applied to each panel edge before the panels were screwed together, forging a very airtight structure. Both developments feature green roofs. In most other aspects, the dissimilarities predominate. The PV system, the windows, and all of the mechanical systems are different—a reflection of experience gained and of the availability of new products.

Both Capital Flats 2-The Battery and Bank Flats were designed to be net zero. A 77-kW bifacial PV system shading the roof has almost allowed Capital Flats 2-The Battery to achieve this goal. At Bank Flats the 177-kW PV system doesn't cover just the roof; the bifacial panels wrap the whole structure. The solar façade is held off from the structure by 24 inches and doubles as a shading device. With this system McDonald projects that the whole building, which has a footprint of 5,200 square feet, will be net positive, producing 20% more energy than the building needs—a goal that wouldn't have been possible if only the roof were covered.

McDonald has not installed utility submeters for each apartment in Bank Flats, because he considers them a waste of space and money when the monthly per-unit bill is expected to be quite small. He is monitoring each apartment's electrical use, which will help with commissioning and detecting abnormally high usage. Bank Flats' rental fees include a monthly fixed charge for electricity use.

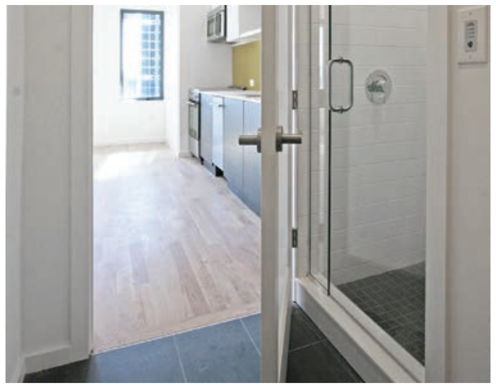
Thanks to the prefabricated components, Bank Flats went up in five weeks—and the windows had already been installed. The cooling load turned out to be the defining factor for these window specifications. Although triple-pane windows were used in past projects, for this building McDonald specified double-pane windows with a U-factor of 0.2, because triple-pane windows would have actually kept too much heat in during summer and swing seasons. The solar heat gain coefficient for the windows is .32, and screens were added that are designed to reflect heat from coming into the building. The double-pane window, the reflective screens, and the use of the PV panels as an effective shading device all helped the project to meet PHIUS requirements for heating and cooling.

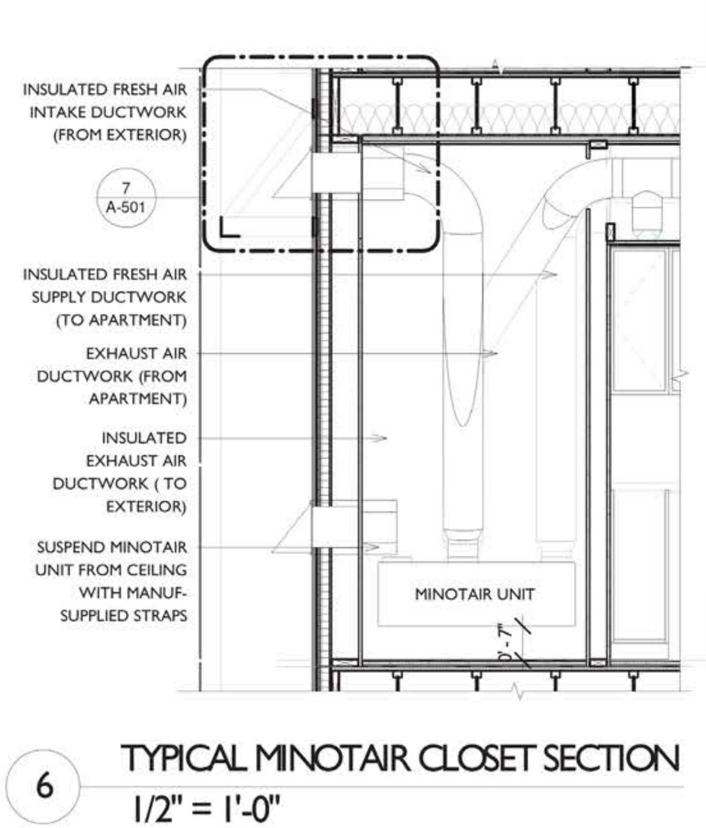
To address these heating, cooling, and dehumidification loads, McDonald chose very quiet, decentralized HVAC units—one for each apartment. Each unit combines energy recovery ventilation with heating, cooling, and dehumidification. In case the heating supply is insufficient for the occasional extremely cold night, McDonald opted to have electric-resistance post heaters installed in line with these units as a backup.

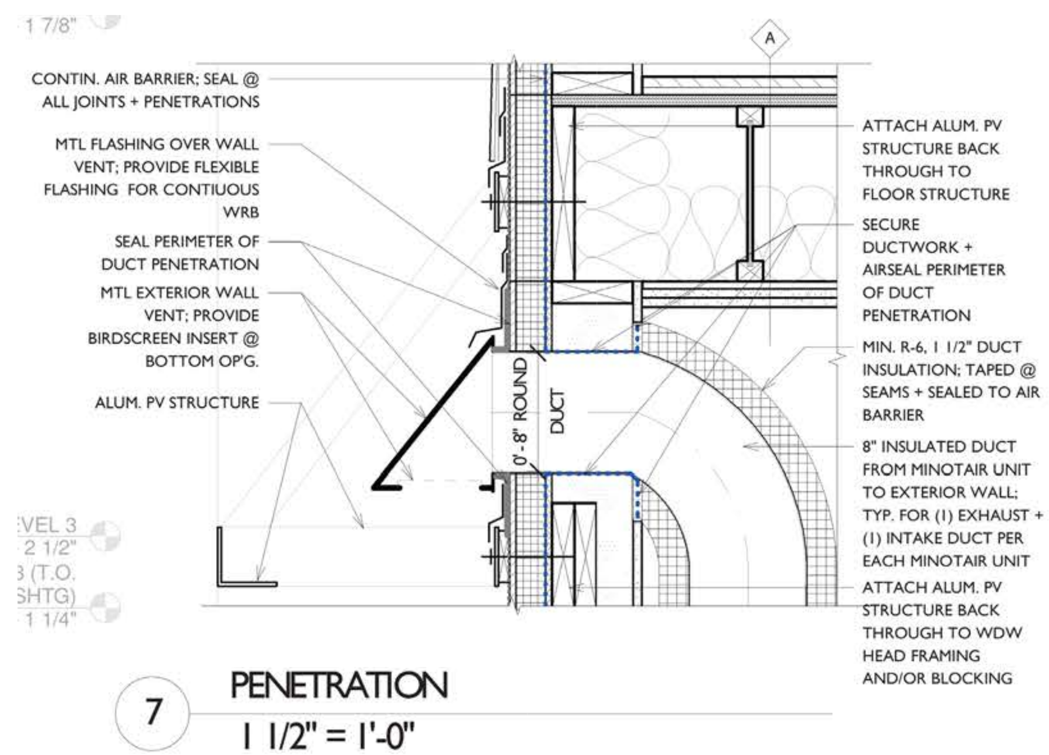
Hot water is the next-biggest load in multifamily buildings. In Capital Flats 2-The Battery, McDonald had used an open-loop geothermal system that delivered hot water and space heating and cooling. Theoretically that was a very efficient system, but in practice, McDonald concluded that it was too complicated. His lesson learned: "If you can only find one person to give a bid on a system, then there's only a 50/50 chance of getting it done right."

For help in finding a simpler way to reduce water heating energy use, McDonald brought in Gary Klein, a national expert on efficient hot water systems. He helped design a semicentralized system using a series of heat pump water heaters that each service six to seven apartments. Klein optimized the hot water runs, cutting piping lengths from an original layout by roughly 50%. He also introduced McDonald to a pipe-in-pipe system where the return loop runs inside the supply loop, reducing the need for pipe insulation by 50% while minimizing heat loss.

Onion Flats' next project, two 44-unit buildings known as Copper Flats, is currently under construction. The mechanical system approaches will be carried over to this project, but McDonald is working with a new panelization system that will deliver to the site most of the buildings—interior and exterior walls, roofs, and floors. The components will be preinsulated with a wood fiberboard; the windows and doors will be installed; and all mechanical, electrical, and plumbing (MEP) will already be included. "This turnkey approach with ONE subcontractor to deliver the entire building with full MEP reduces construction time on the project by 50% and could be a game changer for Onion Flats' ability to





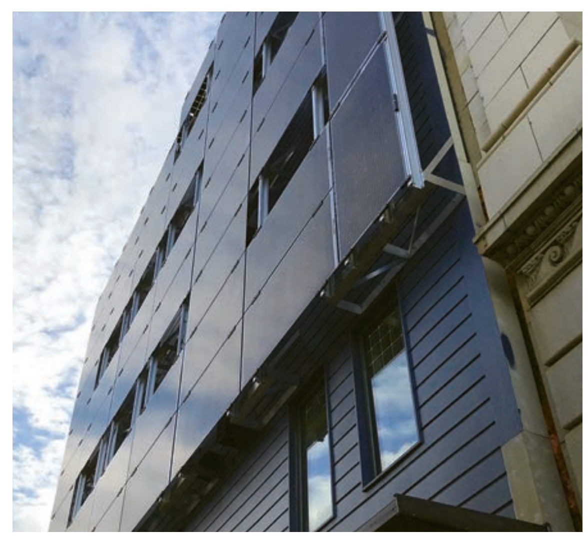


deliver cost-effective, high-performance market-rate and affordable housing projects," says McDonald.

As this project is coming together, McDonald is simultaneously working on another way to share his expertise. He and his colleague David Salamon are putting together a *High-Performance Affordable Housing Design Manual*, a step-by-step series of decision trees about how to build high-performance, net zero multifamily buildings. The manual will guide readers through such nested questions as "Will the building be all electric? If yes, here are the metering decisions you will face. What are the factors affecting the choice of a centralized or decentralized HVAC system?" The manual will also include many practical details, such as how to build a thermally broken threshold that meets ADA (Americans with Disabilities Act) requirements.

Currently the manual exists only as a two-hour workshop, and McDonald and Salamon have delivered that workshop to hundreds of interested architects, builders, and developers several times over the past two years. They are exploring grants that would allow them to turn "The Manual" into an open-source PDF document that can be shared with the industry. When completed, it will allow readers to vault right over the moments when McDonald thought, "I'm never going to do that again," when reviewing what were innovative decisions at the time, and to land squarely on the hard-won lessons.

—Mary James



Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	1.50	4.09	46.40	0.79 ACH_{50}
kWh/ft²/yr	0.44	1.20	13.60	
kWh/m²/yr	4.71	12.84	145.52	

A MULTIYEAR Home Retrofit

Construction photos courtesy of Jesper Kruse

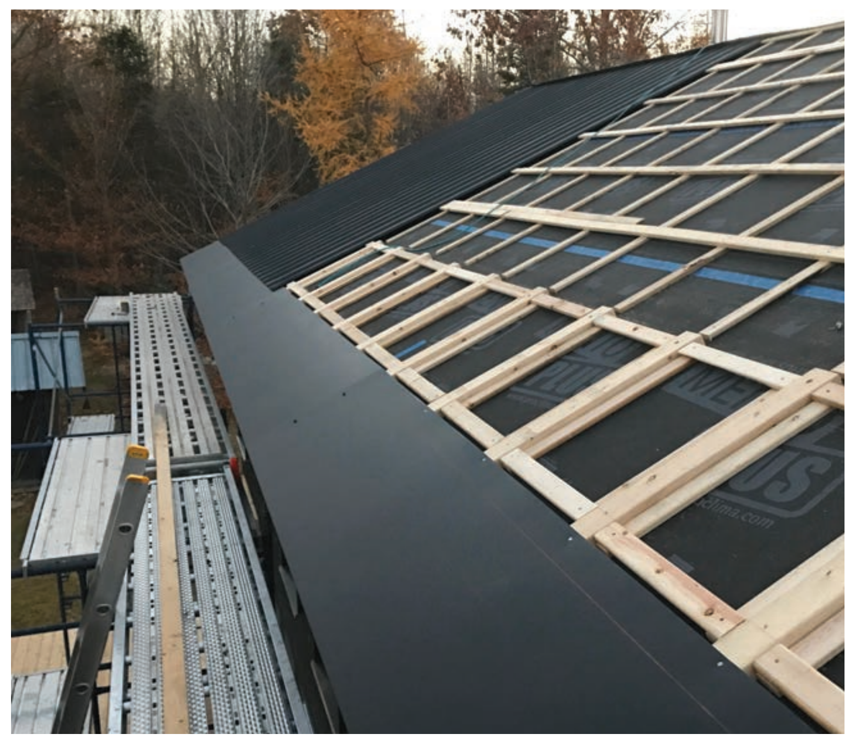
You're a builder who specializes in Passive House. You and your family live in a cold Maine climate. How long can it be before you start your own Passive House retrofit?

For Jesper Kruse, owner of Maine Passive House in Bethel, the inevitable retrofit has been a phased multiyear process that is finally coming to a close. Kruse built his almost 2,000-ft^2 house in 2000, six years before he knew about Passive House. By 2014 he had started the retrofit, fitting it in when he could among his other projects.

The original house was built with 2 x 6 walls sitting on a slab insulated with 2 inches of EPS, on top of uninsulated frost walls. The first floor features a kitchen, dining and living rooms, a half bath, and a large entry with a frequently used porch. The second floor has three bedrooms and an office plus a full bath. He and his wife—and sometimes others as well—have been slowly going around the house, one side at a time, upgrading each assembly.

Addressing the frost walls was fairly straightforward: Kruse excavated around the foundation and added 10 inches of EPS. For the above-grade walls, they removed the existing cladding and windows and applied an air barrier membrane with a low-perm rating from the foundation up and over the existing sheathing. They then bolted truss joist I-beams (TJIs) to the existing framing, which they packed with cellulose, and added an airtight, vapor-open membrane on the exterior and reverse board and batten for the siding. New overhangs were bolted to the sheathing. The windows were replaced with high-performance triple-pane units that Kruse imported directly from Denmark.

For most of the walls, the amount of insulation in the new vapor-open assemblies has almost tripled, from 5½ to 16 inches of dense-packed cellulose. The wall that borders the 8-foot porch, though, was a conundrum, because thickening the walls subtracted from the deck area. Kruse whittled down the size of the TJIs there to 3½ inches. Having modeled the change in the PHPP, he was surprised and relieved to find that the modification did not change his overall heat loss through the walls that much. He finally finished the last two walls last year.

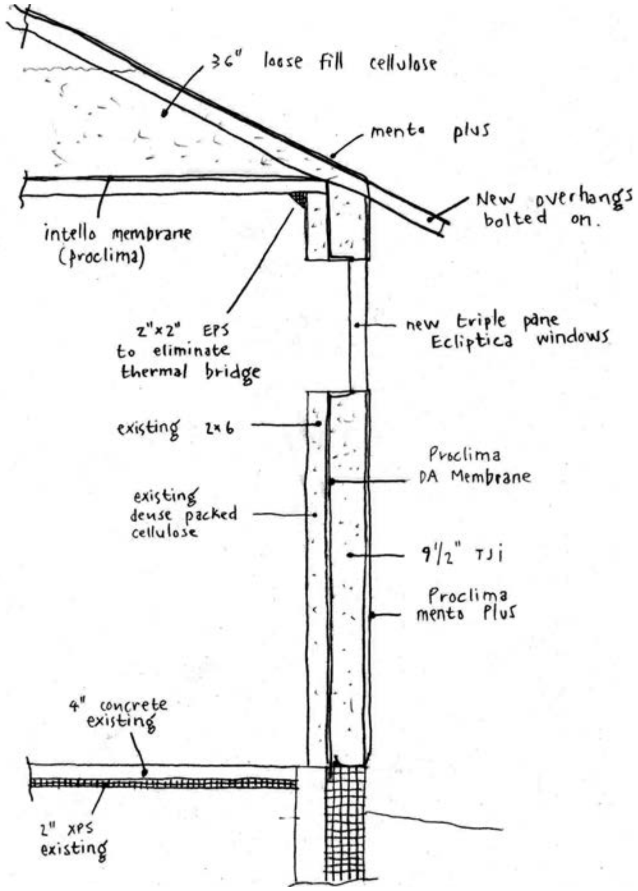


Retrofitting the roof assembly has been a more complicated task, which only got fully tackled after a conference presentation Kruse attended on potential moisture problems in unvented roof assemblies. The speaker emphasized the need for a really good vapor retarder on the warm side of the assembly. "Originally we were going to run an exterior weather-resistant barrier right up over the roof," says Kruse. "I got cold feet about relying on that." He decided to supplement this approach by installing a vapor-permeable air barrier membrane on the attic floor, a process that was complicated by the presence of trusses at 2-foot intervals, not to mention the 16 inches of loose-fill cellulose that had to be shoveled out of the way. That task got under way in early summer but had to be postponed until late fall, because the attic environment was unbearably hot.

In the corners where the walls meet the attic floor, Kruse installed 2-inch by 2-inch pieces of EPS to alleviate the thermal bridging where the low heel of the truss intersects with the wall.

The interior of the house has not been touched except for the window rough openings. With no place to run new ducts for a ventilation system, Kruse chose a balanced decentralized ventilation system.

The home's open floor plan was a big benefit when it came to devising a new heating system. One mini-split heat pump unit hangs in the living room, helping to keep the house tolerably warm, or at least above freezing on the coldest nights. Last winter, before the final two walls were upgraded, supplemental heat was needed, especially for the upstairs bedrooms. Fortunately they have a wood stove and live on a forested lot. "Firewood is free and readily available," says Kruse, "so the reality is that we are heating with the wood stove and using the mini-split as backup." With the wood stove in the middle of the house, he has had to create a dedicated air supply to it and replace the existing chimney with a better-insulated metal one. In a comment that will be all too familiar to many home retrofitters, Kruse sighs, "Everything is a big project."



With all of this work, Kruse was extremely pleased to find that he hit 0.5 ACH_{50} when he conducted his final blower door test last fall. Still, the home is not quite meeting all the EnerPHit targets. Kruse ascribes this shortfall to key preexisting conditions. There isn't enough insulation under the slab, but he's not changing that. He also won't be redoing the existing rough openings, even though the window placement is not ideal for maximizing heat gain during the winter.

What is ideal are the benefits the retrofit has brought to his family. His kids hang out comfortably in the windowsills even in the dead of winter. And the snugger home is more resilient when the power gets knocked out by an extreme weather event.

There are also marketing benefits for Kruse, whose company has grown in recent years and now has ten full-time employees. He can speak at first hand of the increased comfort, sometimes persuading clients to do just a little bit more. He recently retrofitted an old three-story barn, creating a new restaurant on his clients' very tight budget. They became receptive to many Passive House elements, according to Kruse, including airtight construction, an ERV, and minimized thermal bridging. The one element that unfortunately could not be made to work with the budget was triple-pane windows. "We pushed it as far as we could," he concludes.

That's what Kruse did with his own house and with every job he works on, to ensure that Passive House levels of efficiency and comfort, or as close as possible, are built in.

—Mary James

Photo courtesy of Emily Delamater Photography

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	11.80	1.02	24.00	0.54 ACH_{50}
kWh/ft²/yr	3.46	0.30	7.03	
kWh/m²/yr	37.00	3.20	75.26	

PRODUCTS

Air/Moisture Control
Pro Clima from 475

Ventilation
Lunos from 475

WINDOWS AND DOORS
Schuco AWS75 by
European Architectural Supply, LLC

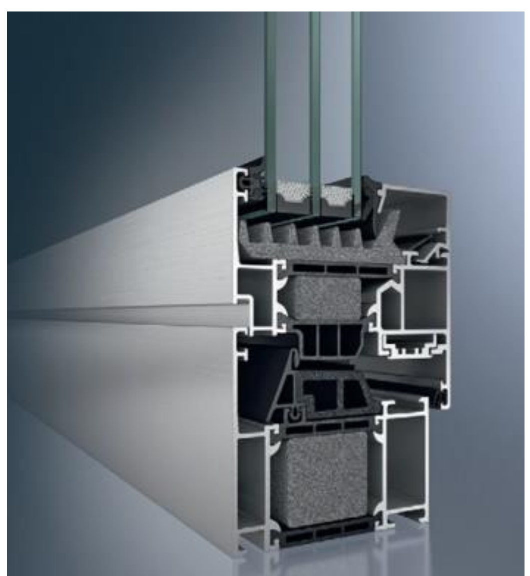
ARCHITECT
Chris Benedict, RA

DEVELOPER
Synapse Development Group

Multi-unit Passive House Window Installation

European Architectural Supply, LLC supplied and installed windows for the largest multi-unit Passive House project in Manhattan. The company managed the project from design through manufacturing, delivery and installation.

Completed in 2018, Perch Harlem is among the largest Passive House projects in the US. Chris Benedict, the project architect, brought EAS on board to explore the possibility of using Schuco thermally-broken aluminum windows for this seven story multi-unit PH project. The design called for floor-to-ceiling windows, with the largest reaching 8x8ft. The architect selected Schuco AWS75.SI+ aluminum window system for its thermal performance and cost per square foot.



SCHÜCO

EUROPEAN ARCHITECTURAL SUPPLY
MAKROWIN

Full-Service Passive House Windows Procurement, Delivery and Installation

EAS differentiates itself among window suppliers by offering full service procurement of windows from design through delivery, installation and after-sale service. This project involved 21 tons of triple-pane windows with largest window units weighing 620lbs each. The EAS staff coordinated the delivery and unloading of windows before the building was enclosed to enable easy placement of 6,000lbs pallets on the individual floors. The OSHA-certified EAS installation staff worked with the General Contractor to stage the window installation in a manner to provide maximum weather protection as the building's walls were erected during the winter months.

European Architectural Supply, LLC
sales@eas-usa.com
www.eas-usa.com
(781) 647-4432

SKEENA Residence —A Community Asset

Photos courtesy of Sawchuk Development; Rendering courtesy of PUBLIC Architecture + Communication

As a global leader in sustainability, the University of British Columbia (UBC), no longer satisfied with minimizing harm, is moving toward net positive contributions to environmental well-being. UBC acts as a living laboratory by integrating its academic—research and teaching—activities with operational mandates.

A major part of UBC infrastructure is student housing. With 12,000 students living at the Point Grey campus and more than 2,100 beds at the Okanagan campus in the near future, the university has become an industry expert in this building typology. Along with this expertise comes the ability to take well-assessed risks such as UBC Okanagan's new Skeena Residence for students, which is aiming for Passive House certification. Skeena is an expression of applied sustainable building research, and as such will benefit other universities, municipalities, and communities.

Designed by PUBLIC Architecture + Communication, the Skeena Residence will provide 220 bedrooms and amenity space across six floors. Completing an ensemble of residence buildings that encircle a large common green space, the project focuses on student life and support services while synching up with the existing campus.

The architecture team understands that student residences aren't just for sleeping. In the design for this typology, a balance of academic priorities and recreation is important. On the first level, Skeena Residence has a large laundry room in close conversation (a glass wall separates them) with adjacent lounge and social spaces. The relationship between the two spaces encourages chance meetings and happenstance gatherings. Moreover, the transparency offers passive surveillance, or visibility that promotes a sense of security. In short, the design of the building supports community life.

To further maintain safety and privacy, the upper five floors contain the residence apartments, semiprivate living, and study areas. Each of these five floors contains a homey house lounge with views of the surrounding mountains and a kitchenette, dining table, and couches, and—to keep unlike activities acoustically separated—a study room at the other end of the building.

DESIGN INFLUENCES

Ultimately, Skeena's design was driven largely by the programmatic requirements. The neighboring student residence had a proven layout of two bedrooms separated by a shared bathroom. The layout of this module was repeated for Skeena within an optimal building length, width, and number of floors—optimal being determined by the least amount of energy required to heat and cool the building while also delivering the requisite number of beds.

This Passive House goal of minimal energy use for heating and cooling also shaped other design choices. Given that ornamentation is tricky to insulate effectively, a simple form without irregularities such as corners, steps, overhangs, or canopies performs best. Mechanical systems also work best within a narrow, contiguous box. This limits aesthetic parameters to material, color, pattern, and texture. The simpler the building, the more important material choices and detailing become to the design.

To preserve responsiveness to budgetary concerns, the architectural team designed the Passive House wall assembly like a jacket—or, as students might say, a beer coozy —in the sense that it can simply be removed. Structurally the same as a conventional building, Skeena's skeleton allowed for the potential subtraction of the Passive House elements without hiccups in cost or schedule.

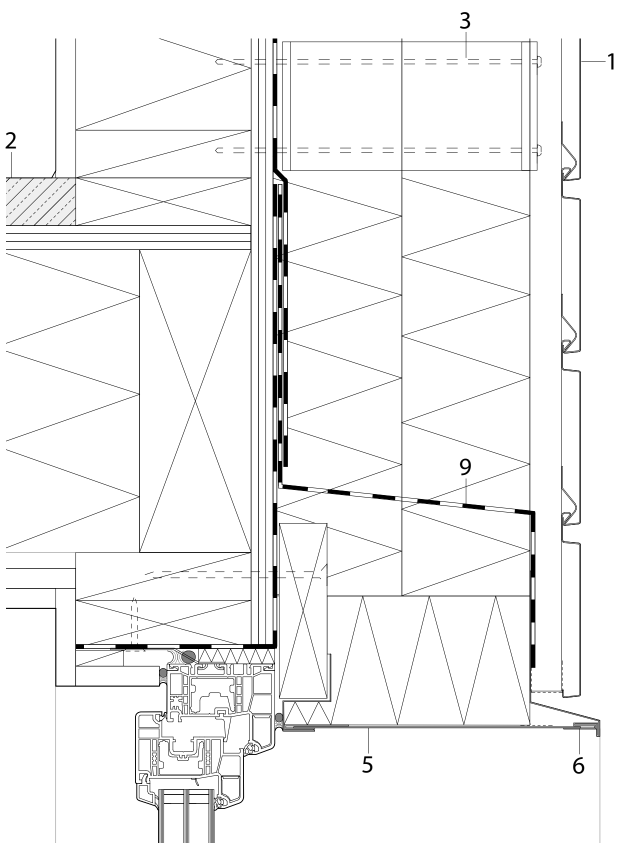
Design decisions are also swayed by other practicalities, such as standard and locally available materials and techniques. The building is 80% wood-framed, with some concrete on the ground floor. A wood structure was chosen for its inherent insulative properties as well as its ready availability and ease of construction.

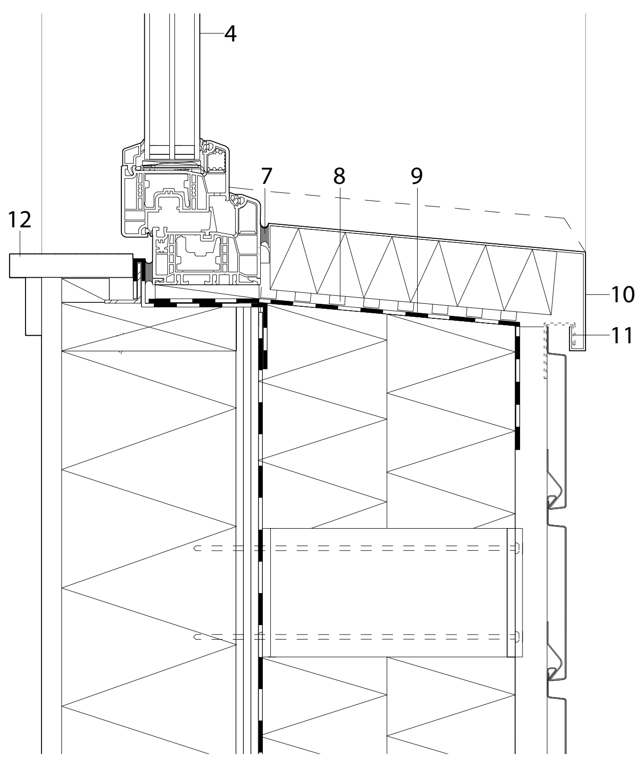
THE BUILDING ENVELOPE

Designing multiunit buildings to the Passive House standard presents a unique set of challenges and opportunities, and PUBLIC Architecture + Communication was grateful to have the assistance of a team of Passive House professionals from RDH Building Science, led by Monte Paulsen. More than with conventional building methodologies, the integrated design process is vitally important to achieving Passive House. Conventionally, a design process begins with broad strokes and with each successive iteration becomes increasingly refined, ending with details. Passive House, however, inverts this process.

The process for Skeena required accelerated decision making and involved a heavier workload during schematic design. For example, understanding thermal bridging implications and other Passive House success factors necessitated front-loading assembly and junction detailing. These details were also critical for determining if Passive House heat recovery units could service the project, or if cooling would be required in the Okanagan climate.

However, the good news was that working through these problems in the beginning achieved significant time and cost savings in the long run, most importantly by preemptively avoiding changes late in the process. Late changes are more consequential with Passive House, due to its holistic design approach. Any change of a component will alter the energy performance of the entire building. In initial phases, any increased energy demand caused by, for example, swapping out a window could be made up for by increasing insulation or by making other alterations to balance efficiency. However, a proposed window change during construction would have taken up to five weeks for research, evaluation, and sign-off of all consultants. Additionally, as the components are more specialized and





1. **EXTERIOR WALL CONSTRUCTION**
   26ga steel siding
   1" vertical z-bar
   8" mineral wool thermal insulation
   Vapour-open air barrier membrane
   3/4" plywood sheathing
   2 x 6 wood framing w/ mineral wool thermal insulation
   5/8" gypsum wall board
   Vapour retarder paint primer
2. **TYPICAL FLOOR FINISH**
   Carpet finish
   1-1/2" gypsum cement underlayment
   3/4" plywood subfloor
   9-1/2" engineered wood I-joist
   1/2" resilient ceiling channel
   5/8" gypsum board ceiling, 2 layers
3. **FIBERGLASS THERMAL SPACER**
4. **WINDOW**
   Triple glazing 3mm annealed LoE² + argon cavity + 3mm annealed clear + 3mm LoE in vinyl frame with fiberglass reinforcement
5. **24GA METAL HEAD CLOSURE**
6. **WEEP HOLE WITH PERFORATED METAL BACKING**
7. **DOUBLE-SIDED TAPE AND SEALANT**
8. **DRAINAGE MAT**
9. **FOIL-FACED THROUGH-WALL ASHING**
10. **24GA PREFORMED METAL SILL WITH END DAMS**
11. **PERFORATED METAL ASHING CLIP**
12. **WOOD INTERIOR SILL**

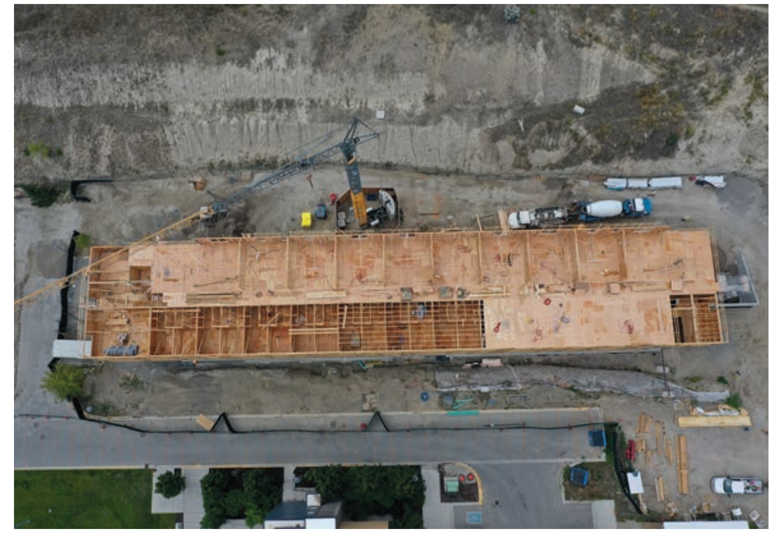
the supply chain is more spread out, getting Passive House-quality products usually requires longer lead times, especially for products that are shipped from abroad.

Working out the detailing of the mechanical systems early on was also vital to preserving the schedule and budget. All of the pipes for mechanical servicing required more insulation than is the case in a conventional building. Adding just a few inches of insulation to pipes can require custom wall and floor assemblies at a significant expense. Instead, because of the integrated design approach that we used, we were able to maximize the amount of insulation possible for the pipes while still fitting within typical assemblies, adjusting other building components to achieve the project's energy goals.

MECHANICAL APPROACH — AME CONSULTING GROUP

For the mechanical engineers, aiming for Passive House certification also means engaging in the integrated design process much earlier than is typically the case in a conventional construction process, as well as additional coordination with the other team members throughout the project. That extra insulation on the hot water pipes affected more than just the floor assemblies. The Passive House emphasis on maximum efficiency from all sources and details translated into reduced heat loss from the pipes and, not incidentally, minimized the need for air-conditioning. Domestic hot water is being supplied by heat pump water heaters, a relatively new technology for some that required extra planning.

The most obvious difference when designing the mechanical equipment for a Passive House building lies in its much lower peak heating demand than a typical building would have, which makes conventional heating equipment inappropriate. A less- obvious consequence is that specifying and ordering right-sized equipment brings a project to a mechanical point of no return—in terms of committing the project to achieving its Passive House targets—much earlier than other design aspects might.



FURTHER COMPLEXITIES

The density of students in a Passive House student residence necessarily presents further challenges. With a student population comes a far greater number of fridges, hair dryers, and computers per square meter than are found in a typical midrange residential building. These appliances create an enormous plug load, or electrical draw.

LESSONS LEARNED

- Skeena is built into an existing context that did not have the same parameters as those required by Passive House. This sets up unrealistic design expectations. To counter these expectations, our team allowed for time to educate and inform the client and user groups.
- Construction of the wall assembly is new—and therefore challenging—to many tradespeople. To offset this learning curve, RDH Building Science, the envelope consultant, offered on-site workshops focused on Passive House construction.
- Some key components of Passive House building have long lead times. To avoid schedule delays, it is advisable to pre-tender key components such as HRV units and triple-glazed windows.

To further the complexity of student residences, when students aren't chilling drinks, drying wet hair, or researching on their laptops, they are conducting humidity-intensive activities such as showering. To combat the excess moisture, air circulation is completely renewed every three hours via highly efficient mechanical systems, thus warding off the threat of mold. Ventilation air is provided by heat-recovery ventilation units. Despite its high energy demand, the Skeena Residence has not required hookup to the available gas connection or to the roughed-in connections for a PV array.

THE VICTORY LAP

The Skeena Residence is a victory, particularly given the extreme seasonal temperatures at this UBC campus. Not only is the project expected to achieve Passive House targets when complete, but the building systems are expected to perform within the anticipated conditions of climate change.

—Brian Wakelin

Brian Wakelin *is an architect and principal at PUBLIC Architecture + Communication.*

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	4.59	0.35	24.20	0.6 ACH_{50} (design)
kWh/ft²/yr	1.35	0.10	7.09	
kWh/m²/yr	14.40	1.10	75.90	

PRODUCTS

Ventilation
Swegon GOLD RX

A Resilient SENIOR Community

Photos courtesy of Bill Purcell Photography; Detail courtesy of Green Hammer Design Build

The residents of The Oaks Zero Energy Neighborhood at Rose Villa Senior Living are reaping the benefits of an opportunity that is unfortunately rare—the chance to live out their environmental values while cultivating a deep sense of community. The Oaks, a neighborhood of 12 homes for older adults in Portland, Oregon, opened its doors last February. The buildings are designed to meet their own energy needs through a combination of Passive House-based design and on-site renewable energy generation.

All 12 Craftsman-style homes in The Oaks sold before build-out—a testament to the market demand for eco-friendly senior living options and to Rose Villa's commitment to creating ample opportunities for residents who want their homes to match their social and environmental values. "Many people think of senior living communities as places where they may have to give up their way of life. At Rose Villa, we offer many ways people can continue to live their values and do the things they love," says Vassar Byrd, Rose Villa CEO.

Portland-based Green Hammer Design Build led the design and construction of The Oaks. Established in 2002, Green Hammer is a leader in zero-energy and Passive House design principles. (Green Hammer was one of 16 firms that in 2019 met the goals of the American Institute of Architects' 2030 Commitment, a voluntary effort to achieve carbon neutrality in the built environment by 2030.) The firm's previous experience designing and building zero-energy multifamily projects in the Portland region, including Ankeny Row and Tillamook Row, helped it to complete the Oaks Neighborhood early and below budget.

The Oaks' success is already increasing the availability of this housing type. Green Hammer and Rose Villa are working on a second zero-energy neighborhood, Trillium Townhomes, which will include six new 1,200-ft2 zero-energy townhomes. Completion is expected in the summer of 2022.

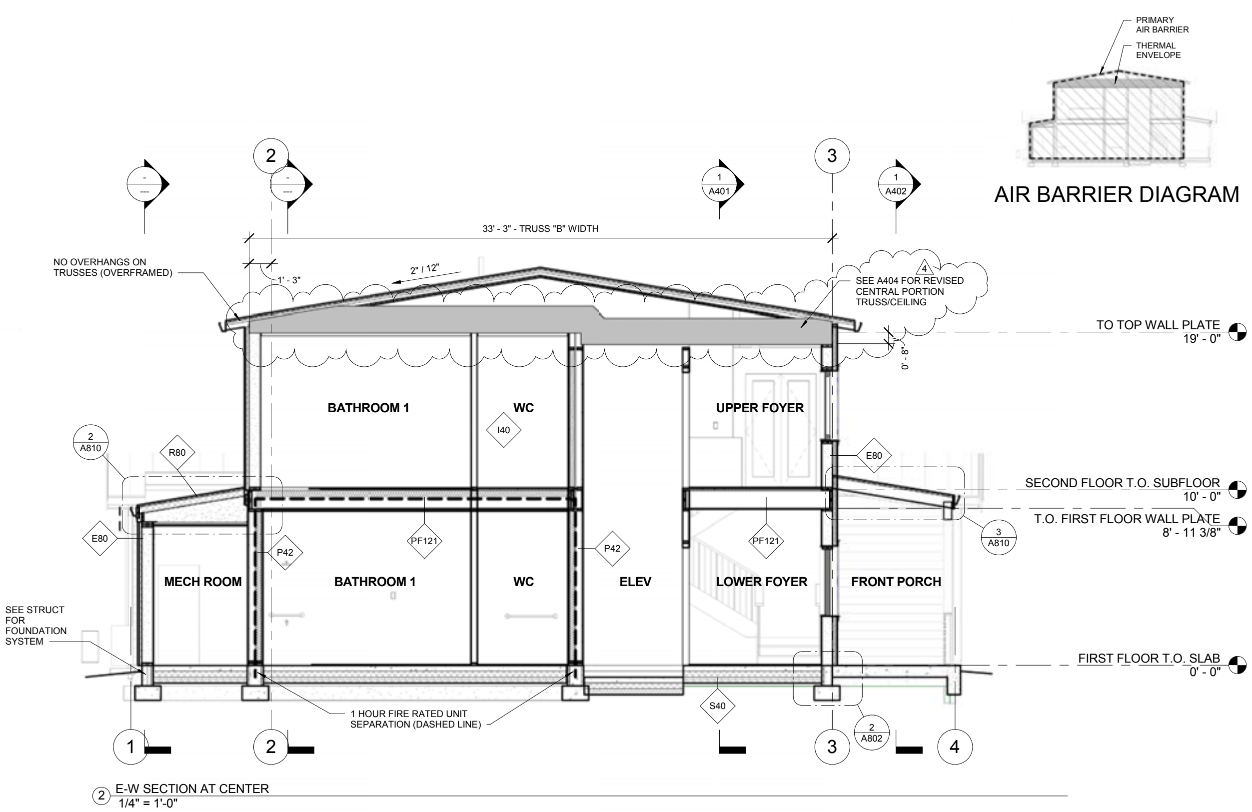
Green Hammer applied Passive House design principles to drastically reduce heating and cooling loads at The Oaks. The homes are expected to achieve a 70% reduction in total building energy use relative to existing comparable buildings. With tight building envelopes and efficient mechanical ventilation systems, the homes provide residents with unparalleled comfort and health benefits. "Indoor air quality and thermal comfort are important for people of all ages—especially those with asthma, allergies, or other health concerns," says Erica Dunn, Green Hammer director of design.

In designing The Oaks, Green Hammer incorporated Passive House design elements that are common to all of its projects, starting with superinsulating the envelope and making it airtight. To minimize thermal bridging, the shell is wrapped with 1½ inches of mineral wool insulation and the wall cavities include 7¼ inches of blown-in cellulose insulation. Cellulose was used in these 2 x 8 Forest Service Council-certified walls to help reduce overall embodied energy and increase moisture storage capacity in the building. Triple-pane, tilt-turn windows keep the homes warm in the winter and cool in the summer, making them more resilient in times of extreme heat or cold and during power outages.

The airtightness was achieved using a diffusion-open, breathable membrane formulated for roofs with a parallel product on the walls, sealed with a proprietary tape at the seams and penetrations. A liquid-applied membrane was used for continuity of the air barrier between the diffusion-open façade membrane and the stem wall and for slab penetrations and connections of the slab to the stem wall. An expanding-foam tape was used to insulate and air seal the windows to the framing. The slab was insulated continuously below with 4 inches of EPS type 2 and type 9 as needed for structural. One and one-half inches of type 2 EPS was used to insulate between the slab and the stem wall.

The roof assembly consists of raised-heel scissor trusses with 20 inches of blown-in fiberglass, chosen for its light weight and high R-value. The trusses do not overhang the walls, but instead sit flush, allowing the roof membrane to be attached directly to the top of the trusses and taped over the membrane adhered to the walls below. To create the Craftsman-style overhangs and a vent cavity, 2 x 4 lumber was placed on its side over the top of the membrane and plywood was then nailed to the flat 2 x 4s. Green Hammer employs this assembly on many of its projects to make an airtight and code-approved ventilated roof assembly.

Heat-recovery ventilation systems provide continuous fresh, filtered, outside air to each bedroom and living space within every home while continuously extracting air from the kitchens and bathrooms. Each home is heated and cooled with a single, centrally located wall-mounted mini-split heat pump.



State-of-the-art CO_2-based heat pump water heaters cut water energy use by half compared to the next highest performing options currently on the market. Energy Star-rated appliances and low-flow water fixtures keep energy and water use down.

A 74-kW on-site solar-panel array, spread out among south-facing roofs and the south-facing carport, generates clean, renewable energy. As these buildings are all-electric, this renewable-energy production is expected to supply all of The Oaks' energy needs on an annual basis.

In addition to energy-saving measures, Green Hammer incorporated universal design elements such as no-step entrances and roll-in showers that allow residents to live independently as their health and physical condition changes. Meanwhile, pedestrian paths and a shared courtyard encourage people to go outside and engage with their neighbors as well as nature—which includes enjoying the historic oak tree central to the site, around which the neighborhood was designed.

"By combining the Passive House design standard with universal design principles, we're creating durable, healthy, comfortable spaces that can adapt to people's changing needs," Dunn says. "Zero-energy homes are becoming more common because homeowners are realizing the huge return on investment—not just in energy savings but in their health and well-being."

The lessons learned from this zero-energy community—the first of its kind in the Portland senior housing marketplace—will help Rose Villa and other developers meet a growing demand among baby boomers for housing options that allow them to minimize their ecological footprint while maintaining a high quality of life.

—Stephen Aiguier

Stephen Aiguier *is the founder and president of Green Hammer Design Build.*

Passive House **METRICS**

	Heating energy	Cooling energy	Total source energy	Air leakage
$kBtu/ft^2/yr$	13.24	0.96	49.47	0.6 ACH_{50}
$kWh/ft^2/yr$	3.88	0.28	14.50	
$kWh/m^2/yr$	41.52	3.00	155.15	

PRODUCTS

Air/Moisture Control
Siga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LOGIC
WINDOWS & DOORS
Truexcullins Architecture | Ryan Bent Photography


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Low annual and daily electric usage allows complete energy offset with PV panels
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heat pump water heater
for 2-3 people (possibly 4)
Accelera® 300 E
80-gallon
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A MODEL Remodel in Austin

Photos by Trey Farmer; drawing courtesy of Positive Energy

Architect Trey Farmer and his gradually growing family lived for seven years in a 100-year-old Craftsman-style house that never quite attained the moniker of comfortable. That's unsurprising: The prerenovation blower door test came in at 16 ACH_{50}—definitely drafty, although at least the holes weren't big enough for mosquitoes to fly through. "A good chunk of the time we've lived here we've been designing its remodel," says Farmer, who works with Forge Craft Architecture + Design in Austin, Texas. He and his wife, Adrienne Farmer, a designer with Studio Ferme and a part-time personal chef, designed the final remodel together.

Farmer's home is just a few blocks from downtown Austin. The neighborhood is designated as a national historic district, although the original 1,400-ft^2 house hadn't garnered any particular recognition. The neighborhood status, along with the existing home's nonconforming setbacks, limited his redesign options. The single-story home remains single story; an addition to accommodate more bedrooms has resulted in a 2,100-ft^2 home featuring three bedrooms, two and a half baths, and a large open-plan kitchen, dining, and living room. At first designed with the 2015 PHIUS standard in mind, the home is now a pilot case for the 2018 PHIUS standard in a hot-humid climate.

Part of Farmer's intent with this remodel is to set an example for the local building industry that is practical to imitate. The changes to the PHIUS standard in 2018 have helped in this regard, according to Farmer, because the newer standard is more attainable and more attractive from a cost standpoint than the 2015 standard was. To further increase this project's attractiveness in the eyes of local builders, "I've been trying to use products and methods that are commonly used in the speculative and custom home industry in Austin," he explains.

Although the project started as a remodel plus addition, it became closer to entirely new construction once the existing house was taken down to the studs. Extensive termite damage was found. The big advantage to this setback was that Farmer was able to rebuild mostly with 2 x 6 walls, rather than having to work with the old 2 x 4 ones, and could fit more insulation into the wall assemblies. Within the wall, Farmer installed mineral wool batts. For a continuous thermal break, he opted for an insulated exterior sheathing that includes a 1-inch layer of rigid foam along with a water-resistant facer. He chose this product partly because its uninsulated version is familiar to the building community there.

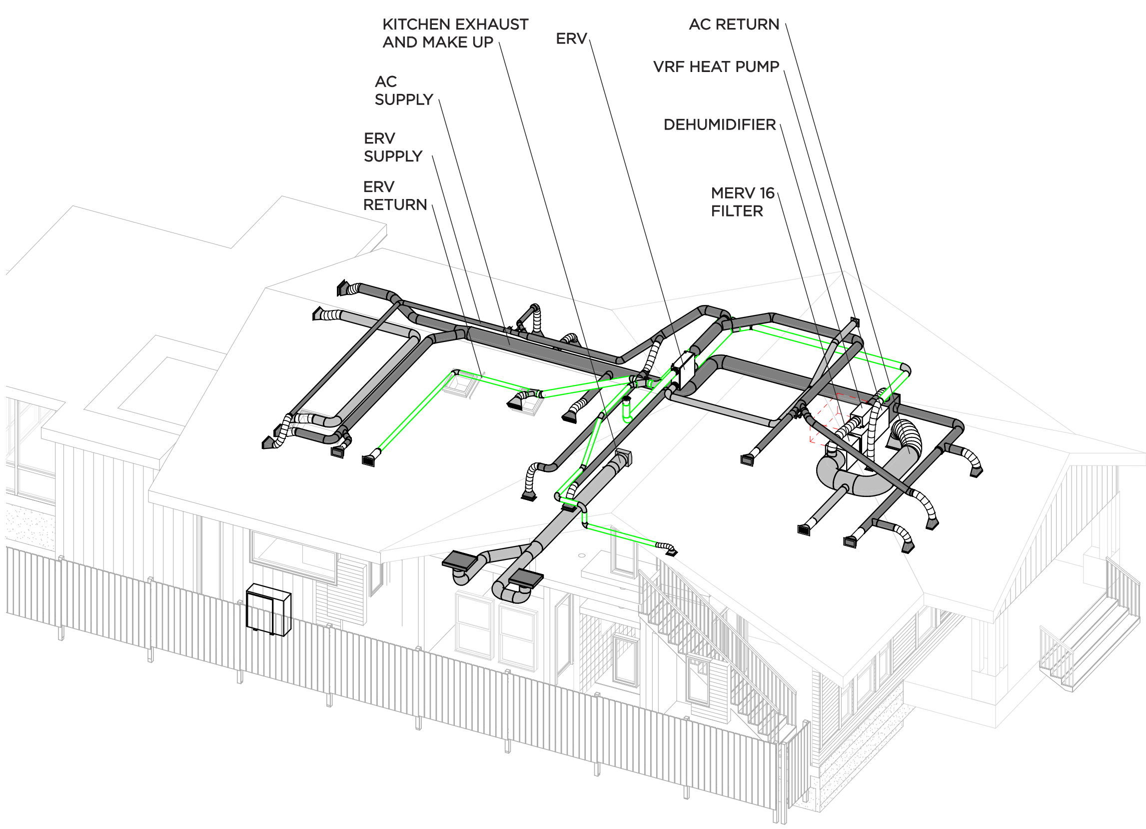
The question of how best to insulate at the roofline was one of the rabbit holes that Farmer fell into, as he describes it. Local code requires encapsulation of insulation installed at the roofline unless it's part of a cathedral ceiling, which was only the case for 30% of the ceiling. After debating the merits of sprayed foam—a common approach locally—Farmer chose two layers of mineral wool batts stacked on top of each other, yielding an R-value of 38.

Below the house, the crawl space was insulated using a sprayed foam product—not Farmer's favorite aspect of the project from a carbon viewpoint. He had explored creating a conditioned crawl space but got scared away by a friend's experience with that approach, who found it to be expensive and a headache. "Working under a 100-year-old house, there aren't a lot of options," he says.

Windows were another rabbit hole for Farmer, as he worked to balance cost and optimal performance for specific façades, along with his ever-present concern for sticking with typical brands. At various points in the design process, Farmer had consulted with another architect whose specialty is historic remodels, and this architect helped preserve the cottage feel in front while ensuring that the views of downtown Austin from the rear addition weren't sacrificed for slightly better performance. Ultimately Farmer ended up with three types of window from the same manufacturer. In the front of the house, to preserve the original look, he selected triple-pane wood-clad faux double-hungs, most of which are fixed with strategically placed casements. Other walls feature triple-pane windows, and the addition boasts larger, modern-looking windows with a U-factor of 0.17.

The east-facing modern windows are shaded by a screened porch, which gets extensive use in three, and sometimes four, seasons. A panel of vines filters out the summer sun on the southern façade. The west side gets shading from a front porch and extensive tree canopy—a benefit of being in a well-established neighborhood. According to Farmer, the most recent WUFI version can accommodate shading geometries generated by certain BIM programs, which he found helpful when it came to estimating the impact of these different shading components.

Humidity is a major concern in this climate. An ERV helps with screening out moisture, aided by a dehumidifier programmed to run when the interior relative humidity hits 55% on the indoor air quality monitor. A separately ducted variable refrigerant flow heat pump provides heating and cooling. Even with this equipment, the local green building group expressed concerns that the ERV would not be able to sufficiently exhaust the bathrooms during showers, and indeed might be triggered into conserving the indoor moisture and redistributing it. To avoid that possibility, in each of the two full baths Farmer had dedicated exhaust fans installed that are controlled by in-line humidistats. Damper systems keep these vents sealed when not in use to minimize their potential leakiness.



The home is all-electric, with a heat pump water heater supplying the domestic hot water. The induction cooktop has been a pleasant adaptation, especially for the trained chef of the family. "We love cooking on induction and try to put it in all our projects," says Farmer. "Once you see how responsive and powerful it is, it's hard to go back to anything else."

A rooftop 7-kW PV system is expected to keep the house net positive on an annual basis, producing more energy than the family is expected to consume, which is why the site energy use shows up as a negative: -1.33 kBtu /ft^2/yr. The PV array was sized to power an electric vehicle as well as the house, and Farmer also felt the oversizing was important to make a statement about trying to be a net positive contributor in a broader sense.

According to Farmer, the 2018 PHIUS standards reduced the required amount of insulation, cutting his project costs significantly compared to what would have been required under the old standard. He is tracking his home's energy use and working with other experts to better understand the carbon impacts of all the decisions made in this project and how to optimally balance embodied and operational carbon in Austin's climate.

—Mary James

Passive House METRICS

	Heating energy	Cooling energy	Air leakage	Site energy
kBtu/ft^2/yr	3.10	12.80	0.025 CFM/ft^2 at 50 Pa	-1.33
kWh/ft^2/yr	0.91	3.75		-0.39
kWh/m^2/yr	9.72	40.14		-4.17

ALL-ELECTRIC Passive House in Berkeley

Photos by Steve Mann; detail courtesy of Matthias Oppliger

Building a Passive House can be an adventure. My wife and I just completed our second in Berkeley, California. The first, a 300-ft^2 cottage that we designed and essentially built ourselves, was an excellent starter project. For the second, a 1,000-ft^2 two-bedroom, two-bath home with attached garage, we hired an architect and general contractor.

Our architect had designed and certified his own Passive House. He understood what needed to be detailed in the plans in order to communicate to the builder and to the certifying body. Our builder, on the other hand, had never heard of Passive House. We selected him for several reasons. Most of the builders we contacted found the project too complicated: We were pursuing both LEED Platinum and Passive House certification. Our builder, and more importantly, his crew, relished the challenge. Although they thought that some of the Passive House requirements, such as the insulation levels and the airtightness, were clearly crazy for our mild California climate zone, they approached the project with interest and enthusiasm.

The assemblies are suitable for Passive House-level performance in much of California. Most walls are 2 x 6 at 24 inches on center with 2 inches of exterior insulation. The roof has 12-inch I-joists with an additional 2 inches of exterior insulation layered between 2-inch framing for the overhangs. The house wall and roof insulation are blown-in mineral wool. Since we're in an earthquake liquefaction zone, the floor is an 8-inch mat slab plus 3 inches of high-density rigid foam topped with a 3.5-inch concrete radiant floor. The attached garage, framed with 2 x 4 lumber, is also insulated with fiberglass batts. The garage is often a few degrees warmer than the house because that's where the heat pump water heater tank (not the compressor) is located.

I like to approach the building of a Passive House as an exercise in constructing an insulated balloon. This helps keep everyone focused on the airtightness requirement, usually the most complicated issue if the house is properly designed and relatively thermal-bridge-free, and definitely the hardest part of the process when the builder has no experience building airtight enclosures. For this project, the strategy was to first create an airtight shell—the balloon—with an under-slab vapor barrier connected to the wall and roof sheathing covered with a vapor-permeable peel-and-stick air-and-water barrier. We left one door-sized opening for the initial blower door test, which came in at a respectable 0.45 ACH_{50}. Once we hit that number, I knew we would be fine for subsequent tests. The general contractor and crew were very interested in this initial test and quite proud of the results.

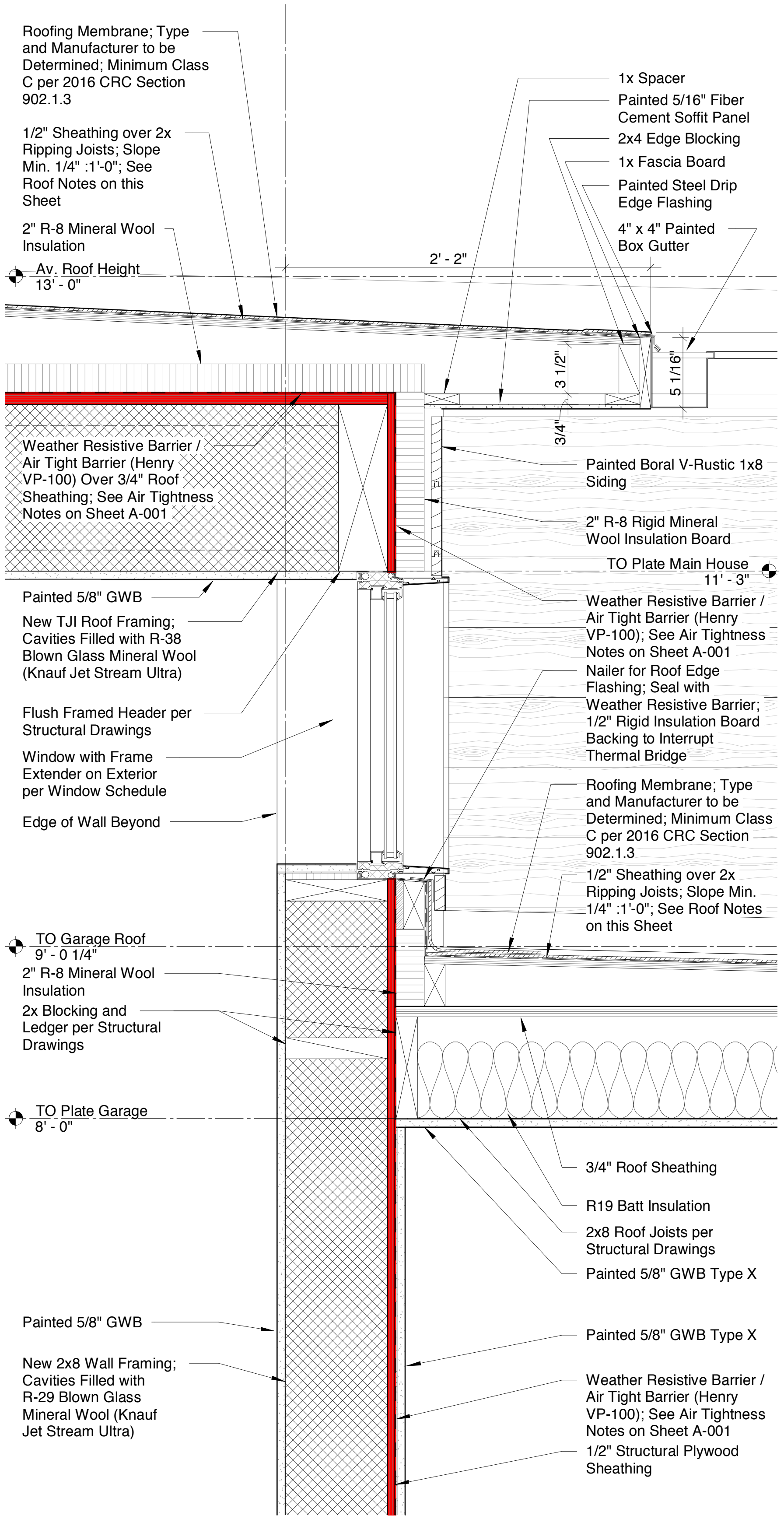
Because we lived in the 300-ft^2 cottage in the back of the lot during construction, I was able to monitor the construction progress daily. I was also readily available if there were questions about any of the Passive House details, or if other questions or problems arose. After the initial blower door test, I did most of the air sealing, making sure the various trades didn't seriously affect the airtightness. As a Certified HERS Rater, I was able to use my blower door equipment to assist in finding those hard-to-spot leaks. I found that being on-site as an active quality assurance inspector and air sealer made all the difference in maintaining the shell's integrity. Subsequent blower door tests after rough-in, after window and door installation, after insulation, and again after drywall all came in under 0.5 ACH_{50}.

The all-electric house has a heat pump water heater, an induction cooktop, 100% LED lighting, very energy-efficient appliances, a heat pump washing machine, and an electric tankless boiler to heat the radiant floor. We had decided to go all-electric about a year prior to Berkeley's decision to eliminate natural gas from all new construction. For those of you having the gas-versus-induction-cooking discussion, we are both very happy with the induction cooktop after a brief acclimation period.

The PV array has a nominal 2.88-kW rating. Actual production based on site conditions is estimated to be 3.87 megawatt hours per year. The building is essentially net zero from a site energy perspective. Circuit-based monitoring reveals that the kitchen appliances use about 3 times more energy than the combined usage of the ventilation system, the heat pump water heater, and the heat pump washing machine.

The only electricity issue we've run into so far was during the first cold spell of the season when daytime temperatures were in the 50s, nighttime temperatures were in the 40s, and there was no sun. We left town for a long weekend and hadn't set the thermostat to turn on the radiant-floor system. When we got back home, the interior temperature was 65°F. It took several hours to raise the slab temperature back to a comfortable 68°F. On sunny days, the solar exposure plus internal heat gains keep the interior cozy. A stretch of several cloudy days typically requires a daily short boost from the radiant boiler to satisfy the 2,800-Btu heating load.

I had thought that once we built a Passive House, we would move in and life would be perfect. We would benefit from all those attributes that are often mentioned: excellent indoor air quality, great comfort, low energy consumption, and so on. We are quite comfortable, except for our one radiant-floor mishap, and we pay essentially nothing for our electricity. However, once my wife mentioned that she was feeling stuffy in the bedroom,



we started opening the windows a bit more at night. That didn't seem to eliminate the problem.

I decided to investigate further with an indoor air monitor. It turns out that our nighttime air has higher-than-recommended CO_2 and nitrogen dioxide (NO_2) levels. I attribute the CO_2 levels to a lower-than-needed supply to the bedroom and a total exhaust rate that is slightly lower than the total supply rate, so that the CO_2 isn't completely flushed. The lesson is that even if you design a house according to Passive House principles, you aren't guaranteed a perfect living environment. You should test. I'm in the process of recommissioning the ventilation system to eliminate the CO_2 problem.

NO_2 is a byproduct of vehicle traffic and the burning of fossil fuels. We live near a major freeway, and in a section of Berkeley that is slowly being redeveloped from industrial to residential uses. These factors argue against opening the window, and instead relying on the ventilation system. Reducing that pollutant reinforces the idea of ventilation recommissioning. However, we have to balance the recommissioning against ventilating too much and reducing the indoor humidity to an unacceptably low level. High-quality Passive House ventilation isn't always as simple as it seems.

Despite these few hiccups, we couldn't be happier in our new Passive House. Even though we haven't yet completed the usual punch list items like arranging furniture and hanging the pictures, we're talking about doing yet another Passive House project. To build any other way just doesn't make sense.

—Steve Mann

STEVE MANN *is a Certified Passive House Designer, Tradesperson, Building Certifier, and Trainer.*

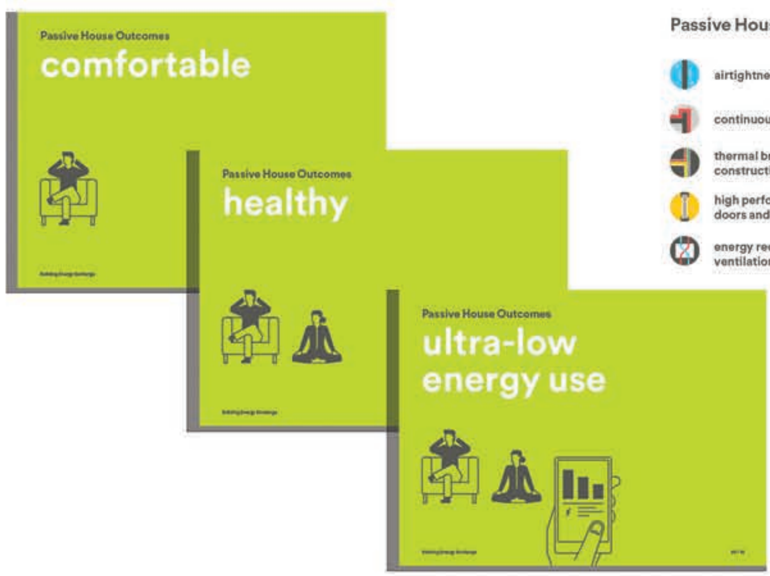
Passive House METRICS

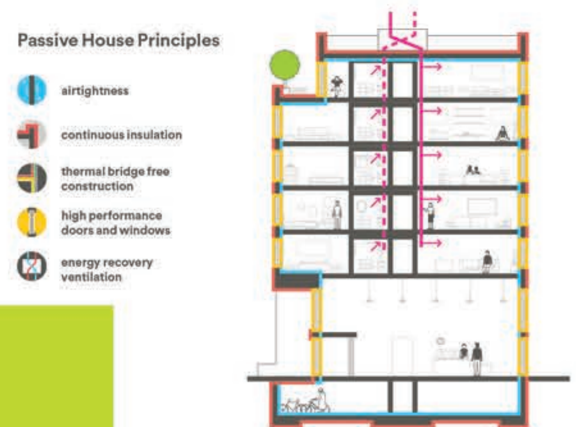
	Heating energy	Total source energy	Primary energy renewable (PER)	Air leakage
kBtu/ft²/yr	3.51	36.99	16.90	
kWh/ft²/yr	1.03	10.84	4.95	0.4 ACH_{50}
kWh/m²/yr	11.00	116.00	53.00	

PRODUCTS

Windows
Alpen High Performance Products


passive house
primer
classroom


Passive House Outcomes
comfortable
Passive House Outcomes
healthy
Passive House Outcomes
ultra-low
energy use


Passive House Principles
airtightness
continuous insulation
thermal bridge free construction
high performance doors and windows
energy recovery ventilation


keep it
cozy
with Passive House

QUEENMARY in Fort Langley

Photos by Karel Jonker; Detail courtesy of Architrix

Karel Jonker is working on his third Passive House in British Columbia, and he's set an extremely ambitious airtightness goal of 0.15 or even 0.1 ACH_{50}. And he's feeling confident for good reason. He recently partnered with his son on his family's nearby Passive House—both homes are in Fort Langley—and working with the same panel manufacturer and builder, that house tested out at 0.17 ACH_{50}. Jonker might have a small competitive streak—he was an Olympic rower—but that's not why he's set the new target lower. "We've made some improvements," he says.

Jonker dubbed his new net zero, all-electric house, which is being constructed for himself and his wife, QueenMary for its location. The home was designed to be future proofed, making it not only resilient in the face of climate change but also attractive from a marketing perspective for decades to come. "It will still be salable 50 years from now," says Jonker, in contrast to residences that depend on fossil-fueled appliances to function and also have high energy costs. His 7-kW rooftop PV system will charge his electric car as well as his house.

The three-story QueenMary features a low-slope hip roof and is oriented toward the south for optimal solar gain. The conditioned basement has two bedrooms, a bathroom, and a separate entrance so it can be used as a rental suite, an essential amenity in a market with high land costs. A great room occupies the ground floor, while the master and two guest bedrooms are on the third floor.

An elevator whose shaft was built using cross-laminated timbers (CLTs) forms the core of the building. The shaft functions as the main structural support, allowing open-floor plans to flow without supportive beams interfering. A beautiful stairwell, also built using CLTs, is a central design feature.

"It's a dream Passive House project," says Jeff Clarke-Janzen of Impact Engineering, who was responsible for the home's PHPP energy modeling. The owner had a clear vision. Architrix, the architectural firm involved, had Passive House experience, and so did the builders. Indeed, Kingdom Builders, who had worked on Jonker's son's Passive House, simply moved the jobsite two blocks to start on QueenMary. Both houses were built using prefab panels manufactured in British Columbia. "There's been no hiccups," Clarke-Janzen adds.

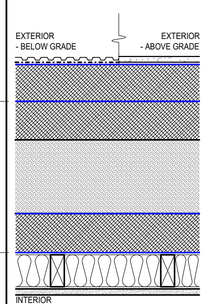
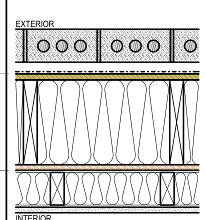
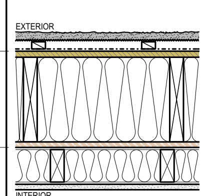
The flat roof assembly was constructed using 12-inch truss joists filled with cellulose and topped with a 40-mm wood fiber product. "We suggested this product because its embodied-carbon impact is so much lower than the foam alternatives, and it's a nicer substance to work with," explains Clarke-Janzen. "If you cut it, you can leave the fibers on-site, and they'll degrade in a week." Topping off the assembly is a standing-seam metal roof on 4-inch-over-12 sloped trusses. The metal roof was chosen for its fire resistance and ease of cleaning—critical in the wildland-urban interface area where this house is located, because dry twigs and leaf litter are easy fuel for embers to ignite.

The foundation is a raft slab sitting in 14 inches of insulation. Eight-inch ICFs with a further 4 inches of EPS rigid foam form the basement walls; an interior 2 x 4 stud wall is filled with R-14 mineral wool batt insulation. Above grade, the 2 x 10 wall panels are insulated with cellulose and fitted out with a rain screen before leaving the factory. Interior to the panels is a 2 x 4 service cavity wall. The triple-pane windows, which were installed on-site, were imported from Austria, delivering high performance at a price that rivals local double-pane windows, according to Jonker.

With extensive glazing on the south-facing façade, external shading was a necessity to prevent overheating in summer. Jonker waxes enthusiastic about the external venetian blinds on his first Passive House in Whistler: "They are fantastic! We use the blinds early in the morning when there's low sunlight, and by noon we open them completely. They provide the added bonus of almost completely dark sleeping areas." In the current home the external blinds will have automated controls.

Even with this solar-control measure, Clarke-Janzen doesn't recommend building a home without cooling, as extra people visiting on hot days can push the house into overheating that can take several days to recover from, not to mention the warming climate. Each of the two upper floors has an air source heat pump for backup comfort control. A centralized HRV with in-line MERV 13 filters distributes fresh air to all floors—a great help year-round and especially when nearby forest fires increase the particulate count.

Although there is no cooling in the basement, there is a radiant-floor heating system that is piggybacked off the CO_2-based heat pump water heater. Kingdom Builders suggested this approach to warming the basement, which doesn't benefit from solar gain in winter, after hearing about it from the Artisans Group in Olympia, Washington. PEX tubing snakes through the basement floor with a 12-inch spacing, allowing for just the right amount of heating to keep the floor at a constant 70°F.

TYPE	PLAN DRAWING DETAIL	DESCRIPTION
W1 1'-4 1/2" ICF THICKNESS		**EXTERIOR FOUNDATION WALL (ICF PANELS)** DRAINAGE MAT (BELOW-GRADE) - *SOPREMA Sopradrain 10-G or equiv.* BITUM. DAMP PROOFING MEMBRANE (BELOW-GRADE) - *SOPREMA Colphene ICF W/ Elastocol Stick H20 or equiv.* FIBRE-CEMENT BOARD ON P.T. STRAPPING or GLUED TO ICF FORMS TO COVER INSULATION ABOVE GRADE ADDITIONAL 4" EPS RIGID INSULATION AT EXTEIOR OF ICF FORM 4 1/4" EPS RIGID INSULATION (EXTERIOR ICF FORM) 8" REINFORCED CONC. WALL ICF WALL (A/B) (REF. STRUCT.) 4 1/4" EPS RIGID INSULATION (INTERIOR ICF FORM) 2X4 STUD WALL @ 24" O.C. - SERVICE CAVITY FILL STUD CAVITY W/ 3.5" [R14] BATT INSULATION 1/2" GWB - PAINTED (USE VB PAINT IN BATHROOMS) **NOTE FOR CONCRETE:** RECOMMEND HIGH SLUMP CONCRETE AND INTERNAL VIBRATION DURING PLACING TO ENSURE CONSOLIDATION OF CONCRETE IN THE ICF FORMS.
W2 10 1/2" PANEL THICKNESS		**EXTERIOR WALL (BRICK VENEER)** 3.5" THICK BRICK VENEER - *BELDEN roman facebrick : dark range - smooth finish or IXL INTERSTATE or equiv.* W/ NON-CORROSIVE CORRUGATED METAL TIES MIN. 1" AIRSPACE WRB MEMBRANE OVER PANELIZED WALL - LAPPED & TAPED SEAMS INCL. TAPE & TOP OF FOUNDATION & TOP OF WALL SHEATHING- *SIGA Majvest or equiv.* PRE-FAB PANEL: 5/8" THICK VAPOUR-OPEN HIGH-PERM. INSULATION BOARD - *AGEPAN or EGGER* 2x10 K.D. WOOD JOISTS @ 16" O.C. (SEE STRUCT.) JOIST CAVITIES FILLED W/ CELLULOSE INSULATION [R-37] DENSE-PACKED 5/8" PLYWOOD or OSB SHEATHING (A/B) (V/B) - ALL JOINTS & TAPED AND SEALED - *SIGA Rissan tape or equiv.* 2X4 STUD WALL @ 24" O.C. - SERVICE CAVITY FILL STUD CAVITY W/ 3.5" [R14] BATT INSULATION 1/2" GWB - PAINTED (USE V/B PAINT IN BATHROOMS)
W3 10 1/2" PANEL THICKNESS		**EXTERIOR WALL (STUCCO CLADDING)** 2-COAT STUCCO CLADDING ON METAL LATH 3/4" x 2" TREATED (BORATE-COATED) PLYWOOD VERT. STRAPPING @ 16" O.C. or 3/4" MESH RAINSCREEN DRAINAGE MAT - *KEENE Driwall rainscreen 075-1 or equiv.* WRB MEMBRANE OVER PANELIZED WALL - LAPPED & TAPED SEAMS INCL. TAPE TO TOP OF FOUNDATION & TOP OF WALL SHEATHING- *SIGA Majvest or equiv.* PRE-FAB PANEL: 5/8" THICK VAPOUR-OPEN HIGH-PERM. INSULATION BOARD - *AGEPAN or EGGER* 2x10 K.D. WOOD JOISTS @ 16" O.C. (SEE STRUCT.) JOIST CAVITIES FILLED W/ CELLULOSE INSULATION [R-37] DENSE-PACKED 5/8" PLYWOOD or OSB SHEATHING (A/B) (V/B) - ALL JOINTS & TAPED AND SEALED - *SIGA Rissan tape or equiv.* 2X4 STUD WALL @ 24" O.C. - SERVICE CAVITY FILL STUD CAVITY W/ 3.5" [R14] BATT INSULATION 1/2" GWB - PAINTED (USE V/B PAINT IN BATHROOMS)

Jonker anticipates that this small amount of hydronic heat, coupled with the solar gain upstairs and the overall airtightness of the house, will maintain a cozy 70°F interior temperature throughout the winter on all floors. This assumption is based on experience. When he first moved into his Whistler home, it was uncomfortably hot, even though it was October. The problem was traced to a faulty thermostat setting controlling a bathroom's tile warmers. "That one small bathroom floor was overheating the whole house," says Jonker.

Jonker is confident about this home's airtightness, because to start with the panels are tested for airtightness before they leave the factory, are sealed to each other on-site, and then are wrapped in a vapor-open air barrier membrane. Proprietary tape is used to adhere this membrane to the basement walls. As one of the improvements made to this house, all plumbing and electrical penetrations go through the foundation, leaving the above-grade walls intact. Finally, all of the airtightness detailing is familiar to the crew from Kingdom Builders, making it a reasonable goal to attain a better number than they did at the last house.

Jonker has not yet calculated the cost premium for this house, but based on his experience, he expects the utility savings to immediately offset his mortgage increase. In any case, he can't imagine building a house any other way. Five years ago, selling an electric car in Vancouver was challenging, and now Tesla is the top-selling car there, Jonker points out. He foresees a similar revolution in the housing market in the next five to ten years.

—Mary James

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	4.15	0.64	14.99	0.3 ACH_{50} (design)
kWh/ft²/yr	1.21	0.19	4.39	
kWh/m²/yr	13.00	2.00	47.00	

PRODUCTS

Insulation
Gutex from 475

Can Buildings Be Leveraged to Help Reverse CLIMATE CHANGE?

In 2018, the Intergovernmental Panel on Climate Change (IPCC) published a special report on the impacts of a 1.5°C (2.7°F) increase in global warming over preindustrial levels. According to this report, global greenhouse gas (GHG) emissions must be reduced to at least 45% and 100% below 2010 levels by 2030 and 2050, respectively, if we are to avert catastrophic climate change.[1] With organizations, governments, and individuals increasingly focused on reducing emissions, much attention has been paid to improving the energy efficiency of the built environment.

Buildings play an important role in addressing climate change. Globally, building operations account for 28% of annual GHG emissions.[2] Strategies such as improving airtightness or increasing the thermal performance of a building's envelope can therefore contribute significantly to reducing building emissions, especially if those buildings are heated using fossil fuels, or powered by an energy grid reliant on fossil fuels.

As buildings become ever more efficient and utility grids decarbonize, the role played by operational emissions will be surpassed by the role played by emissions embodied in the buildings themselves. In construction, embodied emissions are defined as the GHG emissions released during the extraction, transportation, manufacturing, construction, demolition, and disposal of a given material or product. These GHG emissions are primarily released prior to and during the building's construction, with a fraction of the emissions released at the end of a product's service life.

As it stands now, the embodied emissions of building materials, including the emissions released during construction, account for 11% of annual GHG emissions.[3] The production of concrete alone is responsible for over 9% of annual emissions.[4] Due to the long atmospheric lifetime of certain greenhouse gases and the feedback loops they generate, the emissions produced within the next decade will have a significantly greater impact on our ability to address climate change within the next 30 years than those produced in subsequent years.

Compounding the problem, future emissions are often reduced at the expense of current emissions; improvements in the energy efficiency of a building are often tied to increased embodied emissions resulting from additional insulation materials, more-complex mechanical systems, or the use of triple-pane rather than double-pane insulated glass units, for example. It is therefore incumbent on architecture, engineering, and construction (AEC) professionals to properly assess and address the entire life cycle impacts of a given building in order to strike the appropriate balance between embodied and operational emissions. (Fortunately, this balance is gaining increasing attention, and life cycle analysis calculators are becoming increasingly available, as detailed below.)

A good starting point is to look at the emissions profile of the local electrical grid. The EnergyStar Greenhouse Gas Emissions Technical Reference guide provides emissions factors for Canadian and American utility grids.[5] If the grid is supplied by a coal, diesel, or gas-fired power plant, operational emissions will probably still play a dominant role in the emissions profile of a building. Similarly, if the client or engineers insist on heating with fossil fuels, the embodied emissions associated with increased energy efficiency beyond code requirements should quickly be offset by the resulting reductions in operational emissions. However, if the local grid has relatively low GHG emissions, or will be transitioning to fossil-fuel-free means of energy production, the calculus rapidly changes.

There is, however, a caveat that is of the utmost importance. Not all building materials are created equal. While some building materials are energy and emissions intensive to produce, and others slightly less so, some building materials actually remove carbon from the atmosphere during their production.An increased use of these materials in a given construction project—an increased use of cellulose or cork for insulation, for example—could not only reduce the embodied carbon of the building, but also reduce operational emissions.

Although the use of plant-based materials is an important first step to reduce embodied emissions, it is just as important to ensure that those materials are sustainably sourced. In a study comparing the embodied emissions of a 12-story tower built using either concrete or timber, the authors found that while sustainably sourced timber from local manufacturers would sequester roughly as much carbon as the use of concrete would emit, the use of timber from nonsustainable forestry sourced at a distance would have an emissions profile approaching that of concrete.[6]

The use of agricultural residues and waste fibers represents an even more interesting alternative to conventional construction materials. Not only could materials made from these agricultural by-products sequester carbon, but they would also reduce agricultural waste and maximize the useful output of arable land. Agricultural products also have a significantly shorter growing cycle than timber, and given that the agricultural residues and waste fibers are already in continuous production, their use in construction materials offers the potential to rapidly and cost-effectively reduce the GHG emissions of the built environment.

The degree to which plant-based materials sequester carbon remains somewhat contentious. However, there is little disagreement as to whether their integration into the built environment is currently one of the best strategies to reduce the embodied carbon emissions of buildings.

For AEC professionals looking to take a more-sophisticated approach to reducing the life cycle GHG emissions of their projects, a variety of life cycle analysis (LCA) tools are currently available on the market. Some commercially available software, such as Tally or One Click LCA, offer the ability to quickly conduct LCAs directly from BIM software, such as Revit. Others, such as the Athena Impact Estimator for Buildings or EC3, offer a free LCA alternative requiring slightly more manual input. In all cases, these tools empower AEC professionals to make informed construction material choices specific to the context of a given project.

For design professionals familiar with the Passivhaus PHPP energy modeling software, I have developed a free and open source Microsoft Excel-based carbon analysis plugin, the PHPP v9.[6] Carbon Calculator. The analysis is limited to projects located in Canada and the United States. The tool focuses exclusively on the embodied carbon of insulation materials as compared to the energy performance, and resulting GHG emissions, of a given project over a 60-year period. By using this dynamic simulation tool during the design phase of a project, the selection and quantity of insulation materials can be optimized for the project's specific energy grid to ensure that both embodied and operational GHG emissions are minimized over the entire lifecycle of the building.

As LCA tools become more refined and data sets more robust, AEC professionals will be able to hone their designs to shift the focus from simply lowering embodied carbon emissions to maximizing sequestered carbon, all while minimizing operational GHG emissions. It is both refreshing and empowering to consider that growth in the construction sector could serve as a climate change mitigation strategy when the appropriate material and design choices are made.

—Philippe St-Jean

Philippe St-Jean is McGill University's sustainable construction officer.

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2. *International Energy Agency and the United Nations Environment Programme.* (2018). 2018 Global Status Report: Towards a zero-emission, efficient and resilient buildings and construction sector. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/27140/Global_Status_2018.pdf?sequence=1&isAllowed=y
3. *International Energy Agency and the United Nations Environment Programme.* (2018). 2018 Global Status Report: Towards a zero-emission, efficient and resilient buildings and construction sector. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/27140/Global_Status_2018.pdf?sequence=1&isAllowed=y
4. P.J. Monteiro, S. A. Miller, and A. Horvath, "Towards Sustainable Concrete," *Nature Materials* 16, no.7 (2017): 698.
5. U.S. Environmental Protection Agency. (2019). *Greenhouse Gas Emissions.* Retrieved from https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf
6. B. King, *The New Carbon Architecture: Building to Cool the Climate* (Gabriola Island: New Society Publishers, 2017).

Heat Pump Water Heaters as BATTERIES

A super-high-efficiency heat pump water heater (HPWH) is a game-changing technology that allows for the elimination of carbon emissions from water heating in buildings. And if that isn't enough of an enticement, HPWHs have a less well-known added benefit. When used optimally, an HPWH can double as a clean-energy battery by essentially storing emissions-free solar energy to use during times when the sun isn't shining. That's the conclusion of the California Public Utilities Commission, which found that HPWHs can provide effective local energy storage to balance the grid, helping California meet its ambitious goals to harness plentiful but variable solar energy.[1]

Currently, California's residential and commercial buildings consume more gas for heat and hot water than all the power plants in the state.[2] They also produce 7 times more air pollution. Eliminating gas use in buildings is critical to meeting clean-air and climate goals. Switching from gas-fired furnaces and water heaters to highly efficient electric heat pump technology is one of the most cost-effective measures available to achieve zero-emissions operation in a building. Energy storage is like the icing on the HPWH cake.

HOW THIS WORKS

HPWHs use electricity to heat water by collecting, concentrating, and moving heat from the air around them into water in the tank. They essentially function like a refrigerator running backward: They move heat into the hot water tank instead of moving heat out of the refrigerator. HPWHs are currently the most efficient electric water heating technology, 3 to 5 times more efficient than typical gas water heaters (meaning that they use only one-fifth to one-third of the energy to heat a given amount of water).

To act as a clean-energy storage device, an HPWH can be set to run in the middle of the day, producing hot water when renewable energy generated by PV panels is plentiful. With good tank insulation, it is possible for the water in the storage tank to stay hot enough for at least 12 hours, or even longer with well-insulated pipes and fittings. This strategy avoids using electricity in the evening, when it is more likely to be generated by the dirtiest fossil fuel power plants. In this way the HPWH is acting as a thermal battery to store renewable energy.

MATCHING DEMAND WITH SUPPLY

Traditionally, electricity is produced as needed to meet customer demand. To ensure that there is always electricity available when a customer flips a light switch, utilities must keep power plants ready on the grid to meet the maximum amount of power that might be needed. This maximum is called peak demand, and in California it typically occurs in the early evening when people return home, turn on the air conditioner, start to cook dinner, and watch television.

Although California's peak electricity demand occurs in the evening, the state's available clean- energy supply peaks during midday, when the sun is shining the brightest. This misalignment means that Californians cannot always consume the renewable energy produced, and the state must still rely on expensive and polluting fossil fuel power plants to meet evening peak demand, because it doesn't have enough storage capacity or demand flexibility to shift zero-emissions solar electricity for later use.[3]

On most days in California, the cost of producing one more unit of electricity (known as the marginal cost) spikes dramatically during peak demand hours, which typically occur between 4 pm and 9 pm, depending on day and location. Transmission and distribution lines need to be built out, and spare capacity needs to be reserved to meet peak demand, which all add up to the cost of meeting the highest amount of electricity use (see Figure 1). Conversely, marginal production cost plunges to zero or even negative in the middle of the day when supply exceeds demand, leading to curtailment of some solar and other renewable-energy generation.

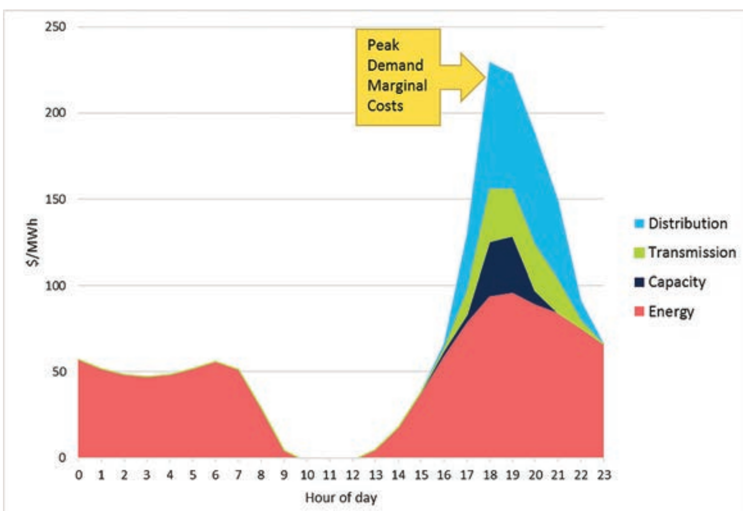


Figure 1. PG&E 2024 Marginal Costs (Average Day Over the Entire Year), NRDC 2018

This mismatch will hinder California's pursuit of a fully decarbonized grid if it remains unresolved. That's where flexible electric loads like HPWHs can help.

LOAD SHIFTING FOR SAVINGS

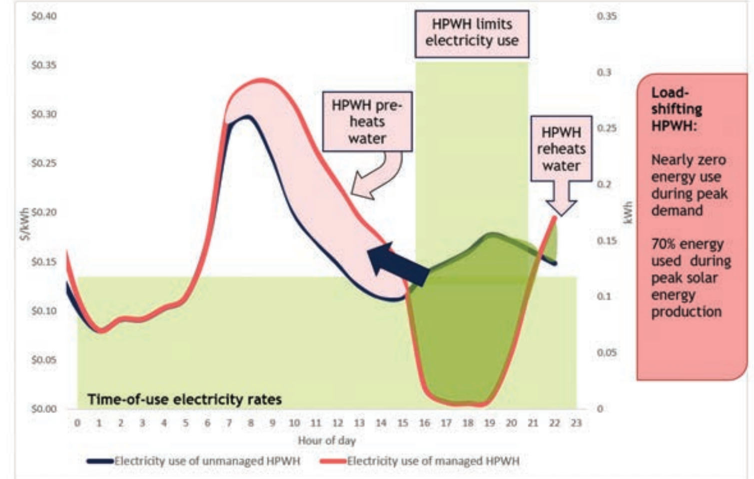


Figure 2. Electricity use of heat pump water heaters with (pink line) and without (black line) load shifting. (NRDC)

Grid managers orchestrate electricity production using price signals and dispatch commands, which tell power plants when to ramp generation up or down. These same signals can be sent to buildings and electric appliances to help automatically manage demand. Demand-flexible HPWHs are one of the largest residential loads that can respond to time-of-use utility rates or grid signals to optimize when they operate, minimizing bills automatically without customer action.

How does this work? Much in the way that a phone battery charges when it's convenient and can then be used on the go all day, HPWHs can heat water many hours in advance and still provide piping-hot showers during the evening. Demand-flexible, or "smart," HPWHs easily provide cost savings with no compromise on hot water availability. And when many of these water heaters are used together across the state, they can provide system-wide cost savings and emissions reductions, helping to build a fully renewable electric grid.

A 2018 modeling study found that HPWHs can shift their entire evening electricity load into the middle of the day's solar peak, with 70% of the water heater electricity use taking place while solar power is inexpensive and abundant, and almost none taking place during the evening peak, when electricity is dirtiest and most expensive (see Figure 2).[4]

EASING MARKET ADOPTION

HPWHs that shift energy loads can be an essential part of our clean-energy transition, but we need policies that make market adoption easier and ensure that they are used to maximize grid benefits. These policies include

1. encouraging builders to install HPWHs when constructing new homes, by providing incentives—both financial incentives to jump-start the market, and compliance incentives in building energy codes and other construction requirements for new buildings;
2. reflecting marginal electricity costs in electric-rate design, with time-of-use rates that have a significant ratio of peak to off-peak electricity costs, to allow flexible loads like HPWHs to operate on low rates during off-peak hours, thereby encouraging load shifting sufficiently to spur market demand; and
3. spurring market development by early adoption. Homeowners, installers, builders, architects, and designers all have a key role to play through early market adoption, sending manufacturers and other market actors a clear signal that there is a market for and money to be made in clean-energy water heating.

—Pierre Delforge and Olivia Ashmoore

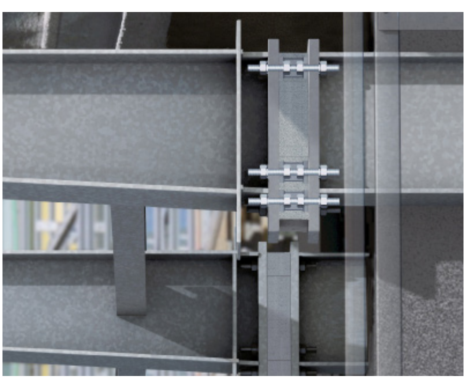
PIERRE DELFORGE *is a senior scientist at Natural Resources Defense Council (NRDC) and Olivia Ashmoore is a graduate student at the Goldman School of Public Policy at UC Berkeley and a fellow at NRDC.*

1. Decision Implementing the AB 2868 Energy Storage Program and Investment Framework and Approving AB 2868 Applications with Modification.
2. GHG Current California Emission Inventory Data.
3. How Not to Waste Clean Energy: New Support for CA's AB 813.
4. P. Delforge and J. Vukovich, "Can Heat Pump Water Heaters Teach the California Duck to Fly?" ACEEE Proceedings (2018).

Schöck Isokorb® Structural Thermal Breaks.

Prevent condensation and mold, cut heat loss.

- Improve the effective R-value of your wall assembly by up to 50%
- Reduce heat loss by up to 90%
- Most efficient way to meet code requirements for continuous insulation
- Prevent condensation and mold
- Increase warmth of interior floors by up to 34°F / 19°C



Uninsulated balconies, canopies, parapets and slab edges penetrating building envelopes create thermal bridging between the cold exterior and the warm interior structure that supports them, causing heat loss and condensation.

Isokorb® Structural Thermal Breaks prevent thermal bridging by insulating the building envelope at the penetration, while supporting loads equivalent to conventional concrete and/or steel structures, offering multiple benefits.

Isokorb® Structural Thermal Breaks for concrete construction (above) contain engineered stainless steel rebar for casting into interior and exterior sides of the penetration.

Isokorb® Structural Thermal Breaks for steel construction (left) bolt interior steel structures to cantilevered balcony supports, canopies or rooftop connections.

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