Fall/Winter 2020

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Cover image: Whistler Housing Authority multifamily residence. Photo courtesy of Vetta Building Technologies.

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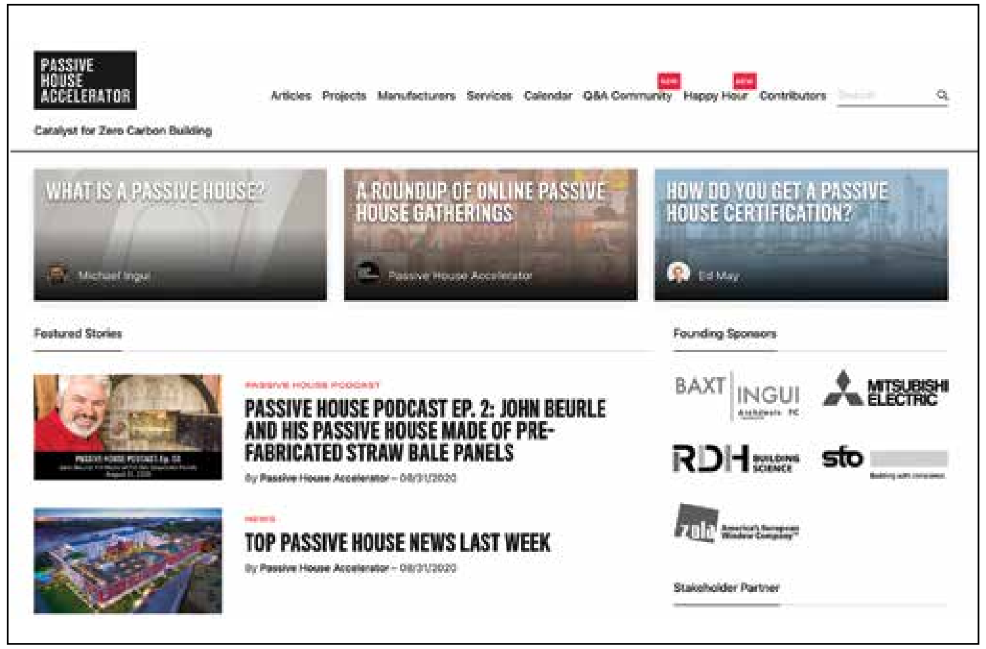
EDITORIAL



Passive House Buildings is very pleased to announce that we will be merging with Passive House Accelerator. Both organizations share a similar mission—promoting building designs and techniques that sharply reduce carbon emissions from the building sector, thereby helping to stabilize the climate. We are excited to be working together to provide the best one-stop source for all Passive House-related content, and we warmly invite you to join us at passivehouseaccelerator.com as we launch into this new chapter.

Passive House Buildings has been on the forefront of Passive House news for more than a decade, reporting on and compiling a rich network of North American Passive House projects from Guadalajara, Mexico to Resolute Bay in Canada. Passive House Accelerator has done an outstanding job of creating a richly informative website featuring diverse types of content, from increasingly well-attended informational happy hours to project tours to fact-filled articles and a new podcast. Together we will be delivering essential Passive House news, timely videos, special events, specialized publications, and so much more.

As always, a big thank you goes out to all the sponsors who have supported *Passive House Buildings* over the years and in this issue. We look forward to continuing to work with you in our future publishing endeavors.

—Mary James, Editor and Publisher

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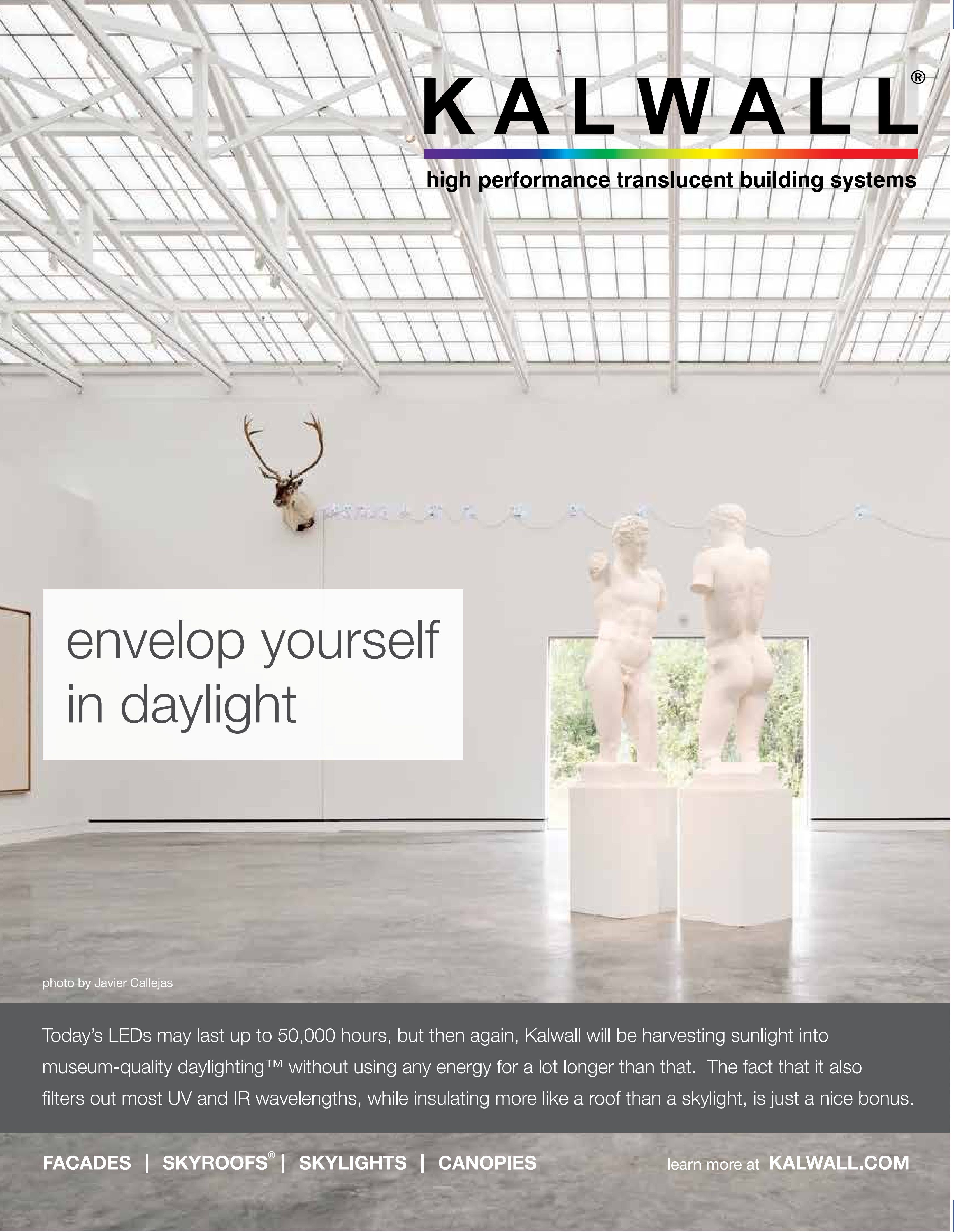

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WOOD-FIBER Insulation: *Born in the U.S.A.*

By next spring a new option in low-embodied-carbon, North American-produced insulation will be hitting the market: wood-fiber insulation from GO Lab. Maine-based GO Lab was founded in 2017 by Matt O'Malia, architect, and Josh Henry, a materials chemist. The first products, expected out in 2021, will be loose-fill and batt insulation. Wood-fiber boards will be out in early 2022.

"I love wood fiber as an insulation. It's carbon sequestering, recyclable, and vapor permeable," explains O'Malia. Yet opting to use this environmentally beneficial insulation has meant importing it from Europe, which has its downsides. "The shipping costs from Europe double the price," O'Malia notes, which was particularly aggravating for an architect based in a state with a large forest economy. Then in 2016, six paper mills were shuttered in Maine, a $1.6 billion loss to the state economy. O'Malia and Henry figured the wood residuals that weren't being used in those former paper mills could be repurposed.

GO Lab has since purchased one of those former paper mills and is busy transforming it into a 200,000-ft^2 manufacturing facility. There, green wood chips are pressurized, steamed, smashed, and then blasted into a flash tube dryer that brings the moisture content down to 7%. Both the batt and loose-fill products are treated with boric acid, which acts as an insect and flame repellant. The denser boards don't need this treatment to achieve flame-spread specifications for low-rise residential buildings.

To shift the insulation market toward greater sustainability, GO Lab is intending its wood-fiber insulation to be cost competitive with comparable insulation products on a dollar per delivered R-value basis. "There's no point in bringing an expensive specialty product to market. That's not going to change anything," says O'Malia. GO Lab has set a target market radius of 200 to 400 miles from the plant in Madison, Maine. At greater distances, shipping costs can eat into the product's affordability. "When we're at full capacity, we could address from 5% to 8% of the Northeast insulation market," O'Malia asserts.

O'Malia and Henry started GO Lab to help designers and builders of low-energy and Passive House buildings successfully slash those buildings' overall carbon footprints—including both operational and embodied energy. Wood-fiber insulation is a solution that O'Malia is extremely excited to be making more accessible. Raising the funds, buying and retooling the plant, engineering the manufacturing process—it's been an exhilarating, and occasionally terrifying, start-up experience. Once GO Lab is fully established, plans are in the works to expand so that its sustainable solution can reach broader markets, most likely starting with the Pacific Northwest.

—**Mary James**

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Most of our homes were designed for the past—not for the climate and energy reality we're facing. Finding an effective, commercially viable retrofit solution that meets our climate, well-being, and equitable-housing needs will unlock a massive market opportunity. The Reframed Initiative—a joint effort by the BC Non-Profit Housing Association, the city of Vancouver, and the Pembina Institute—aims to facilitate unlocking this opportunity. The goal of Reframed is to demonstrate next-generation retrofit solutions that could be delivered at scale and meet three key social objectives: reduce carbon pollution, improve climate and seismic resiliency, and enhance occupant well-being.

Upgrading housing is complicated and often costly. To scale up deep retrofits, we need to integrate retrofit solutions into packages that are easier to procure, finance, permit, and operate. Reframed is bringing together the construction industry, building owners, policy makers, and the financial sector to scale up deep retrofits by demonstrating the technical and economic feasibility of whole-building retrofit solutions that integrate energy efficiency, decarbonization, seismic safety, and climate adaptation.

This fall, the Reframed Initiative and BC Housing are teaming up to commission deep-retrofit designs for up to five multiunit residential buildings. Multidisciplinary teams will participate in a six-month exploration lab to develop schematic designs for deep-retrofit solutions for low-rise residential buildings in British Columbia's Lower Mainland and/or the Victoria area. Each team will tackle a specific building, with support from its peers and experts on climate change, energy, and health. In parallel, a working group will focus on developing the business case for such retrofit solutions; draw on what the teams have learned; and engage with housing providers, insurers, financiers, and regulators.

A request for proposals (RFP) to participate in the Reframed Lab will be issued in fall 2020. We encourage interested parties to visit reframedinitiative.org/lab/ and register as a solution provider to receive notifications regarding the issuance of the RFP and to signal interest in joining an integrated design team. Registrants will need to provide contact information and indicate their proposed role on a team. Specialty areas needed for integrated design teams could include building science; envelope; mechanical, electrical, and structural engineering; architecture; energy modeling and data capture; and monitoring and building controls. Teams may also include suppliers, manufacturers, fabricators, builders, contractors, and retrofitters.

The list of the registered solution providers will be published on Reframed Initiative's website to facilitate team formation and engagement prior to the closing of the RFP process. Selected teams may also be retained for the detailed design and construction phases of the demonstration projects.

—Ghazal Ebrahimi

Ghazal Ebrahimi is a senior analyst in Buildings and Urban Solutions at the Pembina Institute.

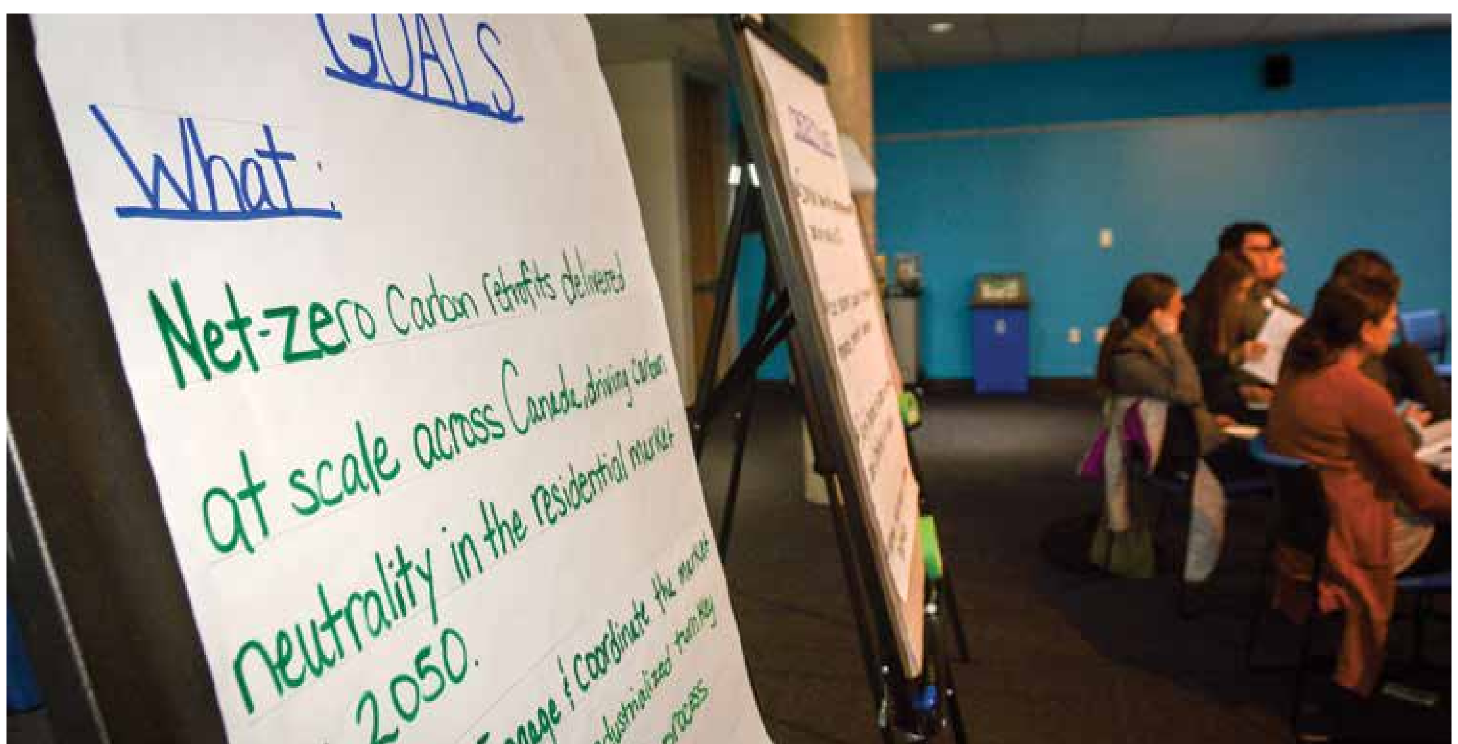

Photo courtesy of Retrofits at Scale workshop at BCIT Downtown Campus, Vancouver, B.C.

Canadian Cities Lead on EMBODIED CARBON

For how long do up-front carbon emissions in building materials outweigh operational energy savings? That question so obsessed Chris Magwood that it became the basis for a two-year research study, earning him a master's degree from Trent University in Ontario in the process. His thesis is chockful of modeled data comparing carbon emissions from various building materials, along with other approaches to slashing emissions from the building sector.

"Climate change departments have had their eye on embodied carbon for a while but didn't have numbers that made it actionable," explains Magwood. His work caught the attention of the municipality of Douro-Dummer, which became the first to turn his data into an incentive program. The city's program helps defray permitting expenses for projects that reduce the combination of up-front and operational emissions, otherwise known as the carbon use intensity (CUI), of a building. Other local governments will be following Douro-Dummer's lead. The city of Toronto is already considering amending its ambitious retrofit program to incorporate CUI assessments.

A fact-filled summary version of Magwood's thesis findings, *Low-Rise Buildings as a Climate Change Solution*, is available from www.buildersforclimateaction.org. As a sneak preview, his research results strongly support using cellulose and wood-fiber board insulation. "Those materials can get most residential buildings down to a zero-carbon-net footprint," says Magwood, "And those materials are accessible here."

—Mary James

WINDOWS AND DOORS
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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.

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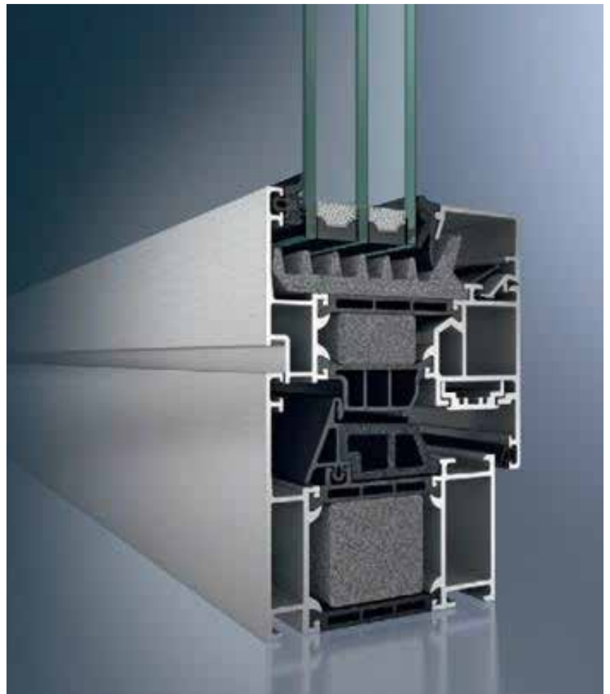

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EAS differentiates itself among window suppliers by offering full service procurement of windows from design through delivery, installation and after-sale service. This project involved 21 tons of triple-pane windows with largest window units weighing 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.

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Renderings courtesy of GBL Architects

Vancouver Multifamily Passive House Dedicated to INDIGENOUS RESIDENTS

A new, 9-story Passive House multifamily residence is going into Vancouver, Canada's, Khupkhahpay'ay (Squamish for cedar tree) neighborhood. The building is a social housing project designed for First Nations residents and those with Indigenous ancestry.

M'akola Development Services, a local nonprofit housing developer, submitted on behalf of the Vancouver Native Housing Society a rezoning application for the 1766 Frances Street site earlier this year. The current building was damaged in December 2017 by a fire that displaced all of the residents. While Passive House is not a required building standard in Vancouver, it is a newly possible path for rezoning projects in Vancouver that brings some advantages, according to Achim Charisius of GBL Architects.

The design will cater to the development's Indigenous residents' ancestry in part by using cross laminated timber (CLT) floors and envelope panels. This technique is intended to honor and continue the legacy of traditional Indigenous wood building, Charisius says, adding, "In keeping with the principles of Indigenous environmental stewardship, the proposed structure will feature a mass timber frame in order to reduce the project's greenhouse gas emissions and overall environmental footprint." Building this project with CLTs recently became possible due to a new code provision in Canada that allows for mass timber construction up to 12 stories.

The CLT envelope panels will be installed in a basket-weave pattern around the exterior of the building, which is meant to pay homage to the longtime tradition of Coast Salish basket weaving. In addition to the basket-weave detail, there will be a number of commissioned Indigenous artworks in and outside the building.

"The building is intended to be a source of pride for its residents. The First Nations artwork is intended to provide a sense of belonging and honor and celebrate Indigenous culture," Charisius states. In addition to the reflective aesthetics, the project will have amenities such as community gathering areas, an on-site sweat lodge, and a rooftop with areas for children to play and for residents to grow food.

The building will have 40 studios, 9 one-bedroom units, 5 one-bedroom accessible units, 14 two-bedroom units, 6 three-bedroom units, and 10 four-bedroom units. Over 35% of the units can accommodate large families, who had previously lived in the building and were displaced by the December 2017 fire. The Frances Street project is being constructed in the midst of a housing crisis where affordable rentals, particularly for large families, are hard to find.

Charisius stresses the importance of using the Passive House standard on this project because the fundamentals of Passive House align with Indigenous ideologies of respect for the environment. "Supporting environmental sustainability is a key component of the vision for this project. Vancouver Native Housing Society has commissioned a building design that will showcase the highest level of energy efficiency, with the goal of achieving Passive House certification," Charisius says.

—Sydney Gladu

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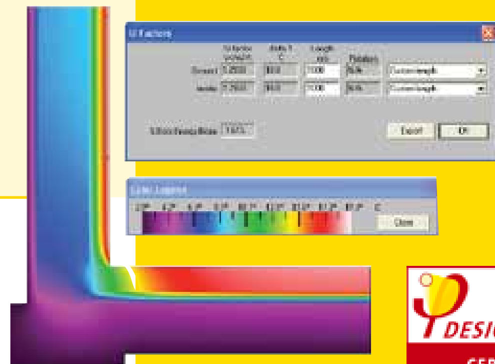

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INTUS WINDOWS

PHPP ENHANCED: *PHribbon*

Photo by Tim Martel

What if your PHPP tool could do more than calculate the energy expenditures of a building? U.K.-based Tim Martel has developed a PHPP plug-in—PHribbon—that has several tricks up its sleeve. Including, he says, saving architects and consultants significant time and effort.

The PHPP program is at the heart of the Passive House process, but its very thoroughness demands hours of effort. Martel's program cuts through the time-consuming aspects of PHPP, such as manual data entry of windows, and also adds functions that account for embodied carbon, cost, and whole-life expenditures, as well as preexisting structures for retrofits. The outcome is not only a more streamlined process but also one that facilitates retrofit planning and calculating embodied carbon.

The U.S./imperial version of PHribbon is still in the beta phase. Martel says that the beta testing for the imperial system has been successful thus far and is available to test on current projects.

Martel has had an eight-year career in England as a chartered architectural technologist, a Certified Passive House Designer, a retrofit coordinator, and a tutor for the Association of Environmentally Conscious Builders (AECB). PHribbon first came about as a supplemental tool for students of a Passive House retrofit training course taught through AECB.

Since then Martel has spent the last few years developing an add-on to the existing PHPP program that has built-in functions and modeling processes that can run anything from cost to embodied carbon. Currently, PHribbon offers a base module for £45 and additional modules, such as the cost module, daylight factor module, and embodied CO_2 module, for prices that range from £30 to £75.

PHribbon is a user-focused tool, giving architects more control and accuracy in the building process compared to other tools on the market. If you are interested in beta testing the Imperial PHribbon plug-ins, visit www.phribbon.co.uk.

—Sydney Gladu

Passive House SCHOOLS *on the Horizon*

Two new Passive House public schools are in the works in downtown Brooklyn, Alloy Development announced in December 2019. The schools are part of a major new development that will include the first all-electric skyscraper in New York City—a 38-story, 500-foot-tall tower. Only the school buildings, located in a very busy section of Flatbush Avenue, will be designed to meet the Passive House standard.

"We committed to Passive House standards during the public approval process in an effort to establish new standards for public school construction in New York City," says Jared Della Valle, CEO and founder of Alloy. "We also believe that the interior qualities that Passive House affords are conducive to a healthy and focused learning environment." The 489 State Street development is a public-private partnership with the city of New York's Education Construction Fund.

Alloy has developed several Passive House projects in the past, including Della Valle's personal home. The two schools—an elementary school and a Khalil Gibran International Academy high school—are expected to be the first passive schools in the city. They are being designed by the Architecture Research Office, a New York City-based architecture firm.

Buildings are New York City's largest contributor to carbon emissions, which is why Alloy has committed to raising industry standards for lower emissions in building and development to combat global climate change. "We are focused on producing built solutions that foster healthy communities and positively impact environments," says Della Valle.

Della Valle believes in the sustainable qualities of Passive House but does not find it suitable for all projects. The all-electric 100 Flatbush Tower, which will be triangular shaped, will not be Passive House, because the building's envelope-floor area ratio would have made meeting that standard too difficult.

The tower and the two schools constitute the first part of a two-part development that will include 256 residential units along with 100,000 square feet of Class A office space and 30,000 square feet of retail space. This first part is set to be complete in 2023. The second part— a 69-story residential, office, and retail tower—will include 200 affordable housing units. The design standard for the second part has not been determined yet, but the development is set to be complete in 2026.

— Sydney Gladu

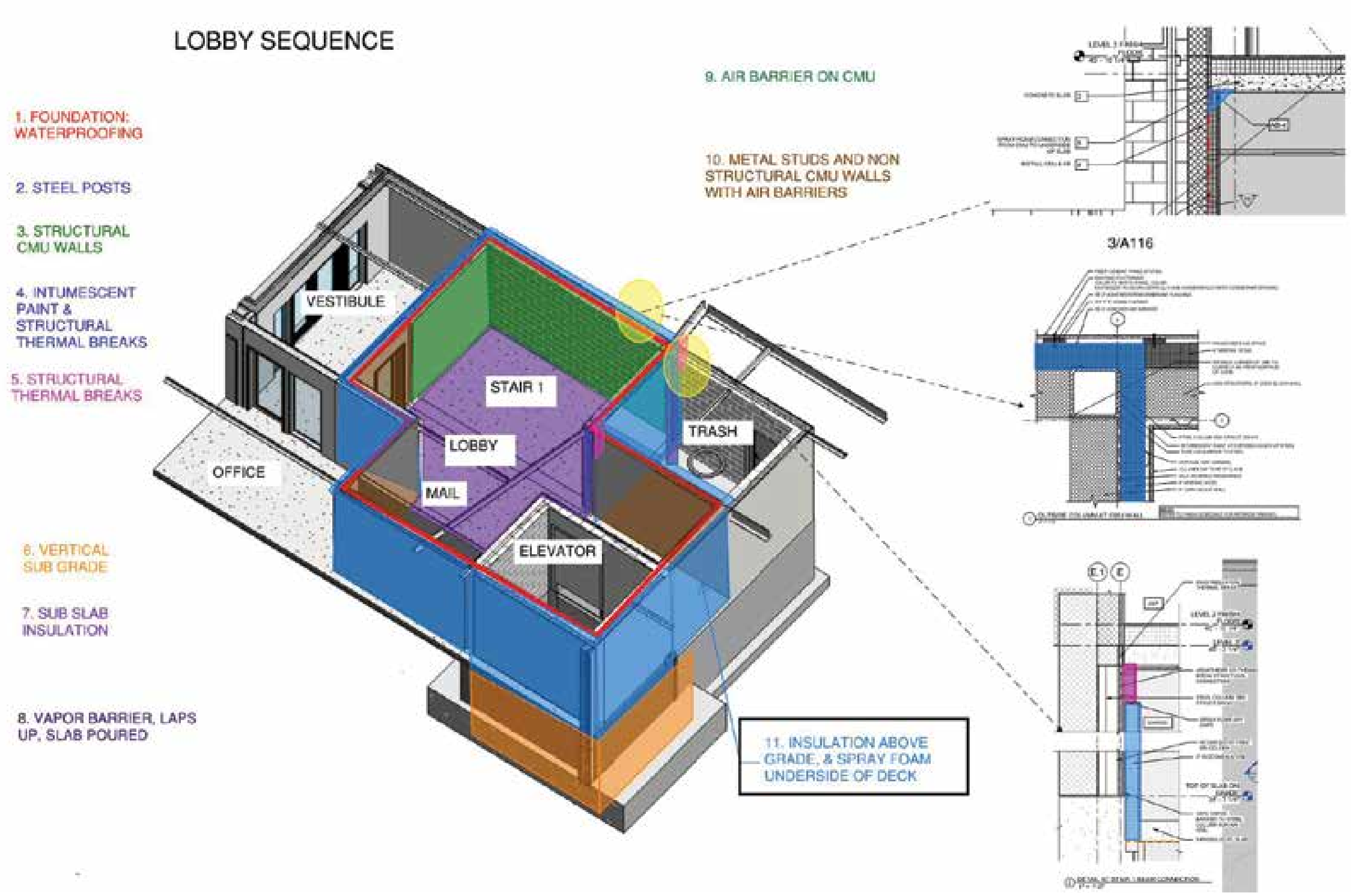
Getting Passive House DETAILS *Implemented*

The New Gravity Housing conference took place virtually this year, from August 5 to August 8, and *Multifamily Passive House: A round table discussion of lessons learned* was a conference highlight. One of the presenters, Michelle Apigian of Icon Architecture, has three Passive House multifamily projects under her belt, including Harbor Village, currently under construction in Gloucester, Massachusetts. The firm has six more in design.

It's a truism that one of the major challenges associated with achieving Passive House performance in any project is getting the details as drawn recreated on the construction site. Apigian related her experiences with that struggle and her solutions, sharing some outstanding details. In her previous projects, she had come to realize that her two-dimensional plans were not detailed enough to communicate precisely what needed to be done at tricky junctions in order to maintain a consistent air barrier. So she changed up how she presented her details, building 3D axonometric drawings that call out the step-by-step construction sequence, often with the products specified for each step.

Great as they are, these improved details are not a 100% solution. "Often a detail we drew could not be executed," says Apigian, "so you need to have humility." Other critical steps to successful construction are building mock-ups of sections or junctions that could be new to the trades on-site, as well as making sure that subcontractors understand how their work fits into the bigger picture.

—Mary James



Rendering courtesy of Icon Architecture

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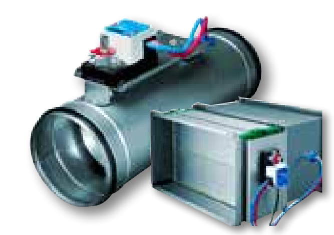

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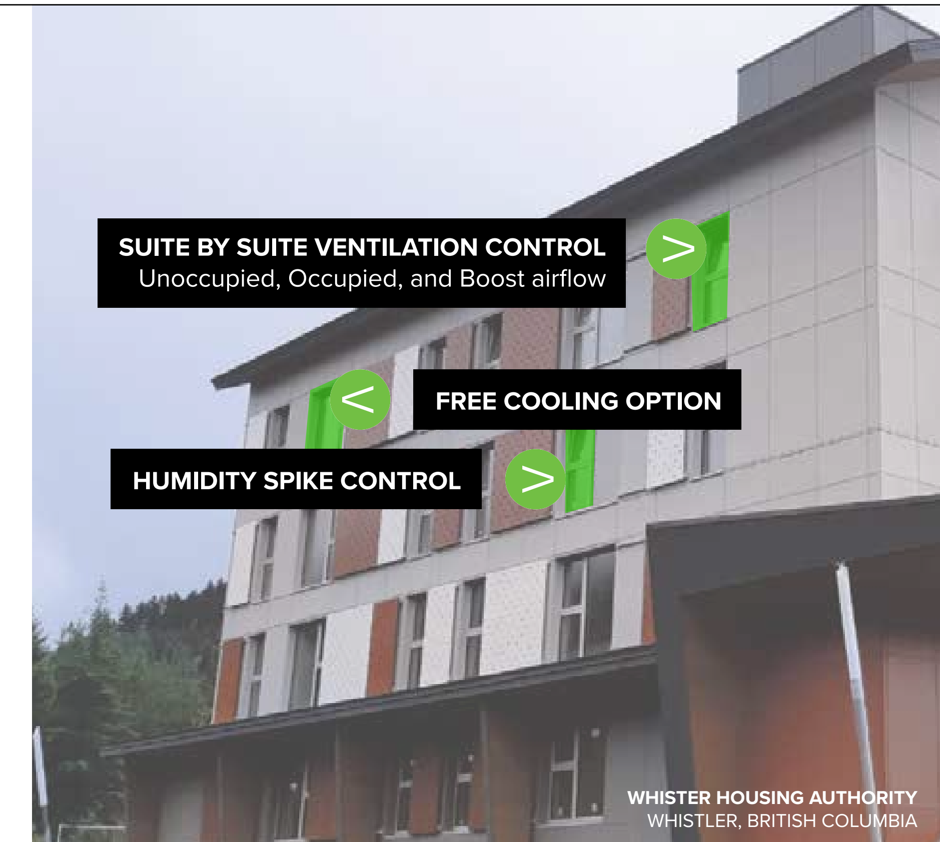

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Photo above courtesy of Melvin Lau; photo opposite courtesy of BC Passive House; rendering courtesy of Integra Architecture

Housing Improvement *for* WHISTLER RESORT

The Whistler resort area in British Columbia has earned a well-deserved reputation as an outstanding ski area, attracting two million visitors each year. Its popularity, though, has led to a housing affordability crisis for the resort's employees. Last November that crisis eased somewhat with the opening of a four-story apartment building developed by the Whistler Housing Authority (WHA). The 24-unit rental property, which has been certified as meeting the Passive House standard, has a mix of studios and one- and two-bedroom apartments, providing housing for roughly 50 employees. The building includes an underground garage, a shared laundry, an elevator, and in-suite storage for bicycles.

This Passive House project posed many challenges, says Duane Siegrist, principal architect with Integra Architecture, yet it also had one strong advantage. "The clients were our champion in this case," Siegrist says. In particular, Marla Zucht, WHA's general manager, ensured that the authority's commitment to achieving Passive House was unwavering. She helped guide the team selection process, including hiring a construction manager whose expertise and local knowledge contributed heavily to the project's success.

Prime among the challenges was Whistler's alpine climate. The area's many months of snow and rain translate into a compressed build season. Another pitfall was the local shortage of skilled trades. In addition, the design had to be frugal, given WHA's strict budget, while still providing the 24 units of housing. "We had to find innovative solutions," Siegrist notes.

Fortunately, one solution—prefabrication—helped WHA to address many of these challenges. The walls, floors, and roof panels were all prefabricated off-site, sharply cutting on-site labor time. The use of these panels allowed for the efficient enclosure of the load-bearing structures despite the temperamental and often harsh climate, thus avoiding potential seasonal delays.

In addition to these efficiency benefits, the panels have environmental advantages as well. They are constructed of low-embodied-energy materials, with cellulose as the main insulator. The approximate effective R-values were R-45 for the walls, R-98 for the roof, and R-71 for the floors. "It went together really well, and the credit goes to the prefabrication," says Siegrist, adding, "The final airtightness testing was tighter than we expected at 0.15 ACH_{50}, leading to PHPP results of 13 kWh/m^2 for the heating demand, and a PER (primary energy renewable) factor of 62 kWh/m^2, which are very strong performance numbers."

Long before construction began, Siegrist wrestled with designing the building to accommodate the authority's program goals on a tight site. To make all of the bedroom types for 24 units fit within the allocated floor area, the building's exit staircase was moved out of the envelope. A dynamic shaped canopy entrance serves as a marker for the public and residents. Placing the exterior stairs so that they overlook the plaza affords ample space to sit, soak up some sun, and socialize. Anticipating the needs of the generally athletic renters who work in the resort area, Siegrist provided space for bike storage in each unit. "We could have provided bike storage below grade

Courtesy of BC Passive House

in the garage, but for many of these renters their bicycles are their most important assets and their only source of transportation," says Siegrist, "and losing one would be a huge deal." The units' entry doors are sized slightly larger than is typical to allow for easy bike access, and the corridors and elevators were designed with durability in mind.

From a Passive House perspective, the site also posed challenges. Instead of facing south—optimal for maximizing solar exposure in winter and controlling it in summer—the building fits on the site in such a way that three façades get direct solar exposure. Early modeling showed that the building would overheat in summer unless shading was addressed. "We had to specify horizontal sunshades not on the south alone but on all three sides," Siegrist says. He adds that this kind of detailing is costly and tricky to implement but was absolutely necessary for occupant comfort and for meeting the requirements of the Passive House standard. At first the design team had considered movable screens to shade the windows, but the team eventually opted for a fixed solution that did not require the occupants' participation or ongoing maintenance by the client, and also avoided potential issues related to ice accumulation.

A centralized ERV and integrated variable refrigerant flow heat pump system supplies constant ventilation, along with post-heating and cooling. Control dampers allow for individualized heating and cooling in each suite. The centralized system provided many advantages, including fitting most of the duct runs in the corridor spaces. Modeling determined that the supplemental space heating load could be met with a cost-effective electric baseboard system.

Although new buildings in Whistler are required to connect to the district energy system for water heating, that system was at odds with the Passive House efficiency requirements. This hurdle was overcome through further study that led to the building's domestic hot water being provided by an electric boiler.

The tenants began moving in last November. All of the feedback that Integra Architecture has received has been very positive. "The clients have been really happy and, I am sure, relieved that the team's plan worked. They were very supportive when it became complex," says Siegrist. "Working on a building type that is new to the industry requires strong leadership and teamwork and good communication skills to be successful. The clients still say how proud they are of this completed innovative housing project." New housing that is designed specifically for the resort's typical employee and that delivers Passive House levels of comfort is a huge bonus in a tight housing market.

—**Mary James**

Passive House **METRICS**

	Heating energy	Cooling energy	Primary Energy Renewable	Air leakage
kBtu/ft²/yr	4.2	2.0	19.8	0.15 ACH_{50}
kWh/ft²/yr	1.2	0.6	5.8	
kWh/m²/yr	13.2	6.3	62.0	

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Kick-Starting INDUSTRIALIZED Retrofits in *Halifax*

Rendering (above) by Nick Rudnicki,RSI Projects; photo courtesy of ©Google 2020

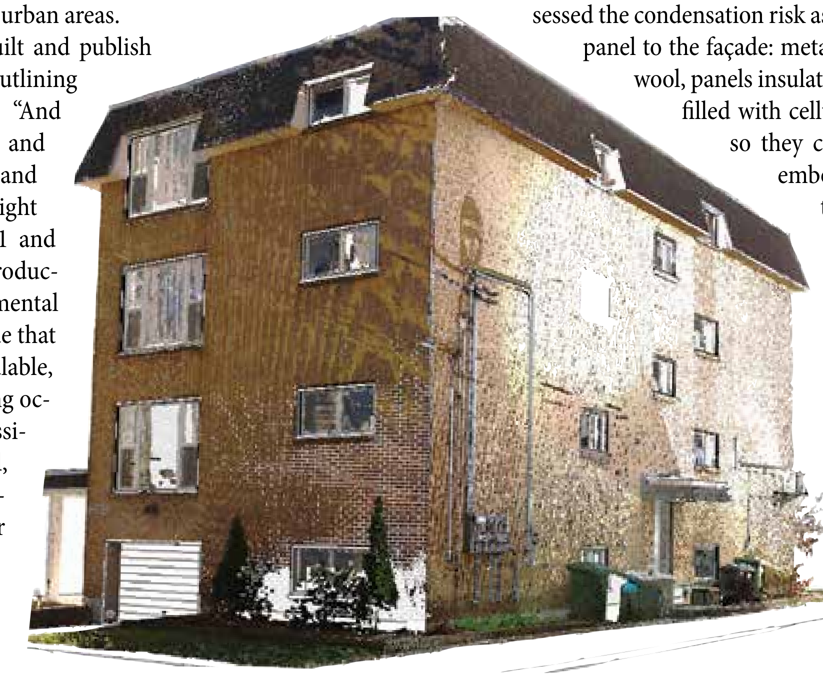
It's no secret that retrofitting existing buildings is crucial to cutting carbon emissions from the building sector, and yet in most jurisdictions, actual deep energy retrofits lag far behind stated goals. "People have to stop studying retrofits and actually do them," says Lorrie Rand, principal of Habit Studio in Halifax, Nova Scotia. "Although the province has aggressive GHG [greenhouse gas] targets," Rand points out, "if we don't do something with existing buildings, we can't hit those targets." Rand has moved into action, cofounding the ReCover Initiative with Nick Rudnicki of RSI Projects, a custom builder, to industrialize deep energy retrofits in Nova Scotia.

Rand is no stranger to retrofits; her firm undertakes 40 renovations each year; but none of them has as yet been an EnerPHit. Even if all of them were, that pace is far too relaxed to achieve the province's GHG reduction goals, which, Rand says, rely in part on completing an estimated 40,000 deep energy retrofits by 2030—just ten short years from now. Rand and Rudnicki kick-started the ReCover Initiative in January of 2020, and by March they had raised funds—mostly from Nova Scotia's Department of Energy and Mines—to cover the initial design work. Although most households in the province are single-family dwellings, they deemed it more efficient to first target a multiunit residential building (MURB), because these tend to have simple forms, and they are ubiquitous in the province's urban areas.

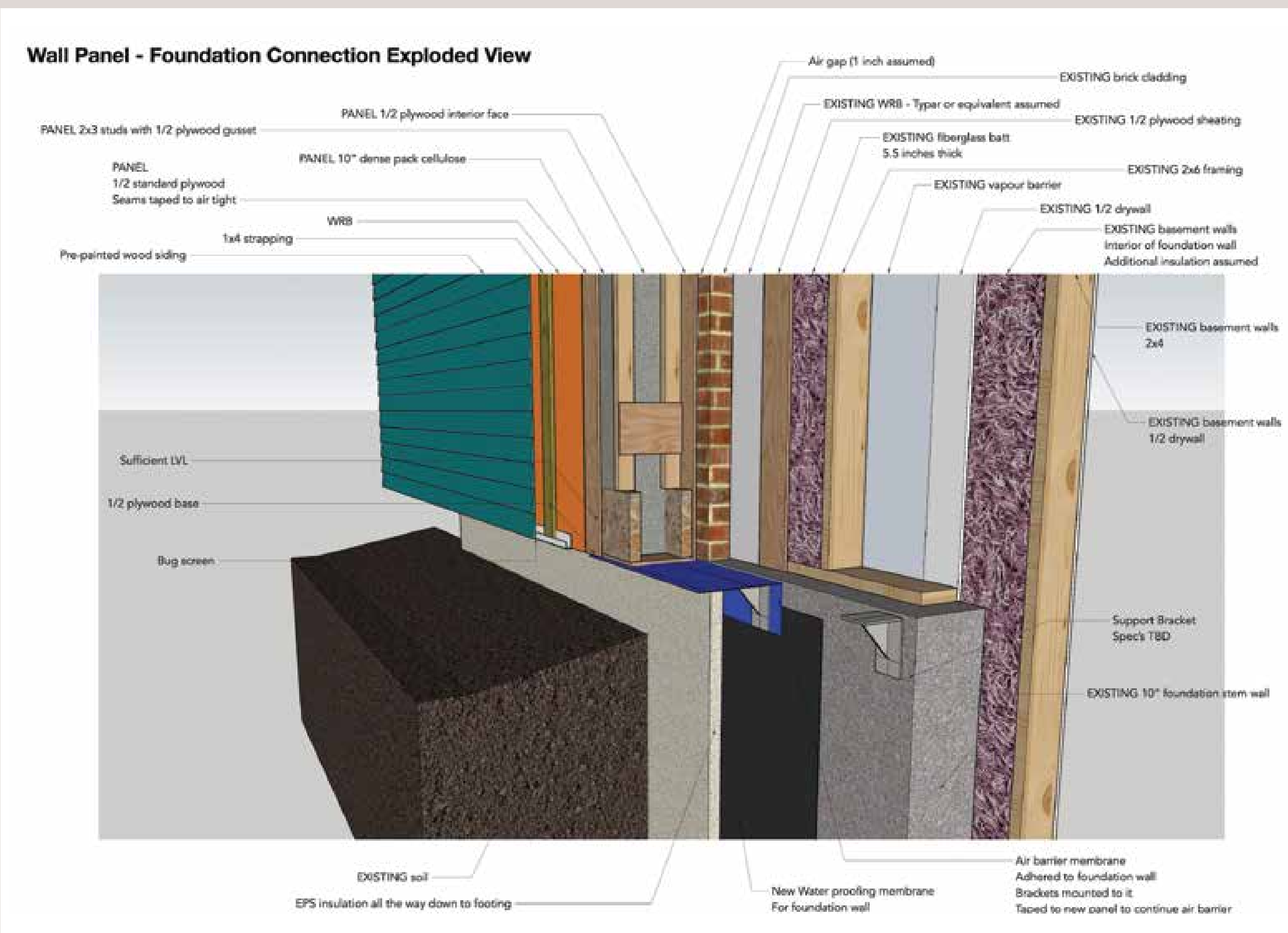
"We have to get one built and publish our findings," says Rand, outlining the initiative's trajectory. "And then get other architects and builders on board." She and Rudnicki are aiming for eight household retrofits in 2021 and increasing the pace of production from there. The fundamental goals for the retrofits include that they be replicable and scalable, that they disrupt the existing occupants' lives as little as possible, and that locally sourced, low-embodied-carbon materials be used whenever possible. Rand and Rudnicki are targeting 1.0 ACH_{50} for the airtightness goal, a vast improvement over the average airtightness of the existing MURB stock, which is 8 ACH_{50}.

In late spring the two found a MURB owner in Halifax who had been contemplating a mostly superficial refurbishment, but was excited to participate in the pilot test case. The brick-clad low-rise MURB currently has an annual energy use of 149 kilowatt-hours per square meter. The owner has set a project goal of achieving net zero energy for the building, with the aid of a 25-kW rooftop PV system.

Rand, Rudnicki, and the ReCover design team contemplated various approaches to this first project, including employing prefab panelized components to envelope the existing façade, following in the footsteps of the innovative Energiesprong initiative first developed in the Netherlands. Using WUFI, Will Marshall, with Equilibrium Engineering, assessed the condensation risk associated with applying three types of panel to the façade: metal-clad panels insulated with mineral wool, panels insulated with EPS, and plywood box panels filled with cellulose. All three options would work, so they chose the cellulose one for its lower embodied energy. When they weren't able to find panel manufacturers willing to meet their specifications, Rudnicki figured that his firm could construct them. He plans to start a panel-manufacturing company after the first pilot is finished.



A LIDAR scan of the existing building, provided by Smarter Spaces, offered sufficient resolution to facilitate the production of CAD drawings.



Rendering (above) and on opposite page by Lorrie Rand; detail courtesy of RSI Projects

A LIDAR scan of the existing building offered sufficient resolution to facilitate the production of CAD drawings needed for the panel fabrication. The panels will run the full height of the building, about 32 feet, and wherever possible they will be 8 feet wide to reduce waste. Laminated strand lumber (LSL) beams are integrated into the bottom of the panels, which rest on custom steel brackets that are attached to the foundation. On the exterior will be a water barrier membrane, a drainage plane, and metal siding for easy maintenance. The existing windows will be swapped out for PHIUS-certified units.

Heating in the existing building is supplied by hot water radiators fueled by an oil-fired boiler. Several mechanical-system upgrades were weighed. Given the humid summers in Halifax, ERVs were selected for ventilation, with individual units being installed in each of the four apartments. For supplemental heating and minimal cooling, a combination of mini-split heat pumps and an electric boiler to supply the existing radiators was chosen. Reusing the existing radiators will minimize tenant disruption.

"We are tiny, and our province's carbon emissions are tiny globally," Rand acknowledges, "but our entire agricultural industry is relying on dikes to keep the ocean back. Our food security, agricultural livelihoods, and countless homes are one bad storm away from devastating damage. So while we are not the worst polluters in the world, we are going to face the effects of carbon pollution sooner than many places will." That nightmarish possibility is what drives Rand to do her part to fast-forward deep energy retrofits.

That scenario also prompts her to nudge all her clients—especially those with new-construction projects—toward more ambitious energy and emissions reductions goals. Rand has been a Certified Passive House designer since 2014, and has been modeling all of her projects using either the PHPP or WUFI since then, partly to ensure that every new build comes close to or meets the Passive House targets; she has set that as an in-house goal for all of her new construction projects. At first, meeting that goal was a challenge, but more recently her clients have been coming to Habit Studio partly for its efficiency expertise.

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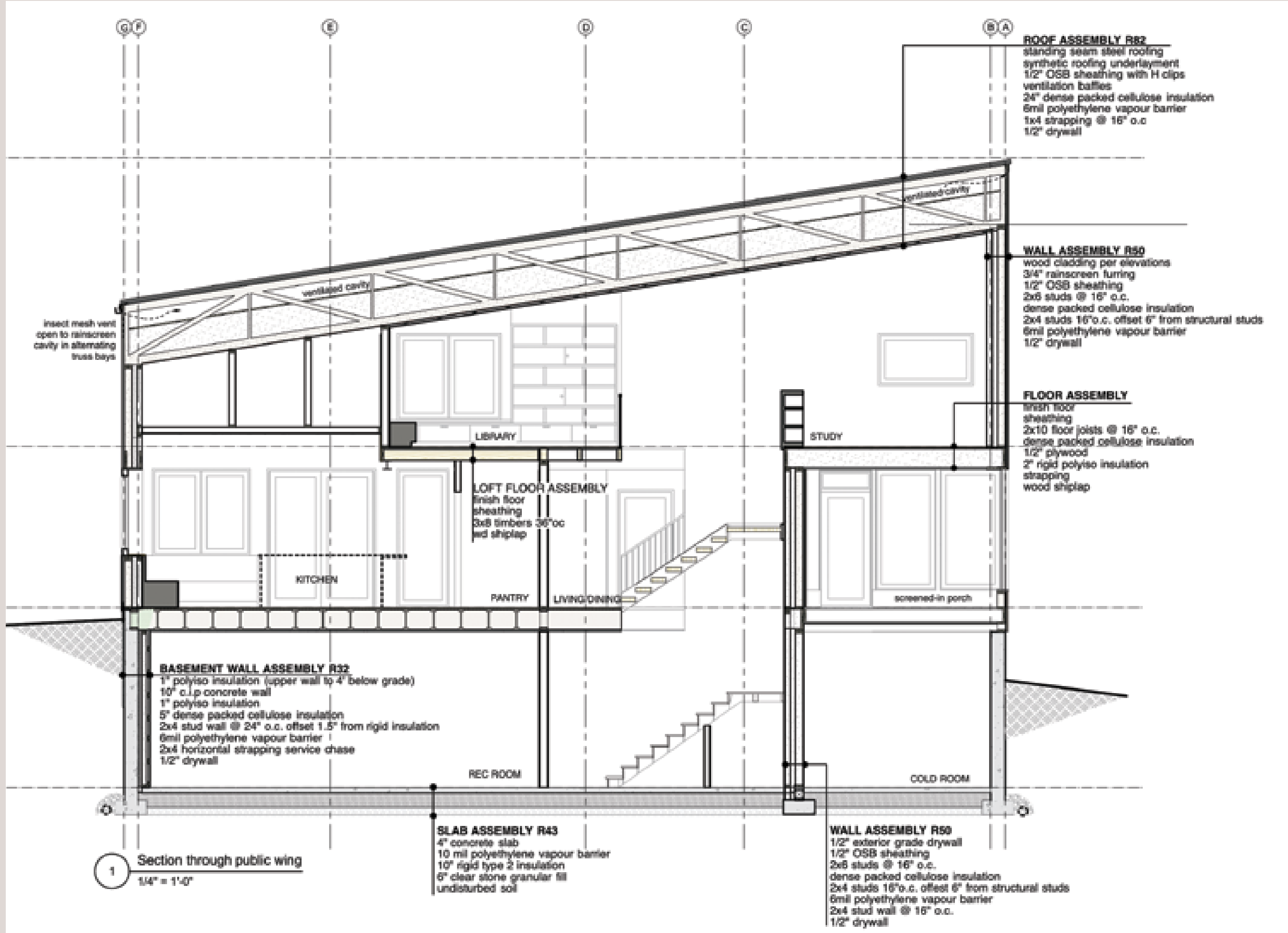

Drawing courtesy of Habit Studio

Such was the case for her recent clients, who wanted the best house they could get for their small farm in the Gaspereau Valley. The couple were definitely interested in efficiency, says Rand, but not militant about it. From the house site, the view toward the north overlooks an iconic piece of Nova Scotia landscape called Cape Blomidon, with a lovely meadow in the foreground. Capturing that view with large expanses of glazing was very important to them. Forest surrounds the home site on the other three sides, providing ample shading for the south-facing glazing. By playing around with the window dimensions and specifying very-high-performance units, among other measures, Habit Studio was able to get the home to meet the PHIUS targets.

Bentley Built Homes, which is constructing this home, will be using its typical double-stud wall assembly, packed with enough cellulose here to deliver wall R-values of 50. The siding will be very locally sourced and milled—from just 5 kilometers away—for most of the building, with charred wood accents sourced from Ontario. The roof assembly will be filled with 24 inches of cellulose. The shed roof's south-facing side will be covered in a PV system.

With the home's mass stretched out into two wings, there will be two ERVs, one in each wing. Summers are hot and humid, so a mini-split heat pump that has one head in each wing will help with dehumidification and cooling or heating as needed. Although Habit Studio prioritizes building with locally manufactured products, the firm made an exception for this home's supplemental heating system, because the clients really wanted a fireplace. The house's main volume will feature a double-glazed high-efficiency, masonry-style heater from Europe. There will be a separate makeup air supply for the heater, which burns at a low heat for up to 24 hours before needing restocking. With a forest on three sides, the fuel for that heater is locally abundant.

—Mary James

Information on the progress of the Recover Initiative can be found at **recoverinitiative.ca**.

Passive House METRICS for multifamily retrofit

	Heating energy	Cooling energy	Site Energy Use Intensity	Air leakage
kBtu/ft²/yr	6.1	6.1	11.8	1.0 ACH_{50} (design)
kWh/ft²/yr	1.8	1.8	3.5	
kWh/m²/yr	19.0	19.0	37.0	

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MODEL CLT Multifamily in *Boston*

Placetailor, a design-build and development cooperative based in Boston, has been creating innovative passive housing projects since 2008. The group, which originally offered only design-build services, added development to its tool kit in 2010 to pursue the type of projects that were important to it. “There’s so much effort to convince clients to make the right decisions and to get a contractor on the same page who is knowledgeable and won’t upcharge for uncertainty,” says Colin Booth, director of strategy for Placetailor. The flexibility inherent in controlling all aspects of a project was critical to embarking on Model C, a five-story Passive House multifamily building constructed using cross-laminated timbers (CLTs).

Creating high-performance passive buildings that offer the occupants a healthy, carbon-neutral lifestyle has been Placetailor’s main imperative—and has proven to be a successful approach. “We recently looked at our historic sales data,” says Booth, “and for those projects sold at full market rate, we’ve been selling at 8% to 28% above market comparables.” Booth is quick to point out the boundaries of these data. Because Placetailor has a serious commitment to affordability, the group internally subsidizes most of its units. “We do not pursue top sales as the driver for development,” says Booth.

Since its inception, the cooperative has continuously worked to do more to address the climate crisis. Five years ago the group ramped up its carbon-cutting ambitions, setting a goal of shrinking both operational- and embodied-energy use. Modeling with a custom-crafted, life cycle emissions accounting tool led it to conclude that using wood products wherever possible was key to shrinking a building’s overall emissions. “We’ve had our eye on CLT for a long time,” notes Booth. But just using CLTs wasn’t sufficient for Placetailor’s aspirations. The cooperative had a vision of creating a replicable model of a low-carbon “CLT cellular” system that achieved Passive House levels of performance.

Finally, the time was right. Just as Placetailor was forming the initial designs for a plot of land it owned in Roxbury, the group met with John Klein, then a principal investigator at the Massachusetts Institute of Technology and now the CEO of Generate Architecture and Technologies. Klein and the Generate team have developed a catalog of mass timber building solutions to pave the way toward the rapid deployment of mass timber systems. Calculating life cycle carbon emissions for the Model C project, Klein and his team found that using mass timber and a kit-of-parts approach that they had developed would reduce total embodied carbon emissions to less than half the emissions of a comparable building made with conventional steel or concrete.

To provide for families of various sizes, the 14-unit Model C will include a mix of housing types, from studios to three-bedroom apartments. The ground floor will contain a pilot project for affordable commercial space, intended as an incubator for local businesses. Its urban location and proximity to public transportation meant that Placetailor didn’t have to provide on-site parking.

"The foundation has concrete in it," says Booth, "and everything else is CLT panels." Model C is a full CLT cellular system, where the floor, interior partitions, exterior walls, and roof assemblies are all CLT panels of varying thicknesses. These panels provide structural strength through continuous attachment of the panel edges, similar in concept to building cabinets with plywood. The exterior assembly is to be insulated on the interior with high-density cellulose, and on the exterior with wood-fiber board. The sawtooth roofline is also CLT, oriented due south for optimal solar PV orientation.

Placetailor considered sourcing the CLT panels from a European manufacturer that had extensive experience with this technology. However, it found a closer source just over the Canadian border in Montreal. Another panel manufacturer—Bensonwood, based in Keene, New Hampshire—will trim the panels to fit and will oversee their installation on-site. Bathrooms will be self-contained pods.

Mechanical ventilation will be supplied by a semicentralized system, with one ERV unit per floor shared among four housing units. A heat pump will provide the cooling, but not the heating, to prevent the condenser from overcycling while meeting the minimal heat load and burning out. Instead, the small amount of heat needed will be delivered by a simple and cost-effective electric-baseboard system.

A gas-fueled combined heat and power (CHP) plant will be the building's source of domestic hot water and some electricity, the first fossil fuel combustion in a Placetailor project in recent memory. Placetailor's calculations show that overall greenhouse gas emissions will be lower with the CHP system than would have been the case if a heat pump water heater had been used, because of how electricity is generated locally. The group is working into the design a straightforward way to transition to heat pump systems as soon as the grid is cleaned up.

The building will be finished with a corrugated-metal siding with a rain screen air gap behind it. The metal panel will be perforated to afford selected views into the building so the exposed wood panels can be viewed from the outside, especially by pedestrians passing at night.

Placetailor is committed to smoothing the path for other developers of small- to medium-scale multifamily projects to use CLTs. To that end, Placetailor is working with Bensonwood to create a standardized kit of parts using Bensonwood's PHlex system—preinsulated and airtight panels that come with windows installed and are designed to achieve Passive House performance. "If we, and other builders, are using the same set of panels, then their price comes down," Booth points out. "Bensonwood has become a strategic partner of ours."

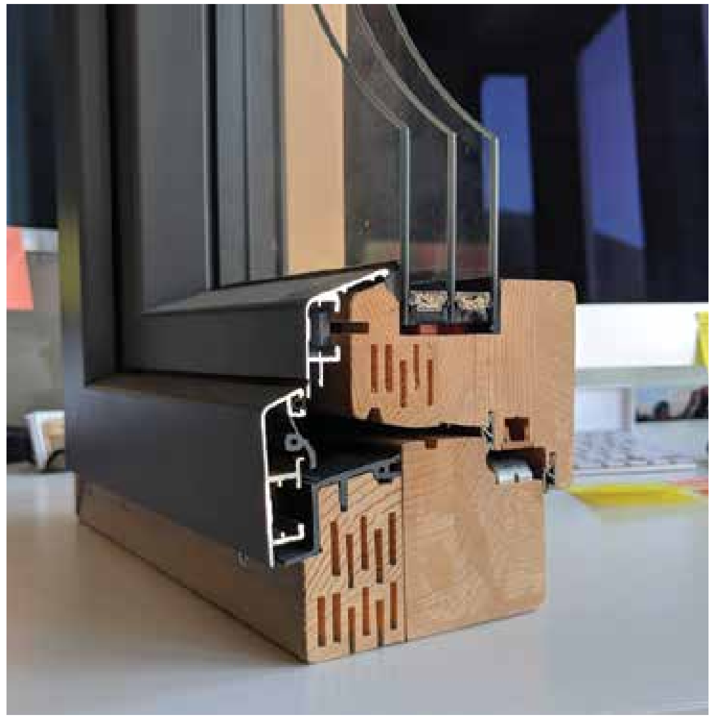
In further efforts to move multifamily new construction toward carbon neutrality, Placetailor recently collaborated on a *Guidebook for Zero Emission Buildings* with the city of Boston (available at **boston.gov**). The guidebook—intended as a resource for developers, designers, and builders—lays out affordable-housing requirements for high-performance assemblies for various building typologies. In researching these recommendations, the team concluded that particular attention to windows, window-to-wall ratio, and airtightness did the most to improve building performance.

The team also analyzed cost data from net zero energy and Passive House buildings in Boston and concluded that construction cost increases were at most 2.5% before rebates and incentives. After accounting for currently available rebates and incentives, the team found that zero-emissions buildings could actually be less expensive to build, while still furnishing long-term operational savings. In other words, as Placetailor has been demonstrating for more than a decade, there's no reason not to set zero emissions as a project target.

—Mary James

Passive House **METRICS**

	Heating energy	Cooling energy	Total source energy
kBtu/ft²/yr	3.6	2.5	3,515 kWh/ person/year
kWh/ft²/yr	1.1	0.7	
kWh/m²/yr	11.5	7.9	



Photos (top left and top right) courtesy of Tree Construction; (bottom left, bottom right, and opposite page) by Britta Kokemore

Throw More TANTRUMS

Revelstoke, British Columbia, a nature lovers' resort town in the Selkirk Mountains, welcomes the Tantrum Bike Shop and office building, an outstandingly sustainable commercial Passive House building.

The owners of the bike sale, service, and rental business on the ground floor named their business and the building after a local mountain biking trail, but builder Greg Hoffart of Tree Construction suggests *tantrum* also expresses the team's outrage at the nearly insurmountable permitting challenges this project had to overcome. Hoffart and architect David Arnott of STARK Architecture hope Tantrum inspires developers everywhere to throw a tantrum in the face of traditional commercial development, choosing innovation over business-as-usual mediocre efficiency, conventional high-embodied-emissions building materials, and complacent design.

In 1910, pioneers developed this downtown 25-foot by 100-foot lot with a one-story, wood-framed building squeezed between a similarly sized building and a two-story one, but a 1960s fire left a hole between the surviving flanking buildings. The larger building, meandering over the property line, also leaned well over the vacant lot. The combination of the encroaching neighbor and a depressed economy squelched redevelopment until today's resurgence of business, fueled by tourists chasing deep powder, rushing rivers, and extreme bike trails. Tantrum's owners had been eyeing this lot for their new shop, and after Arnott and Hoffart created a beautiful and efficiently comfortable new home for them, they knew they had the right team to conquer the challenge. Arnott and Hoffart promised a Passive House building constructed using the most sustainable materials possible (see Certification Tips, p. 38).

DESIGN

Arnott knew he had to make maximum use of the narrow lot and could go three stories high, but how could he avoid inflicting an unsightly box between two heritage wood structures? The solution was to articulate both ends of the box—outside and inside.

Arnott cantilevered the second floor to cover entries for both the front of the bike store and the back where bike rental/service customers come and go. Pulling the third story back hides it from pedestrian view to match the scale of its neighbors. And this design also brings windows closer to the people working in the center of the second-floor offices.

The final touch? Angle the front so that it juts out to meet the larger two-story building's façade but gracefully recedes to meet the front of the charming historic single-story coffee shop next door. As an added bonus, pedestrians can now see the front and windows as they walk from the center of downtown. And the windows are now oriented closer to due south.

Arnott's clever articulation of both ends of the envelope solved exterior challenges, but fire protection requirements for a three-story building were too expensive to meet. The key this time was to create an 18-foot-tall ceiling for the office space in the middle of the second floor by pulling the third floor almost to the back of the building. The third floor, now that it is a mere mezzanine, doesn't trigger expensive fire protection requirements, and also serves as a more private office area.

The exterior and interior articulation created four different kinds of space: (1) a large volume for the storefront retail store and alley-accessed rental/repair shop, (2) traditional office spaces with windows at both ends of the second floor, (3) a large open office area in the middle of the second floor with plenty of natural light, and (4) private and semiprivate mezzanine offices. Tree Construction, now a Tantrum tenant, enjoys the 20-foot-height open office area, which currently hosts a model building of cross-laminated timber (CLT) panels.

CONSTRUCTION CHALLENGES

Building in Revelstoke is not for the faint of heart. Limited labor, short summers, and 40 feet of snow in a long, cold winter are common afflictions for Canadian builders. The first construction obstacle coincided with the initial excavation.

Racing to meet the owner's May 2019 opening deadline, the Tree team discovered during excavation that the overbearing two-story building, like many in its era, was built on heavy timbers instead of concrete. Remove too much lateral supporting soil, and they'd be in litigation and potentially buying expensive renovation of an arguably obsolete building. Driving pin piles for the entire 70 feet to support the neighbor would have been too slow and expensive.

Solution? Hoffart limited the excavation; all that Tantrum really needed was a 6-foot-tall basement sufficient for storing bicycles. The back end of the basement had to be full height, so pin piles on the side of the slouching neighbor allowed full-depth excavation for the grade beams that support the ICF basement walls. Forming and pouring the concrete grade beams and basement slab over a corduroy of EPS foam varying from 2 inches to 16 inches thick during the Revelstoke winter was cold, wet, and miserable. The Tree team added 4 inches of EPS to the outside of the ICF basement walls atop the slab for a total of 9 inches of EPS. Finally, the ground floor was ready to be decked.

The next construction conundrum was, how do you use all 25 feet of your lot's width and also create finished, fireproof sidewalls? Concrete masonry unit blocks would be too labor intensive, slow, and impossible to finish because of the encroaching neighbor.

Factory-built, full-height, concrete structurally engineered panels (SEPs) solved the problem. The 3-inch outside layer of high-strength, low-moisture concrete provides a durable, fireproof exterior. And SEP panels sandwich 7 inches of polyiso foam between the outer concrete panel and the inner 4-inch concrete, so it stays warm in winter and cool in summer. Structural ties of resin-filled fiberglass bond inside and outside concrete layers without thermal bridging. Though largely hidden from pedestrian view by the flanking buildings, the tall, dark panels have a clean, geometric aesthetic. Installation takes only two weeks, and neither the indoor nor the outdoor surface requires any finishing treatment. Speedy installation of the SEPs made up for the excavation and basement nightmare.

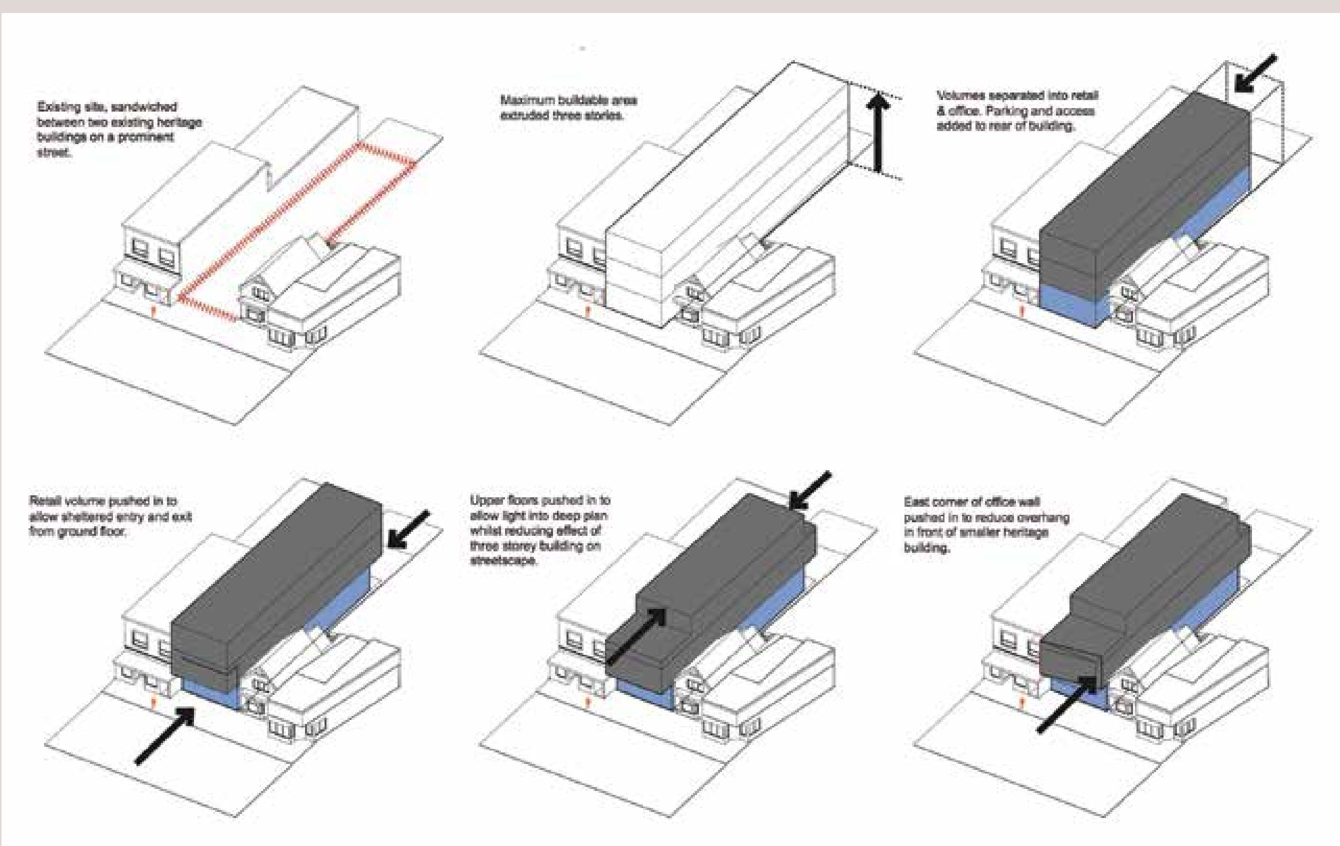


Photo courtesy of Tree Construction

The SEPs also helped Tantrum reclaim its space from the slouching neighbor. Although some SEPs had to be made thinner where the meandering property line encroached, installing the SEPS enabled Tantrum to lever its listing neighbor back to vertical at the property line. The design and construction nightmares from the encroachment had a bit of a silver lining, as a small portion of this sidewall is adiabatic, helping the thermal performance.

FLOOR AND ROOF PANELS

With the foundation and long sidewalls created, Tree employed another time-saving assembly. Angle iron was quickly welded to the inside of the SEPs to support the floors and roof, and then factory-manufactured Swiss Lignatur floor and roof panels, precisely milled to the exact distance between the sidewalls, were craned into place. As each panel was lowered into place, the crew would pound it tight to the neighboring panels, and call for the next panel.

These factory-crafted panels are made up of box beams of dimensional spruce lumber biscuit jointed and glued together into cassettes averaging 4 feet wide. The benefits they offer include speed of installation; a variety of insulating, fire-retarding, and/or sound-absorbing fills; and geometric designs for a finished ceiling. In both the roof assembly and the cantilever floors, the core of Tantrum's thermal protection is the wood-fiber insulation built into these panels. Atop the 11-inch-thick roof cassettes are another 13-3/8 inches of wood-fiber insulation panels, as well as mineral wool averaging 4 inches thick in 2 x 8 sleepers ripped to slope to 2 inches thick for drainage.

The cassettes in the cantilevered second floor are also 11 inches thick, but to avoid penetrations in the panels that would compromise their fire rating, the finished floor is on 2 x 4 sleepers atop the cassettes. This assembly created not only a chase for plumbing, ventilation ducts, and electric, but also space for mineral wool batts where the floor cantilevers. Under the cassettes is 6 inches of wood fiber, strapping, and ¾-inch tongue-and-groove softwood for a total cantilevered floor thickness of 24 inches.

CLT AND WOOD-FIBER INSULATION

With the sidewalls, floors, and roof completed, Greg's team built the end and interior walls. Although some of these walls are 2 x 6 conventional stud framing, some are strategically located CLT panels. Along with some CLT interior walls, they withstand shear in this long, narrow building. Lower-density wood-fiber insulation is covered by thin-

Photos left and right courtesy of Tree Construction

ner, higher-density finish wood-fiber panels held in place by polymer fasteners to reduce thermal bridging, completing the 14-inch-thick end walls.

FINISHES

Strapping supports dark steel cladding, which, in combination with the SEP concrete sides, provides a dark, durable exterior for a commercial building. Inside, the honey-colored Lignatur ceilings complement the light-gray concrete. Flooring is carpet panels made from recycled polyethylene fishing nets with the occasional bright yellow, orange, and red strands providing a fun, light, and warm feeling.

PLUMBING AND MECHANICAL SYSTEMS

With the building's airtight envelope, super insulation, and retail/office-occupant-density lighting and electrical equipment, heating loads can be met by ventilation post heaters and electric-resistance spot wall and ceiling panels. In summer, the concrete thermal mass along with the extensive wood-fiber insulation add up to deliver a high specific heat buffer even on hot days. Night flush cooling and large ceiling fans help on the hottest days.

Given separate retail and office tenants and operating hours, the bike shop and the offices have their own electric-resistance hot water tank and ERV in the basement utility room. A dedicated utility chase from basement to roof is insulated, but the 43-foot-long ducts between the ERVs and roof reduced the efficiency of the ERVs from 76% to 68% and increased the specific heat demand by 0.6 kilowatt-hours per square meter per year.

Not only did Arnott and Hoffart create robust, sustainable assemblies, but they were careful to avoid thermal bridges. They carefully covered the windows and door frames with wood-fiber insulation for low installation psi values, attached cladding with thermally isolating polymer anchors, and minimized plumbing thermal bridges.

Tantrum's clever design, painstaking construction, and advanced materials emphasize function in a beautiful form.

—Tad Everhart

Tad Everhart certified Tantrum and is a member of CertiPHIers Cooperative.

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	4.5	N/A	38.0	0.4 ACH_{50}
kWh/ft²/yr	1.3		11.1	
kWh/m²/yr	14.0		119.0	

CERTIFICATION TIPS

When David Arnott of STARK Architecture contacted us about certification, I jumped at the chance to review the Tantrum. I had reviewed only single-family homes, so I was eager to work on a retail and office building. I secured PHI's promise to assist and got started.

I appreciated the fact that Tantrum was a classic Passive House, in the sense that its envelope did almost all of the work to ensure the building's comfort. I'm not a mechanical engineer, so I prefer reviewing buildings with simple mechanical systems. For this building, only a bit of electric-resistance heat would be needed in winter. And in Revelstoke's dry summer climate, the righteous envelope meant no mechanical refrigeration was needed for the small cooling load.

I'm also deeply in love with wood in all of its forms. Tantrum incorporated wood-fiber insulation not only in the exterior walls and roof, but even within the panelized floor and roof system.

Unfortunately, although the building was exemplary, the process wasn't. Certifiers much prefer to work with the designer from the start, when their experience can prove most valuable to the project, helping to inform the design, if needed. With Tantrum, construction was almost complete when I started. At that stage, certifiers are not necessarily part of the solution, but can be more like a judge or even worse, the IRS!

The designer and builder want to hear "Yes" as soon as possible, even when "No" is a distinct possibility throughout the review process. And understandably, most teams don't want to pay for a full review only to find out they missed certification. So we started with a limited-scope initial review. Once that review was completed, both Susanne Theumer of PHI and I felt certification was likely, but not assured. Tantrum was close enough to the limits that it could have gone either way.

Then we started the deep dive. I quickly discovered the many differences between single-family and commercial buildings, starting with density. For single-family homes, occupant density is based on default densities; for a commercial building, you need the precise occupancy number not only for the high internal heat gains from higher density, but also because those warm bodies come with computers, printers, and servers that can easily push a project past the PER (primary energy renewable) limit.

Estimating occupancy is particularly difficult with retail operations, where you must estimate average customers in addition to staff, and both staffing and customer counts may change seasonally. Fortunately, because the bike shop had opened already and the office tenants were moving in, we were able to calculate the number of occupants (including customers) precisely, ultimately settling on a much lower density than had been assumed in the initial planning PHPP.

On the other hand, estimating domestic hot water consumption was easier with only office and retail uses and less important to the building's energy balance than it is in residential buildings. However, thermal bridges caused by roof-vented drainpipes had to be addressed. The design PHPP had not included these, even though they can cause significant heat loss. Once I explained how these would be included in the PHPP, Tree Construction was able to minimize the heat loss by strategically installing one-way valves and insulating the pipes in the basement.

In another important distinction from a single-family home, retail lighting energy demand, even with 100% LED fixtures, can be substantial. And in this case, the bike repair area required intense illumination. Fortunately, Tantrum's office space is naturally lighted by the combination of its open floor plan and generous windows at both ends of the building that brighten the private offices. Sensors and automatic controls not only turn lighting off when occupants are not present, but also dim it when daylight contributes illumination.

The effect of ventilation was another surprise. Large-volume buildings usually require the Additional Ventilation sheet with its tricks, and ventilation heat losses can be a much larger fraction of total heat loss. Tantrum's certification depended on precise entry of both ventilation times and flow rates, which change depending on the use; the bike shop's retail hours are longer than those of the offices.

Although Arnott and Hoffart successfully overcame Tantrum's slouching, encroaching neighbor, the solution came at substantial thermal cost and only after much thermal bridge modeling. The sub-slab grade beams under the basement floor supporting the heavy concrete SEP sidewalls result in four different combinations of concrete and the EPS insulation under it. Each change in thickness is a thermal bridge, as heat moves both perpendicularly through the floor and laterally through the concrete to where the foam under it is thinner. And the thickness of the polyiso foam in the concrete SEP sidewalls also varies. The design PHPP did not include these thermal bridges. Fortunately, the outside corners, particularly the junction of the long SEP sidewalls and the superbly insulated roof, were negative thermal bridges and offset the positive thermal bridges.

Most teams legitimately worry that the certifier's closer look will reveal only problems, but certification can also reveal unexpected energy savings. While reviewing construction photo documentation, I realized that Hoffart was not kidding when he told me they pushed the encroaching building back across the property line with their SEP sidewalls. You could not see light between the buildings in the photos. So a small area of one sidewall is adiabatic—an unexpected but welcome correction of the planning PHPP.

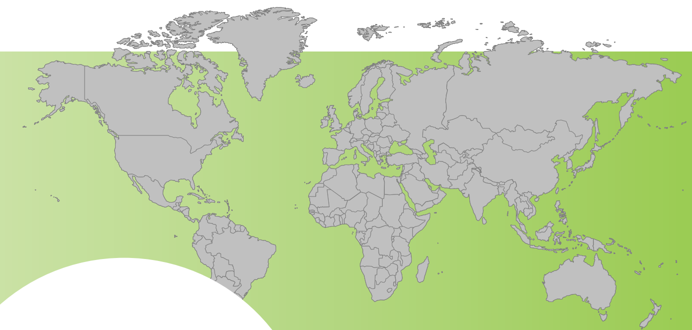
Certification is a team sport that depends on numerous players. Upon my request, STARK Architecture produced numerous diagrams, photos, and marked-up versions of its plans to graphically document the U-values, areas, shading, volumes, and so forth. Tree Construction also provided a constant stream of photos to document the construction and helpfully explained the parts of the building that were difficult to understand from the plans alone. If STARK and Tree learned as much as I did, they will have an easier time creating their next Passive House office/retail building.

Finally, PHI is always part of the team as well. Susanne Theumer and Elena Reyes patiently provided feedback and advice so that I was able to certify the Tantrum as a Passive House.

—Tad Everhart

iPHA – The International Passive House Association

International PASSIVE HOUSE Association iPHA



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iPHA works to promote the Passive House Standard and foster a greater public understanding of its significance.

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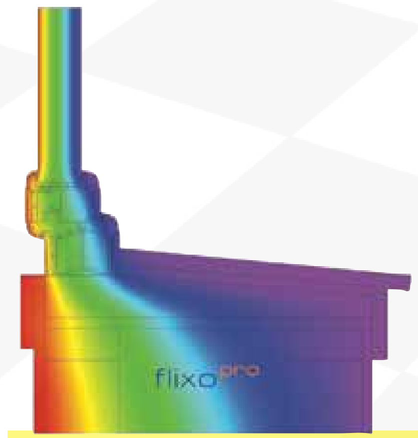
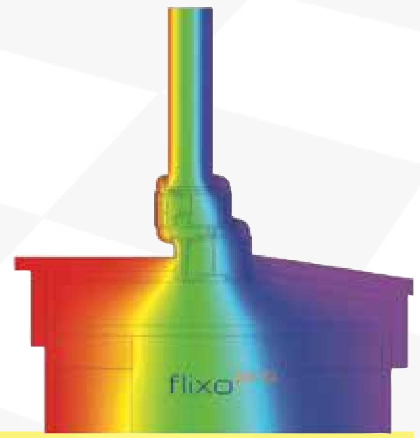
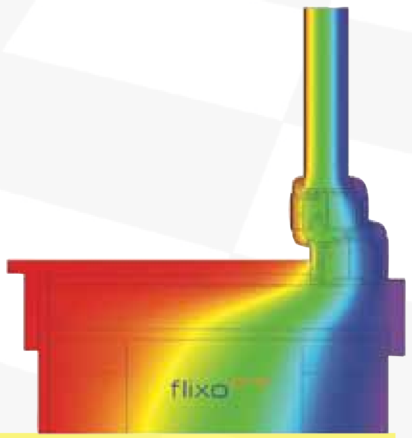
OPTIMIZE Window Installation



Window
U-value - 0.14^2 Btu/hr-ft^2-F
R-value - 7.04 Hr-ft^2-F/Btu
Condensation possible below 3F
Comfort criteria - Not met.



Window
U-value - 0.133 Btu/hr-ft^2-F
R-value - 7.52 Hr-ft^2-F/Btu
No condensation risk
Comfort criteria - Met.



Window
U-value - 0.139 Btu/hr-ft^2-F
R-value - 7.19 Hr-ft^2-F/Btu
Condensation possible below -2F
Comfort criteria - Not met.

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From CLT PANELS *to* HOME *in* Five Days

Photos by Andreas Dyballa

Stich Consulting & Design was founded in 2013 by Tomaz and Jasminka Stich to promote the construction of Passive House buildings. Tomaz—a carpenter, engineer, and certified Passive House Designer—runs the consulting and design business, educating engineers, architects, and carpenters about the benefits of Passive House and renewable energy. The company is a representative for several European Passive House-quality manufacturers in Canada and also offers Passive House courses and exams a couple of times per year.

Now the company founders can speak with extra authority on the benefits of Passive House. Tomaz and Jasminka just completed their own Passive House in Invermere, British Columbia, built using prefabricated cross laminated timber (CLT) panels imported from Europe. The building was recently certified as meeting the Passive House Plus standard. Here Tomaz discusses the process of building their home.

Our focus has never been only on Passive House but also on renewable, wood-based products. As we were very familiar with the cradle-to-grave sustainability and high quality of the products manufactured by the suppliers we work with from Austria, Germany, and Slovenia, we naturally chose to work with them. We decided to have our envelope components prefabricated to the greatest extent possible—about 90%—instead of shipping every material separately as we had done in the past, pushing the limits more than usual in order to prove that to do so was not only possible, but cost effective.

Two truckloads of wood-fiber board were delivered from Germany to Slovenia to be used as our insulation and soundproofing material. Our triple-pane, PHI-certified aluminum-clad wood windows and all the CLT panels came from Austria. All of these materials were assembled in Slovenia by Lamo, a carpenter and client from earlier days when we used to live in Europe.

The prefabricated wall panels include 12 inches of wood-fiber board insulation attached to the CLT panels and built-in windows, with the strapping and siding attached as well. Each wall was basically one panel. All wall, floor, and roof panels were loaded and shipped in four 40-foot open-top containers to Invermere. Assembly of the house was done straight out of the containers by crane and took five days to lock up.

After we finished the roof insulation and roofing, which took a bit longer than anticipated due to climate conditions in the Rocky Mountains, the interior was finished. The finished CLT walls, ceiling, and roof were left exposed. Oak flooring throughout the house was chosen, consistent with our goal of using exclusively natural renewable building products. A 4,000-liter rainwater-harvesting tank was added for flushing toilets and gardening.

Two panels of vacuum tubes (for a total of 60 tubes) installed on the roof will take care of domestic hot water generation year-round. An ERV supplies the ventilation; its supply air is fed through a 100-foot geothermal loop (earth tube) to preheat the air in winter and precool it in summer. This summer on a very hot day the loop was able to cool down the incoming air by 20°C (36°F), which means basically free air-conditioning 24/7. Exterior motorized venetian blinds on all the south-facing floor-to-ceiling windows are used to prevent the building from overheating.

The goal with this high level of prefabrication was to show that it's possible to build a high-performance Passive House with its predictably high level of comfort for the same price—or even less—than standard houses built to code by cutting down on expensive site labor. The cost of the house was roughly $210 (Canadian dollars) per square foot, and that includes the shipping of the containers.

—Tomaz and Jasminka Stich

Stich Consulting & Design represents the following companies in Canada: Schneider Holz (wood-fiber board, CLT, and glulam); Optiwin (windows and doors); and M-Sora (windows and doors).

THERMAL ENVELOPE

Exterior wall
- CLT (Exposed inside) 120 mm
- Wood Fiber Board (WFB) 200 mm
- WFB T&G 100 mm
- Strapping 40 mm
- Wood Siding T&G 25 mm
- U-value = 0.119 W/(m²K)

Basement floor/floor slab
- Oak Flooring 19 mm
- WFB 13 mm
- Plywood 19 mm
- Strapping 45 mm
- Concrete (reinforced) 152 mm
- 6 mil Poly 0.6 mm
- EPS 152 mm
- Gravel Compacted 100 mm
- U-value = 0.097 W/(m²K)

Entrance door
- U d-value = 0.54 W/(m²K)

Roof
- CLT (exposed inside) 140 mm
- WFB 240 mm
- WFB T&G 120 mm
- DO 180 membrane
- Strapping 38 mm
- Cross Strapping 38 mm
- Metal Roofing
- U-value = 0.101 W/(m²K)

Windows/Frame
- Wood Aluminum Clad windows with motorized exterior venetian blinds
- U w-value = 0.63 W/(m²K)

Window/Glazing
- 4 EN Plus/18/4/18/4 EN Plus
- Edge compound Superspacer black
- U g-value = 0.5 W/(m²K)
- g -value = 52 %

Passive House **METRICS**

	Heating energy	Total source energy	Air leakage
kBtu/ft²/yr	3.2	35.5	0.5 ACH_{50}
kWh/ft²/yr	0.9	10.4	
kWh/m²/yr	10.0	112	

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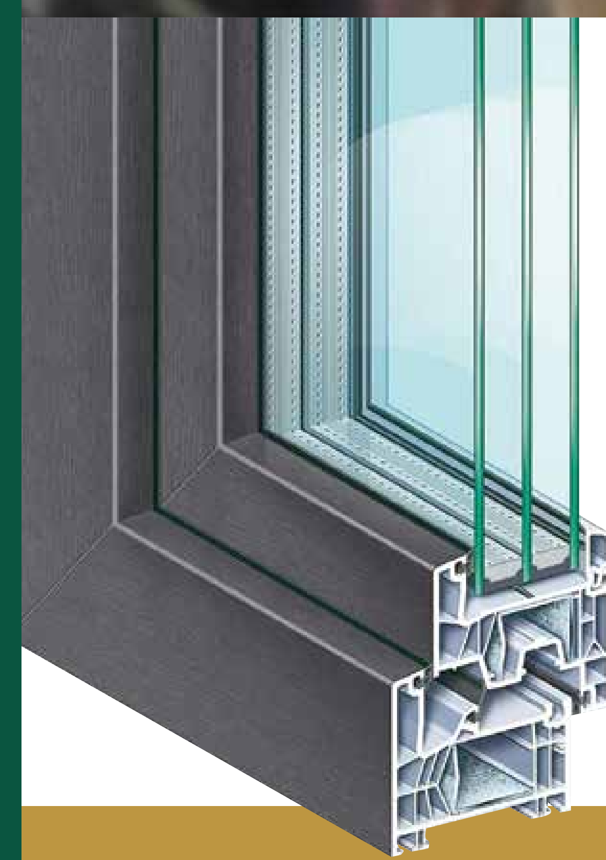

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Pennsylvania WILDS *Goes* Passive

Rendering Courtesy of Moshier Studio; photos on opposite page courtesy of WPPSEF

The existing building, pictured in the middle, had been vacant since 2015.

In northern Pennsylvania, in the midst of the Allegheny National Forest, sits the small town of Kane—"A Star in the Forest" reads the town's slogan. That star has many attractions, and now one more is being added: a gem of a small commercial Passive House building. Retrofitted from the shell of an 1897 structure, the reimagined building will be used to support organizations such as the PA Wilds Center for Entrepreneurship, whose mission is to integrate conservation and economic development in a way that strengthens and inspires communities across the 12½ counties in the Pennsylvania Wilds. PA Wilds, as it is colloquially known, encompasses over 2 million acres of public land—more than Yellowstone National Park.

The existing three-story masonry building had been vacant since 2015. It was purchased in 2019 by 63 Fraley Street, LLC., in collaboration with the West Penn Power Sustainable Energy Fund (WPPSEF), a nonprofit founded to promote clean power and sustainable energy technologies. Passive House was chosen as the performance goal fairly early in the process, and the consortium brought in Gary Moshier of Pittsburgh-based Moshier Studio to steer that effort. A local firm, Inscale Architects, has helped with analysis of the existing structure. The retrofit is envisioned as a learning opportunity for the local workforce and a chance to feature local and low-embodied-energy materials whenever possible.

Joel Morrison, director of the WPPSEF, says that this Passive House project is a centerpiece of the organization's mission, which embraces leveraging sustainability for the revitalization and enrichment of communities. "WPPSEF believes it is time to change the conversation about sustainability and sustainable energy to a more robust discussion centered on a regenerative way of thinking," he notes. WPPSEF is managing the documentation of the project, including developing video segments of the building's history, its revitalization, and its operations.

The project is proceeding in two phases. The first phase is the renovation of the core and shell. The second is the finishing of the interior once prospective tenants have been identified. Anticipated uses are retail for the ground floor, offices on the second, and educational services on the third. Key considerations in tenant selection will be engagement with sustainability practices, according to Barbara Robuck, who manages marketing and communications for the WPPSEF. "The town and PA Wilds region are excited about this project, so it won't be a huge challenge," she says. The building faces onto Kane's main street, affording maximum visibility for the tenants. Although Kane is a small town, interest in the region's recreational opportunities has been growing, and a major new trailhead is opening there soon.

From the front, the building will look thoroughly updated, with an entirely new façade featuring extensive glazing and a Passive House-quality curtain wall that extends from the daylit entranceway to the roof. Behind that façade, in a solid nod to prioritizing low-embodied-energy materials, a good portion of the building is being reused, including the foundation, the party walls, and the three-story brick wall at the back. The interior was gutted except for the floor structures.

The new front wall, which faces east, will feature a 2-inch-thick stone cladding. "We're excited that we were able to source a locally quarried stone for the front," says Moshier. The handrails and stair treads of the

main stairway will also showcase local products—maple and cherrywood in this case—as will the hemlock ceiling above the stairway. Moshier is hoping to use reclaimed wood joists from the building for the new entry canopy.

The front façade's large windows will be surrounded by cowlings, providing the only shading needed in this relatively cold climate. A thermally broken clip system will be used to attach the cladding to the structural sheathing. The primary air barrier will be on the inside of the sheathing with a water-resistive barrier on its exterior surface overlaid with 8 inches of mineral wool.

Below the front façade, the existing foundation consists of rough-hewn stones resting on bedrock, while the rear has a newly poured slab. New foundation piers were sunk to increase the floor loading. The basement, which will house the utility entrances and possibly batteries in the future, is outside of the Passive House envelope. The elevator pit that penetrates into the basement will be thoroughly air sealed and wrapped in mineral wool.

To thermally isolate the basement from the rest of the building, mineral wool will be inserted between the ground floor joists with a continuous layer of rigid insulation below that. A self-adhered membrane on top of the subfloor will be the air barrier.

The brick party walls have been repointed and are being coated on the interior in a water-based acrylic air barrier, allowing for an exposed, painted-brick aesthetic on the interior. The party walls will only need insulating in a few places to eliminate potential thermal bridging issues. An air barrier membrane will function as the transition from the walls to the taped sheathing layer in the roof assembly. The rear masonry wall will be insulated from the exterior, most likely with an exterior insulation and finish system.

Historic photo of the existing building, circa 1930–1940.

Three ERVs will be used to separately ventilate each floor of this all-electric building. Although one centralized ERV might have been sufficient, the floors are anticipated to be leased by three different tenants and put to different uses, and separating the ventilation systems eliminates the possibility of cross-contamination—a particularly important benefit in the time of Covid.

Supplemental heating and cooling will be provided by a variable refrigerant flow system. As the demand for hot water will be relatively small, an electric-resistance water heater can meet the requirements without pushing the total energy demand beyond Passive House limits. The group is excited to field a demonstration of how energy efficiency in design can smooth the transition to all-electric buildings. "And in our case, we are saving money," Moshier points out, "because we would have had to re-establish a gas line to the building."

In keeping with WPPSEF's mission, there will be a 43-kW PV array on the rooftop, which should produce enough renewable energy to cover the building's load on an annual basis. This big contribution from the PV system is allowing the project to get certified using the Primary Energy Renewable criteria.

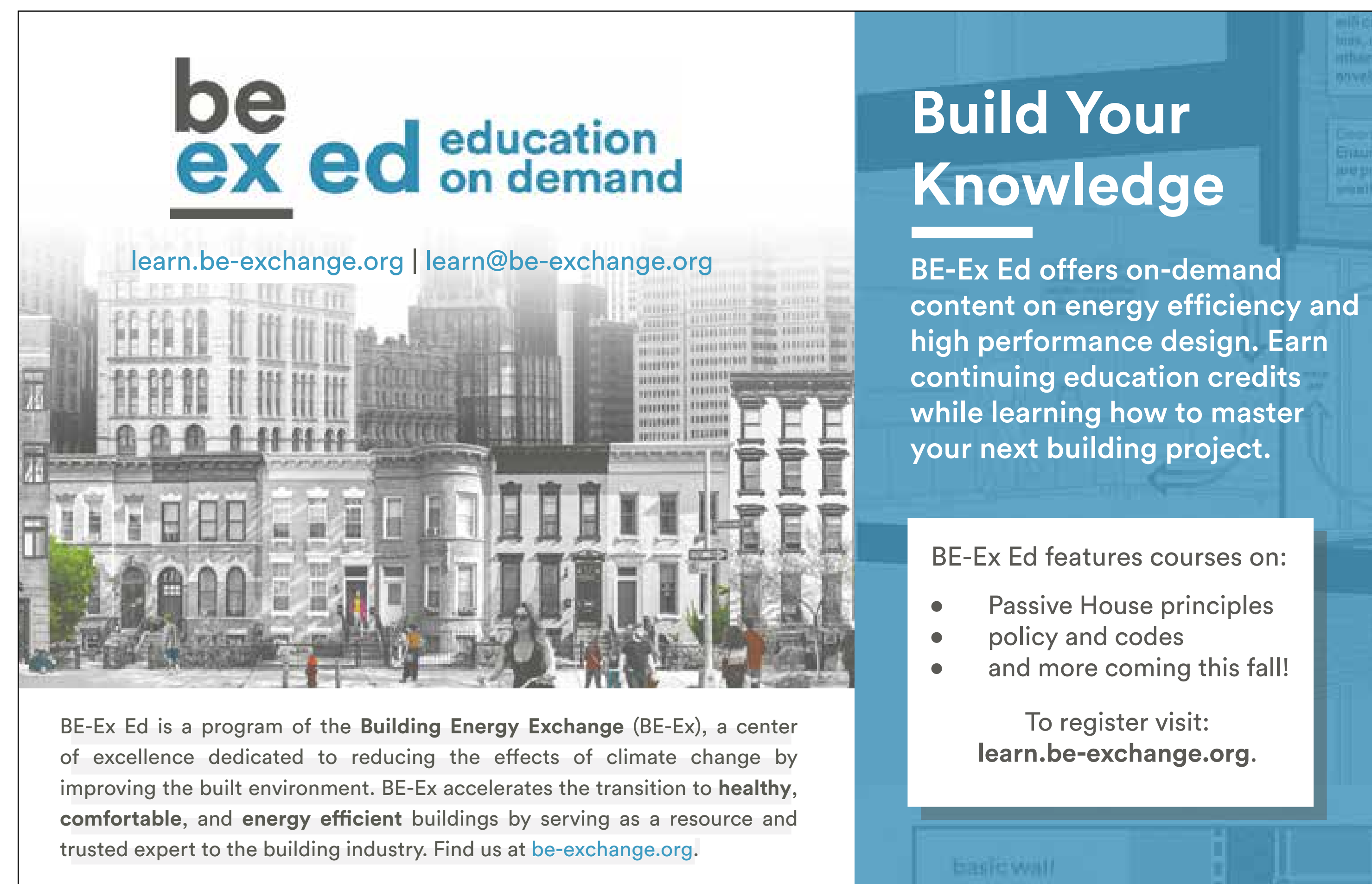
The building renovation has been proceeding in phases, interrupted at times by pandemic-related shutdowns. Even so, the building shell retrofit work is expected to be completed by late fall. Occupancy should begin by next fall, hopefully in time for an anticipated influx of visitors to Pennsylvania's wildest region.

—Mary James

To stay updated on the progress of this retrofit in the PA Wilds region, visit www.facebook.com/kanepassivehouse/.

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	3.86	3.50	45.3	1.0 ACH_{50} (design)
kWh/ft²/yr	1.10	1.02	13.3	
kWh/m²/yr	12.20	11.00	142.0	



Photos by Archetype Photo

A Passive House DREAM Comes TRUE

In 2016 I received a call from a new client, John, who had a dream to build a house. I immediately got the sense that he had a great analytical mind, as John spoke about his research into LEED and his ultimate decision, after further consideration, that his home must be a Passive House. He very much liked our Mamaroneck Passive House, and so we scheduled to meet in person. We immediately clicked and started the journey to realize his Passive House dream on a beautiful lot adjacent to a private pond in the heart of Scarsdale.

John had bought the property in the ’80s, because it was only a short distance to the train station, allowing him to travel in just 35 minutes to New York City, where he worked as a lawyer. He had lived for decades in the small, original house that had been built in the ’50s. However, it had moisture problems in the basement because of the slope in the back and the rock formation it was built on. It became clear that the best path forward would be to demolish the existing home and make room for a new house.

The new home John envisioned had to be clean and modern, with almost a Scandinavian feel. I immediately thought the building must be connected to the backyard with its gigantic trees and the beautiful pond that it faces. The pond is the center of the Crane Berkley historic neighborhood. Before seeking a permit from the Scarsdale Architectural Review Board (ARB), we documented more than 100 buildings in the neighborhood, seeking inspiration for a Passive House that would blend in harmoniously as required by ARB design standards. Unfortunately, the first ARB meeting did not go well; the design was too modern and the triangle window at the top of the gable was considered an affront.

We had to go back to the drawing board. I redesigned the window layout and switched the façade from a horizontal siding to brick, which turned out to pose new challenges but enhanced the design and curb appeal. From that point on, the approval process went much more smoothly, and we even started the second ARB meeting with an introduction to the Passive House concept. We won them over, even gaining consent to omit the highly recommended window mullions because of the thermal bridging issue they would have created.

John wanted a house for himself. Our planning and design discussions could be free of any thoughts related to marketability, because he had no interest in selling it ever. What did interest him were innovation, new technologies, and a connection to nature; he is a world-traveling bird-watcher. A beautifully planned and executed natural landscaping firmly plants the home in its surroundings.

We designed the building as a split level because of the sloping terrain and connected all levels of the house with a central residential elevator. The first floor is an open living space with an integrated modern kitchen, which John described to me as a laboratory for food preparation rather than a traditional kitchen. A large music room was designed over the garage to accommodate John`s harpsichord. The master suite and a guest bedroom and bathroom are separately located on the second floor, each with its own outdoor terrace. The cellar was included in the building envelope and offers a large space to accommodate a gym for daily exercise.

Construction initially went slowly, as we had to chip away at a rock formation to make room for the new cellar and spread footing. Because of the high water table, we decided to insulate the foundation walls from the inside with a French drain on both sides of the footing. Below the cellar floor system, we installed gravel with a radon mitigation system and a 15-mil membrane as the airtight layer and vapor barrier. A highly reflective radiant shield was placed over the membrane to increase the efficiency of the floor heating. This membrane folds up and is connected to the membrane covering the foundation walls. We placed 6 inches of high-density EPS under the membrane. The 4-inch reinforced concrete slab has hydronic floor-heating PEX tubing embedded in it. A major consideration was finding a low-VOC flooring material for the cellar, one that was thermally stable and moisture resistant but vapor permeable. We eventually chose a natural ½-inch cork flooring from Canada.

The entire building is framed with 2 x 6s. We lined them up with the sill plate on the interior of the foundation walls so that the brick façade could rest directly on the foundation with weep holes to the exterior. It was decided to use a self-adhering membrane as an airtight layer and a

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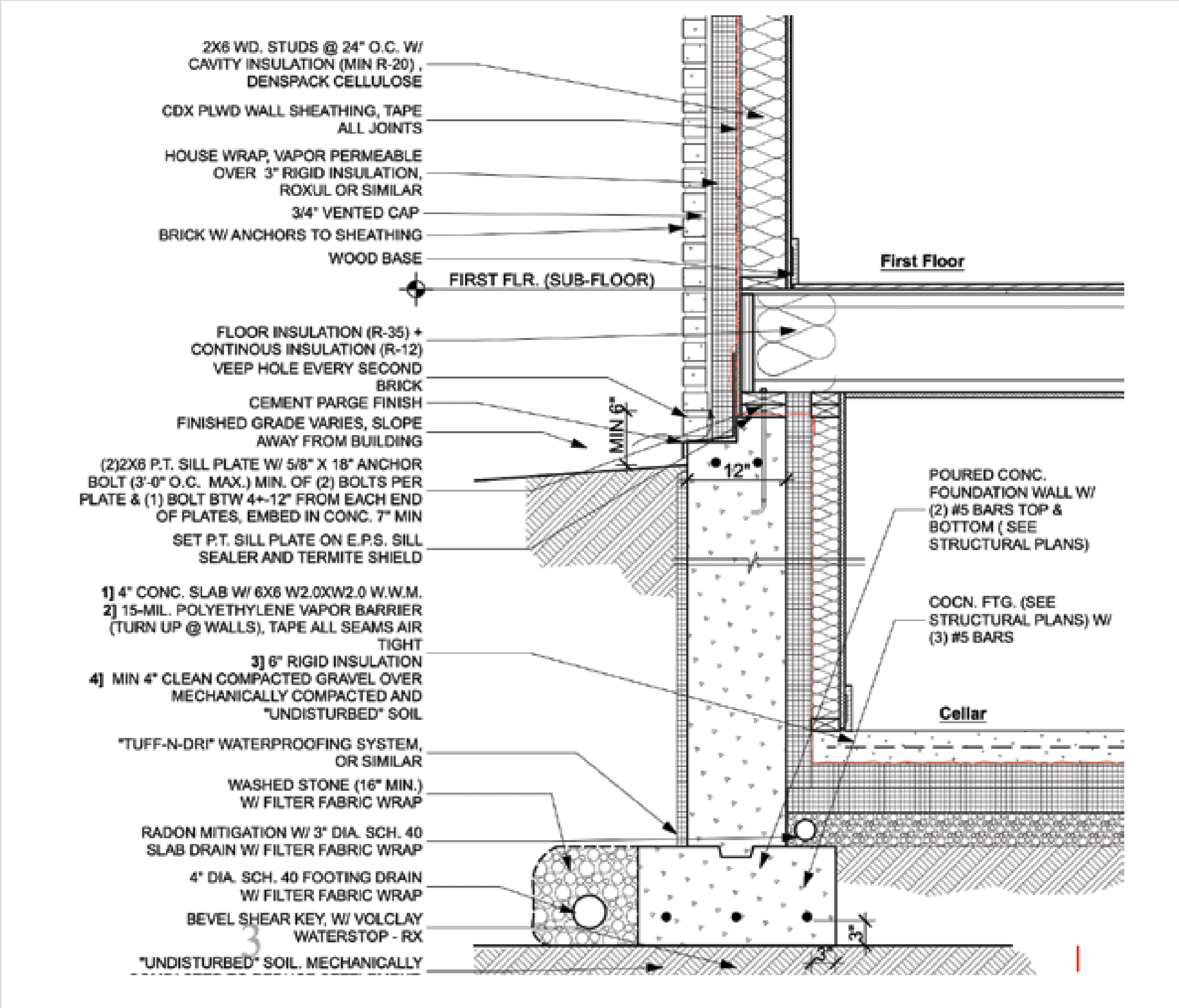


Detail courtesy of Andreas Benzing; photos by Archetype Photo

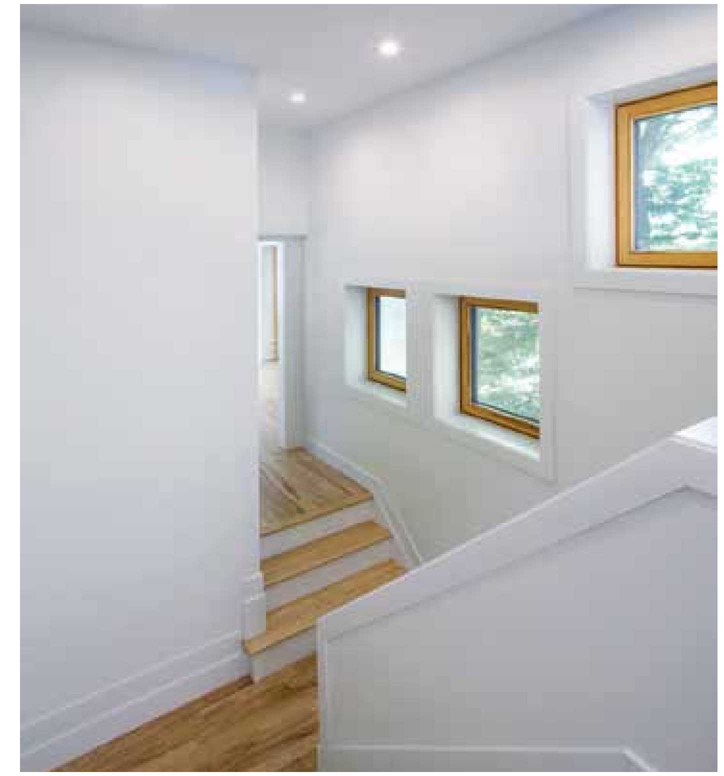
weather-resistive barrier (WRB) over the structural plywood sheathing. We placed a 3-inch layer of comfort board over the WRB and a separate 6-inch layer in the back, where we used horizontal cement board siding. Thermally broken brick ties connect the brick to the structural frame wall. The required expansion joints were integrated at the recessed brick corners and disappear from the eye of the observer. The interior framed 2 x 6 wall cavity is filled with dense-packed cellulose insulation and is used as a service cavity for all electrical wire installations.

Windows are a very important decision, both because of their complex requirements—U-value and solar heat gain coefficient (SHGC) specifications—and because of how they impact the whole project's sequencing and overall aesthetics. My experience tells me to have the window discussion with clients early on. I organized a showroom visit to allow John to appreciate the complexity of the window decision. We decided to use a window with a PVC core, solid wood finish on the inside, and aluminum cladding on the exterior. I specified windows with a higher SHGC for the home's south side to maximize solar heat gain in the wintertime. In the summertime, big deciduous trees provide protection from the steep summer sun.

The windows were installed with a drainage system integrated into the window trim to guide any runoff water to the exterior of the siding. The window screens were integrated into the trim by routing out a channel at the edge of the trim, allowing them to almost disappear into the groove of the frame. This approach turned out to be a very good solution, because the screens can be changed and maintained easily.

John wanted radiant floor heating in the cellar, which turned out to be a pretty good idea. To allow for an even heat transfer to the next floor, I designed the cellar and first-floor plans to be the same. This strategy minimizes the problem of stratification between the different floors and is a good way to maintain thermal comfort throughout the house. Last winter, John's experience with this heating system was very positive, and he particularly appreciated that it evenly heats the entire house from the bottom up. A radiant floor heating system had been installed in all the bathrooms as well, but that turned out to be a redundant measure; the bathroom floor heating never turned on last winter.

Hot water for the radiant floor heating system and for the domestic hot water is delivered from a direct-vent condensing boiler, which is so small it hangs on the wall. I had initially suggested a heat pump water

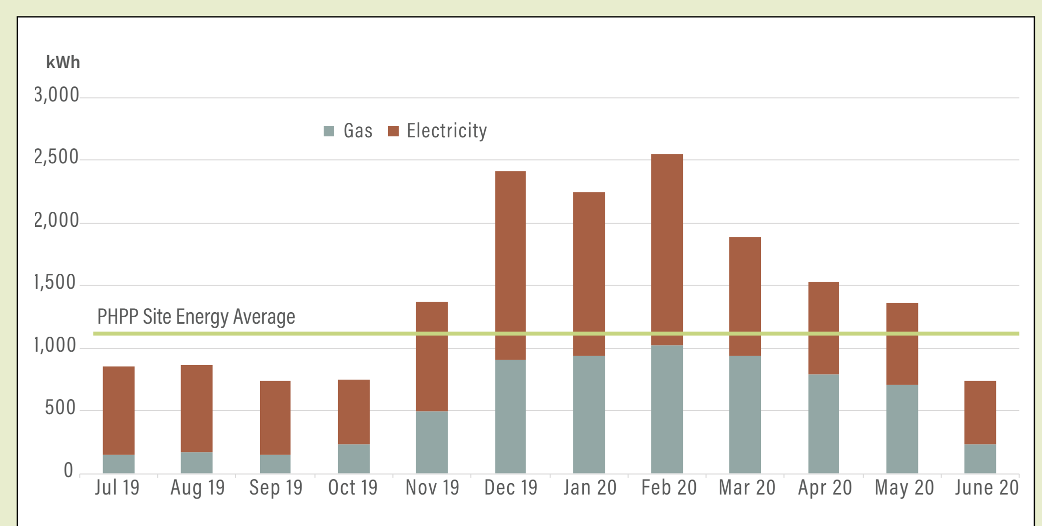


heater, but the instantaneous and almost silent nature of the tankless water heater won the day. The gas connection was installed just before the gas moratorium in Westchester County went into effect. The building would be easy to convert to all-electric, because we designed a hybrid heating system.

The primary heating-and-cooling system is a hyper heat mini-split. One compressor serves two air handlers on the north side of the building. Both air handlers have ducted distribution systems. The first air handler is located in the suspended ceiling of the first floor, serving the cellar and the first floor. The second air handler is located in the attic and serves the second floor. A second outdoor condenser was installed on the south side of the building to serve a wall-mounted indoor unit in the garage and a ceiling-mounted indoor unit in the music room, which is located over the garage and is exposed to the outdoors on three sides. Last winter's heating strategy was to keep the radiant floor at about 72°F and maintain the air handlers' setting at 70°F to minimize the use of the mini-split system.

After the attic floor was framed, we transitioned the airtight and vapor permeable WRB layer of the exterior walls to the edge of the attic floor and on up to the interior side of the roof rafters. Then, we taped the attic floor airtight layer to the air barrier and smart vapor control mem-

SITE ENERGY CONSUMPTION



The home used about 22% more energy overall in the first year than the PHPP had forecasted. There are a number of factors that could have contributed to this difference, one of which is that the data are not weather normalized. Another reason is the model assumes a set point temperature in the winter of 68°F while the owner kept it at around 72°F, resulting in a 9% higher overall energy consumption. I am fairly confident that if the building had been maintained according to the assumptions in the PHPP, the actual energy use would have fully agreed with the modeled results.

Photo by Archetype Photo

brane on the interior side of the roof rafters. This approach allowed us to frame the roof rafter overhang in a traditional way and avoided the need to add an overhang at a later point. We used a 10-inch high-density batt insulation between the 2 x 12 rafters. This created a 1-inch ventilating channel between the outside sheathing and insulation. We then framed an interior 2 x 4 layer along the roof rafters with a 2-inch gap to avoid thermal bridging along the rafters. This layer was filled with dense-packed cellulose insulation and serves as an installation cavity for the electric wires and light fixtures. The attic floor maintains a very even temperature throughout the year, since it is included in the building envelope. In order to create the needed 10-inch overhang of the gable front wall over the brick façade, we decided to reverse the attic floor framing perpendicular to the front wall. This framing strategy turned out to be very successful and is most likely something our office will specify for other projects in the future.

John has lived in the building now for more than a year and from time to time calls me up on a very hot summer day or after a cold winter storm to let me know how well the building is withstanding the extreme weather conditions without much of an energy increase. So far, based on an analysis of the bills from Con Edison for the last year, the building is performing as modeled with the PHPP. When Con Edison came to read the gas meter for the first time last winter, the meter reader assumed the meter was broken, since it showed such a low gas consumption for such a large home. So the utility didn't use its own meter reading, and instead used the average gas consumption for a comparable home in the area. John called and pointed out the invoice mistake and insisted that a Con Ed technician come back to confirm the initial reading. Of course, the next month the invoice showed up with the same mistake, reflecting a continued disbelief in its own gas meter reading. It took until the third month for Con Edison to finally accept how low the energy consumption of our Scarsdale Passive House really is.

—Andreas Benzing, R.A., CPHD, LEED-AP

Architect Andreas Benzing is a Certified Passive House Designer and the president of New York Passive House.

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	4.65	4.23	21.8	0.6 ACH_{50}
kWh/ft²/yr	1.3	1.20	6.4	
kWh/m²/yr	14.6	13.30	68.7	

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AMBITIOUS Uptown Development *in* Pittsburgh

Renderings courtesy of GBBN

Bridging the Gap Development is jumping to the next Passive House level—with élan. After successfully incorporating several Passive House elements into its recently completed Miller Street Apartments, Bridging the Gap is poised to make a major statement with its newest development, Fifth & Dinwiddie. The Fifth & Dinwiddie development straddles two sides of a street in the Uptown neighborhood of Pittsburgh. On the west, Bridging the Gap is building a new mixed-use building that will have 172 units of market-rate and affordable housing plus 10,000 square feet of retail space on the first floor. Across the street, an existing building is being renovated and expanded to create another 40,000 square feet of commercial space. Both projects are targeting Passive House.

Fifth & Dinwiddie got its start when Derrick Tillman, owner of Bridging the Gap, responded to a request for proposals issued by the Urban Redevelopment Authority of Pittsburgh, the city's economic development agency. Tillman and his partners convened a dream team that included the AUROS Group as a sustainability and Passive House consultant, setting their sights on a Passive House development from the beginning. Financing this project has required pulling together a variety of funding sources, including tax credits, HUD financing, and statewide redevelopment funds. One source gave preferential consideration for fixing on Passive House as a goal.

The scale of Passive House buildings in North America has been rapidly expanding in recent years. Even so, "these two projects are in the 1% club of Passive House," says AUROS Group's Craig Stevenson. To address the inevitable complexities associated with a project of this size, Tillman assembled a comprehensive team that includes GBBN, Michael Baker International, and evolveEA.

The sites are within an Eco-Innovation District in Pittsburgh, adjacent to a bus rapid transit (BRT) service stop. The district was established in part to encourage balanced, equitable, and sustainable development. Fifth & Dinwiddie aims to do that and more, creating sustainable and resilient communities while also providing skills training and employment opportunities for the local workforce. Construction on the east site is set to begin at the end of 2020.

The renovation of the former public works maintenance garage on the east site includes a substantial new addition that will double the existing building's size. The planned scope of work will almost double the typical retrofit challenges as well, as the group figures out how to achieve Passive House levels of performance in the older building, the new addition, and the sections where the two meet. The existing building, which is cut into a hillside, is two stories in front, and in the rear its one story is essentially buried in the hillside. The four-story addition will wrap two sides of the building.

Amanda Markovic, associate principal at GBBN, says everyone has been excited since day one to be working on the firm's first Passive House building, noting, "We've been developing our passive design strategies and wanting to push the envelope on performance by actually pursuing the Passive House certification." She adds that after her first charette with the AUROS Group, she came away thinking, "Relying on architecture to reduce energy use, rather than upping a PV array, makes so much sense to me." She is also enthusiastic about how the project's sustainability goals will support the communities that it is nestled in. "Passive House design will encourage resilient communities for the long term," she notes.

The back-and-forth collaboration between GBBN and AUROS Group led early in the design phase to an innovative material choice. After the initial energy modeling indicated total energy use above their target, the group debated possible changes. Markovic was surprised to find that reducing the glazed area did not shift the results. More insulation was always a possibility, but then Stevenson suggested using wood framing instead of steel studs—and that led to a significant decrease in energy use. "Wood framing for a commercial building is atypical," Markovic points out, so she and her team ensured that local code would support this use, which it does. Swapping out the steel for wood framing is also lowering the structure's embodied energy.

The primary high-level Passive House issue is how to keep the air barrier continuous while still allowing people to get fluidly from one part of the building to the other. "To preserve the building's historic look, the front will be air sealed from the interior," explains Stevenson. "Then we will be transitioning by lapping the thermal and air barriers to the outside."

The existing slab-on-grade section of the foundation will be left undisturbed, so only the newer portions will have subslab insulation. All of the punch lights will be triple-pane, while the storefront system, which includes the main entrance, will be double-pane, according to Stevenson. "We will take a hit there on energy consumption," Stevenson points out, "but it's a small hit on a big building." The superinsulated roof, with 14 to 15 inches of EPS insulation, will help to compensate.

At press time the mechanical systems had yet to be worked out, although the team is negotiating the feasibility of connecting to a new district energy plant that is just three blocks away. Ventilation will likely be provided by a ducted direct outside air system.

Across the street, the new building will be offering a residential environment that affords easy access to outdoor spaces. The building fronts onto a landscaped public plaza, which doubles as a rapid bus transit line station, and features several rooftop terraces. To facilitate exercise opportunities, there will be bike parking and a gym on-site.

While modular systems would not be optimal for the east-side renovation, partly because of the challenges associated with working around the existing building, the team is in discussions with several modular manufacturers for the new building on the west side. "Doing modular at this scale—it will be interesting—if we can pull it off," Stevenson says.

"Our last project was not Passive House certified, although it did incorporate Passive House components," says Tillman. The positive feedback he heard from the residents there was a game changer for him. "We were doing the right thing," he says. "We needed to also pursue Passive House here, and we wanted to go to the next level."

For Fifth & Dinwiddie, the next level will include not only Passive House certification but also meeting the RESET Air standard for healthy indoor air quality (see "RESET Air") and Fitwel. When well designed, the RESET Air monitoring system does not have to add a premium, says Stevenson, just as Passive House doesn't, when the approach is designed in from the start. "If you repurpose the control systems—to include fire alarm, lighting controls, access control, and other operational technology systems—to open integrated systems, then you can bring in RESET Air capabilities at par," Stevenson asserts.

Achieving Passive House and RESET within a set budget requires a team with the right experience. Tillman has checked off that requirement, bringing an extremely ambitious project from an early vision to a solid design for a resilient community that will benefit the Uptown neighborhood for generations.

—Mary James

RESET Air

RESET stands for "Regenerative, Ecological, Social, and Economic Targets." It is an international performance-based standard and certification program for healthy buildings that continuously measures performance. Air monitors measure particulate matter (PM2.5/PM10), carbon dioxide (CO_2), total volatile organic compounds (TVOC), temperature, and relative humidity. Results stream to the cloud and can be viewed in real time from any computer or mobile device. The RESET standard is rapidly becoming an industry reference and has been adopted into an international consortium for global monitoring standards, including the International Future Living Institute, International WELL Building Institute, Fitwel, BREEAM, and Passive House Institute U.S. standards.

*For more information on the RESET Air standard, see **www.reset.build**.*

Passive House METRICS

	Heating energy	Cooling energy	Total source energy	Air leakage
kBtu/ft²/yr	4.3	4.0	38.0	0.6 ACH_{50} (design)
kWh/ft²/yr	1.3	1.2	11.1	
kWh/ m²/yr	13.5	12.6	119.9	

Carbon-Neutral ARCHITECTURE —*A Progress Report*

Magnusson Architecture and Planning (MAP) operates at the nexus of affordability and sustainability. For over three decades we've worked with nonprofit organizations, municipalities, and for-profit developers to design housing and neighborhood revitalization projects with a focus on affordable, supportive, senior, and workforce housing. The affordable-housing industry has, in many respects, led the way on sustainable residential development in the New York area for years, and now on Passive House adoption, too. This is due in large part to local and state funding agencies that have adopted sustainability standards as a requirement for public subsidies. Operational costs are key, too; as affordable developers are more likely to own properties for an extended period of time, they often consider investing a *little* bit more in strategies to make them more durable and efficient. We at MAP are very aligned with these efforts.

While we are always addressing a host of factors in our work—unique building typologies, new regulatory requirements, cost considerations for publicly subsidized developments—making progress toward a carbon-neutral architecture has consistently been a high priority for our firm. To gain insights into exactly how we are doing, we recently charted our new construction projects over the past ten years. During that time we have dealt with a wide variety of potential certifications and standards, including LEED, PHI, PHIUS, Enterprise Green Communities, Energy Star, and NYSERDA. This mix of standards complicates the comparison process. In order to provide a comparable metric of our projects' operational energy performance, we decided to focus on energy use intensity (EUI) and corresponding conversions to $kgCO_2/sf$ (see Figure 1).

The yellow line is the mean energy use of our projects, and the solid top line is baseline code for a typical multifamily building in NYC. We show the modeled energy performance of buildings as source EUI, instead of showing it as X% better than this or that code, which is how it is typically shown in sustainability certifications. We have tracked source energy without renewable-energy generation, so we can understand exactly how the rest of the building systems are performing. And, because our New York State grid is expected to vastly improve, we have included the data as site EUI for two of our recent projects, Rheingold and DeKalb. Rheingold Senior Housing is a 94-unit affordable senior housing development, and DeKalb Commons is an 82-unit affordable multifamily project.

These calculations were provided by Bright Power, using a database of baseline models. One can see the implications of the stretch code as well, and just how fast things are moving. Until our codes can provide the structure and regulations necessary to implement a successful low-energy building (built almost certainly with Passive House principles), we will need to rely on certifications such as Passive House to reach low EUIs. Fortunately, our NYC energy code is expected to become performance based by 2025 per local law 32, which will allow for clarity, flexibility, and a focus on the end goal.

Making this chart revealed several important points:

1. While accreditation systems are quite useful, they don't help us compare energy performance across projects. Even comparing within the same system can present challenges when standards change over the years.
2. When calculating EUI per square foot (SF), what you count as "SF" matters. (For example, PHI uses treated floor area instead of gross square feet as we have done here.)
3. The density of a building matters. For example, a building with lots of studios will have more refrigerators and stoves per square foot than one with more three-bedroom units. In part because of this, we are also planning to convert this source EUI chart in the near future into energy use intensity per person housed (which is how PHIUS sets its energy use criteria).

The last point is critical and highlights an important lesson learned from Rheingold and DeKalb: Both are designed to PHIUS 2015 standards, but only DeKalb will be able to certify. (The PHIUS certification is often used by this multifamily affordable typology in our region, because typically double-pane windows will meet the energy, comfort, and hygrothermal criteria, whereas PHI in our climate often requires triple-pane.)

The discrepancy arises from the studio apartment density of senior housing, which translates to high miscellaneous electric loads per building occupant. While all other PHIUS energy metrics have been met, Rheingold's source energy per person exceeds PHIUS thresholds. To meet this requirement, the building would have needed appliances and systems with efficiencies beyond what is commercially available and/or a PV system covering far more roof area than what is physically available or allowed per zoning. Short of these interventions, a cleaner electric grid would have single-handedly brought the metrics within range of certification. While New York State has proactive goals to do just that, as it stands, and despite all the other benchmarks it hits, Rheingold cannot be certified through PHIUS.

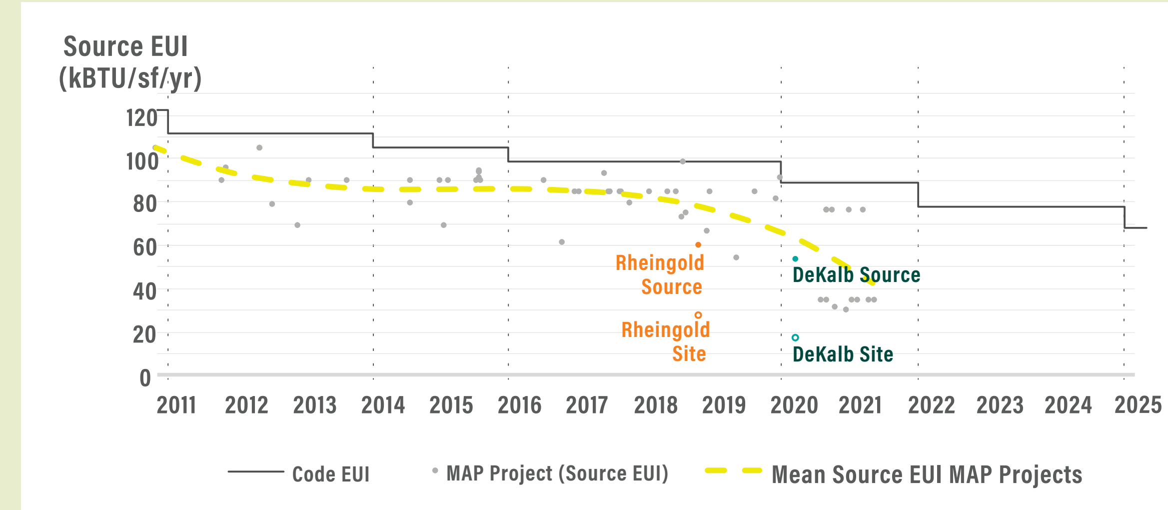
Nonetheless, the project team decided to move forward with a building fully optimized to Passive-House-level performance, facilitated by energy modeling in WUFI Passive, complete with a superinsulated envelope with thermal-bridge-free detailing, airtight specification and details, Passive-House-level efficient mechanical systems and appliances, and a balanced ERV system supplying the ventilation. Rheingold was selected as a NYSERDA Buildings of Excellence Award winner, a competition that recognizes the design, construction, and operation of very low or zero carbon-emitting multifamily buildings. With construction oversight and quality control measures in place as if the project were seeking certification, it will perform like a Passive House with a site EUI of 28.03 and source EUI of 60.4 kBtu per square foot per year ($/ft^2/yr$) (exclusive of renewable generation). It is expected to be ready for occupancy in fall 2022.

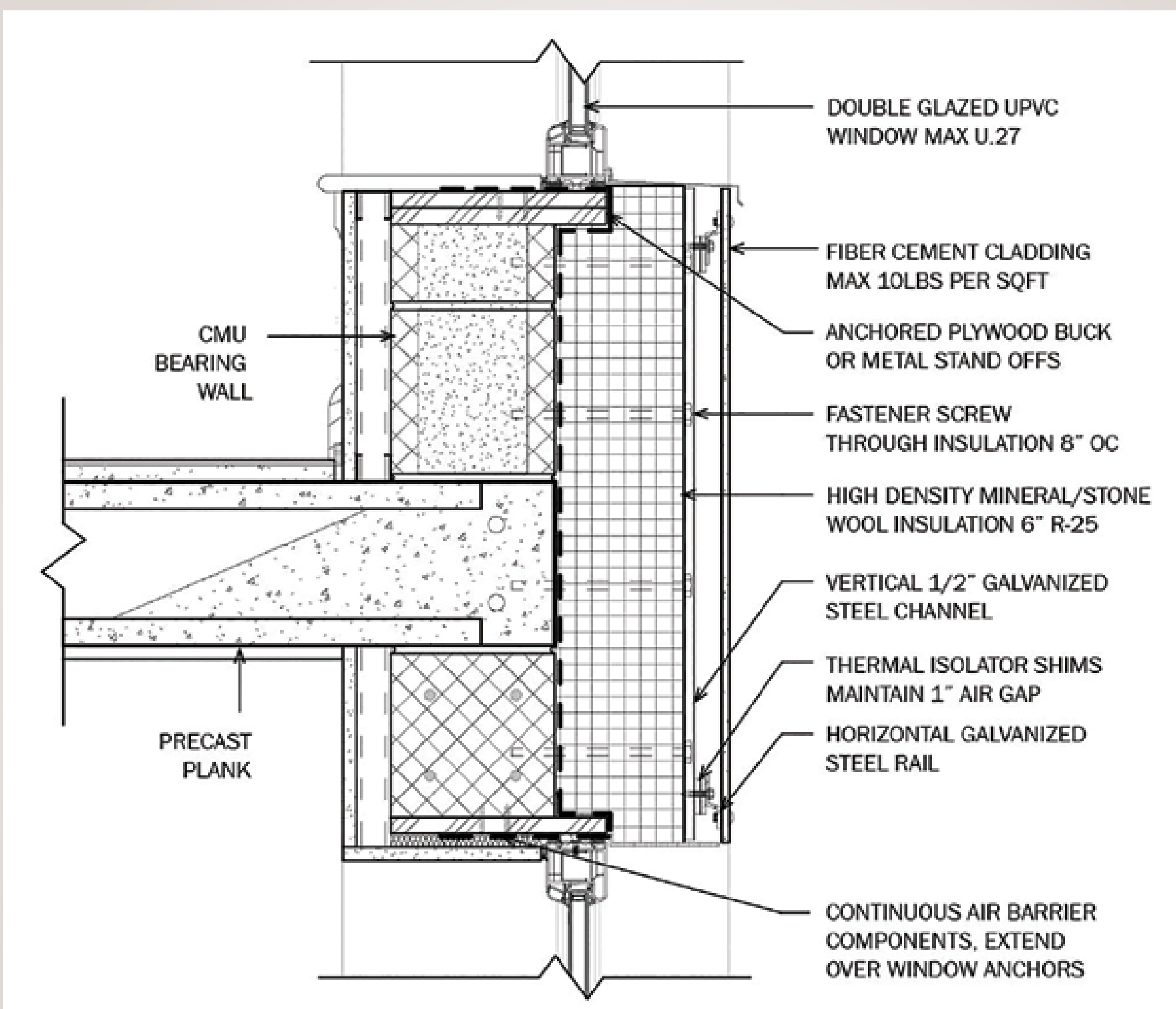
This is very much in line with our DeKalb Commons development, a multisite project at which energy savings is expected to be roughly 30% to 40% compared to NYC ECC2016 code-built buildings. It has a site EUI of 18.3 and a source EUI of 52.7 $kBtu/ft^2/yr$ (exclusive of renewable generation), and is expected to be completed by spring 2023. The design for the two structures maximized the area feasible to provide solar, and they will feature 40-kW and 50-kW systems on the north and south build-

Renderings and detail courtesy of Magnusson Architecture and Planning ings respectively. No fossil fuels will be used on-site. Instead, these all-electric buildings will have electric stoves and laundry equipment and will incorporate air source heat pump domestic hot water (DHW) production, with roof-mounted condensing units. The systems will include storage tanks in the cellar to help ensure that the heat pumps can meet the DHW demand of the building, while also promoting off-peak DHW production. The insulated storage tanks are located in the cellar to reduce the need for structural reinforcement at the roof in these block-and-plank buildings. The piping between the condensing units and storage tanks will be insulated above code levels to ensure that losses will be negligible.

While the efforts of our industry to adopt Passive House technologies—including ERVs and heat pumps—have helped to make them more available in our market, and therefore more affordable, there is still a cost differential associated with constructing a Passive House. At DeKalb, the cost premium is expected to be from 2% to 8%—a premium that translates to energy savings of about $72K annually, shared between residents and ownership.

FIGURE 1. MAP PROJECT EUI COMPARED TO CODE EUI





Many strategies have been employed to simplify construction and limit development costs. The layout of the variable refrigerant flow (VRF) system was optimized to reduce refrigerant runs, which controls that expense. The design also relies on a single cladding system with minimal protrusions into the envelope. The mineral wool insulation is dense enough to support the relatively lightweight cladding with only subframing directly behind the cladding and screws alone penetrating the insulation. This approach saves significant material and expense, compared to the initial option of using thermally broken subframing with a fiber-reinforced polymer girt. Streamlining the façade saved the project an estimated $5 per square foot in material costs alone.

At MAP, when we conduct a construction cost comparison, a baseline of code minimum would not usually be appropriate. When we consider Passive House costs, we compare them against the sustainability options that affordable housing would otherwise pursue. Rheingold is a perfect example. It was originally priced to meet a different, slightly less efficient standard, but we found that the incremental cost to step up to Passive House was less than 1%. The baseline was NYSERDA NCP Tier II with a minimum energy target of 25% above current code (or source EUI of approximately 74 kBtu/ft^2/yr), employing ERVs and heat pumps. With this minimal construction cost increase, the project will now perform 44% above code with a source EUI of 60.4 kBtu/ft^2/yr and save $47K in energy cost yearly. To get this Passive House cost construction differential, we priced the project with four contractors and gave them a detailed Passive House alternate to bid on.

Achieving a high-performance standard for operational energy is only one piece of the truly sustainable housing puzzle, however. In recent years MAP has also been investigating methods for calculating and reducing embodied carbon in our projects. As has been widely discussed in the last few years, embodied carbon represents a large portion of a project's short-term impact on the greenhouse gas balance. Considering that we have a limited budget of greenhouse gases to emit in the next ten years, rapid innovation is required. In searching out lower-embodied-energy products, we have found certain ones easily accessible in our region, while others are more difficult to obtain. Environmentally preferable subslab insulation—expanded foam glass—is becoming more readily available here. This product, which is made of 100% recycled glass and comes in a simple-to-install gravel format, can serve as both an insulation and a drainage layer. (The "foam" in its name refers to the process by which it is created, not to be confused with the petroleum products.) However, New York City currently has few concrete/masonry suppliers who carry low-emitting products. We are steadfastly optimistic and excited about further innovations in biogenic materials, modular construction, and circular products. And we look forward to new opportunities to combine them with near net zero operational energy performance!

—Sara A. Bayer and Matt Scheer

Sara A. Bayer is MAP's associate principal and director of sustainability, and Matt Scheer is MAP's director of communications.

Passive House METRICS for DeKalb

	Heating energy	Cooling energy	Total source EUI	Air leakage
kBtu/ft^2/yr	2.2	7.0	52.7	0.08 CFM/ft^2
kWh/ft^2/yr	0.6	2.0	15.4	
kWh/m^2/yr	6.8	22.0	165.3	

POSTOCCUPANCY PERFORMANCE

of Passivhaus Homes in the UK

An intrinsic part of the UK government's net zero carbon strategy is reducing energy demand from buildings. While improvements in building codes are designed to achieve this on paper, there needs to be confidence that these improvements translate to actual energy savings in use. Unfortunately, it is becoming increasingly clear that there is a difference between the predicted energy demand of a building and the measured energy demand once the building is occupied—the so-called energy performance gap.

Any building constructed to meet a prescribed energy standard may exhibit a performance gap, described as the difference between the predicted thermal and energy performance derived from computer simulations and the actual measured building fabric and energy use once the building is occupied. Some variations in measured energy performance appear naturally, due to differences in household sizes, occupation patterns, and chosen internal comfort temperatures. It is therefore unsurprising for some buildings to use more energy than predicted, and others less. However, emerging research suggests that many buildings use much more energy than predicted—in some extreme cases, 250% more.

This energy performance gap is a concern both for the construction industry and for consumers. If homes consistently use more energy for space heating than predicted, this gap affects carbon emissions reporting at a governmental level, contributes to climate change, and may place more people in fuel poverty. Therefore, it is vital that homes built to a certain standard will meet that standard, both for improving energy efficiency in our homes and for managing carbon emissions reductions nationally.

Many reasons have been identified for this performance gap. These reasons include the quality of the design and building modeling, the quality of the construction and commissioning, occupancy patterns, user behavior, and robustness of postoccupancy testing, among others. One of the challenges in teasing out the contributions of various factors is the lack of postconstruction monitoring, especially at scale. We at Greenbox Associates undertook research to fill in the understanding of certified Passivhaus buildings in the UK by examining their actual performance relative to the modeled estimates.

There are several in-depth case studies of UK-certified Passivhaus homes that typically focus on individual sites and provide a forensic analysis of the performance of the building fabric. The results of this postconstruction building testing show small variations in heat transfer coefficients, in situ U-values, and air permeability, but in general the measured results were close or very close to design predictions. However, as the sample sizes are small, it is hard to draw general conclusions about the delivery of the Passivhaus standard in the UK.

Hence, the aim of our research was to compare predicted and observed space heating energy consumption at scale, from certified Passivhaus dwellings in the UK. There are around 1,300 certified Passivhaus units in the UK. We gathered heating and temperature data from 97 certified dwellings through a combination of (1) monitoring programs by consultants, (2) publicly available Innovate UK data from the Building Performance Evaluation program, and (3) self-reported data from homeowners. The main requirement for inclusion in the study was the availability of at least one year's heating data as well as indoor temperatures. Predicted space heating demand was obtained from the Passivhaus certificate for each dwelling. The data were spread across multiple sites and collected by different actors, and did not follow the same measurement procedure. Hence, special methods were created to account for varying data quality, but in such a way as to avoid biasing results in favour of the standard.

The results reveal that UK homes built to the Passivhaus standard do not show the same space heating performance gap seen in other research into non-Passivhaus homes (see Figure 1). Average measured space heating demand is 10.8 kilowatt-hours per square meter per year (kWh/m²a), which is about 1 kWh/m²a below the mean predicted space heating (11.7 kWh/m²a). This difference is not statistically significant. Just over half of the dwellings (52 out of 97 homes) used less energy for space heating demand than was predicted on the Passivhaus certificate.

Occupant behavior is a known contributor to the performance gap; however, our results show that this effect can be limited though Passivhaus design. Ten homes had no space heating demand at all, while 83 of the 97 homes (86%) used less than 15 kWh/m²a. Only five homes (5%) used more than 30 kWh/m²a, which is still below the predicted performance of a new-build UK home—and in reality, these homes will probably use a lot more energy. These results demonstrate that Passivhaus homes are being consistently delivered in the UK, not just on individual projects, but also from large sites, with a mixture of tenures.

The UK government is currently consulting on the Future Homes standard, which not only sets out new building requirements, but also is designed to address the performance gap. However, without major changes to current building practices, the performance gap may not be eliminated and may even increase—and poor performance will be locked in for a long time to come. Therefore, it is imperative that homes built to today's standards meet design expectations, through a program of monitoring and testing, to ensure that any future improvement in regulation translates into a similar improvement in actual building performance.

Our results provide clear evidence that compliance with the Passivhaus standard delivers low-energy homes that are affordable to heat, with, on average, no statistically significant performance gap. The standard deviation for heating demand in our sample is small, about 1 kWh/m²a—suggesting that the effect of varying occupancy or other factors can be controlled through this type of design; these homes are delivering in practice a 5 times lower demand than that predicted for a new UK home built to current standards. The Passivhaus approach is thus a solution that could be adopted directly, or one whose design and verification process should be closely emulated, to ensure that a similarly robust performance is achieved in the Future Homes standard.

— Rachel Mitchell

Rachel Mitchell leads Greenbox Associates, an architectural engineering consultancy based in Hampshire, UK.

TABLE 1. SUMMARY OF THE DATA COLLECTED

Category	Dwellings			Years of Data	Heat Data		Indoor Temperature
	Flats	Houses	Total		Type	Frequency	Frequency
A	5	27	32	1–3 years	Separately measured space heating	Varies	5–15 minutes
B	4	35	41	3 years	Total heat only	Monthly	N/A
C	12	13	24	2 years	Total heat only	Biannual	N/A

ANNUAL SPACE HEATING DEMAND BY TREATED FLOOR AREA ALL DWELLINGS YEAR 1

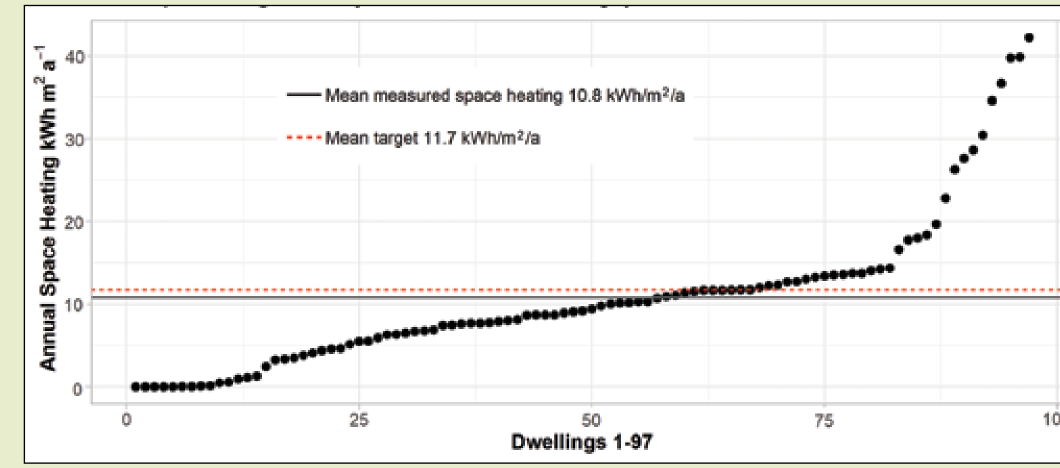


Figure 1. Measured space heating demand (kWh/m²a) for 97 new-build Passivhaus dwellings in the first year of operation, compared to the mean predicted demand on their Passivhaus certificates (red dashed line).

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