PHB
passive house
buildings

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Manhattan Mid-Rise

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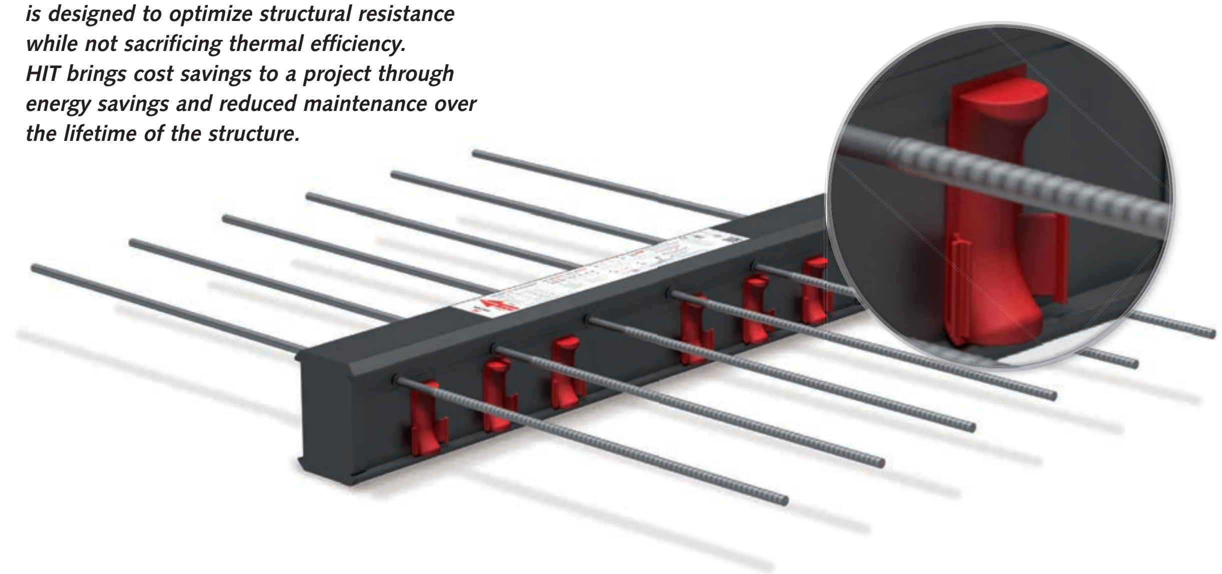
HIT brings cost savings to a project through energy savings and reduced maintenance over the lifetime of the structure.



- ICC-ES Approval – ESR 3799
- HIT units with symmetrical CSBs
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- Mineral wool used for both insulation and fire resistance. All standard units come with a 2HR fire-resistance.
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EDITORIAL

When national politics go low, a good response is to go local, as Congressman Jimmy Panetta, from California's 20th district, suggested recently. As Trump continues to gut environmental policies and Trudeau supports massive new oil pipelines to carry tar sands crude, at least we can take heart from the locales that are incentivizing or requiring Passive House performance. British Columbia, and particularly Vancouver, have instituted policies that encourage Passive House construction. (See "B.C.'s Energy Step Code: Driving Market Transformation," p. 6.) So has New York City. And which cities in North America are hotbeds of Passive House construction? You guessed it.

These areas' relatively fast-paced adoption of Passive House not only serves as an exemplary model, but also creates a demand for products that ultimately help Passive House designers throughout North America. Our ventilation product update ("Ventilation Options Expanding," p. 16) is clear proof of this demand-response cycle.

Another bright star in the Passive House firmament is affordable housing. I've just returned from the inspiring second New Gravity Housing Conference in Philadelphia. The Pennsylvania Housing Finance Agency (PHFA) has helped fund 25 Passive House apartment buildings, each averaging 50 units. Over 1,000 Passive House dwelling units in just one state! And PHFA is walking its talk by stipulating that its expanded headquarters—a new seven-story tower and an adjacent retrofitted three-story building—be Passive House buildings. Thanks to persistent advocacy efforts, 13 other states have adopted similar incentives for affordable housing developers to create Passive House buildings. (See "Connecticut Reaffirms Passive Affordable Housing," p. 8.)

Of course, the PHI didn't open its doors in 1996 and PHIUS didn't incorporate in 2009 just to create efficient, healthy, and comfortable buildings. Their raison d'être is driving down carbon emissions to ensure Earth's livability.

Elusive as this goal can feel at times, especially when many locations in the Northern Hemisphere are in flames, there is some good news from my home state. Check out "Electrification, Decarbonization, and the Leapfrogging of Zero Net Energy: California's New Path to a Low-Carbon Future," p. 88. Here's hoping the upcoming Global Climate Action Summit in San Francisco brings carbon-reducing news from hundreds of locales, big and small.

Thank you all for creating the world's most carbon-sipping, healthy, and comfortable Passive House buildings. And please thank our sponsors and contributing writers who make *Passive House Buildings* possible.

—Mary James
Editor and Publisher

— passivehousebuildings.com

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PHB passive house buildings

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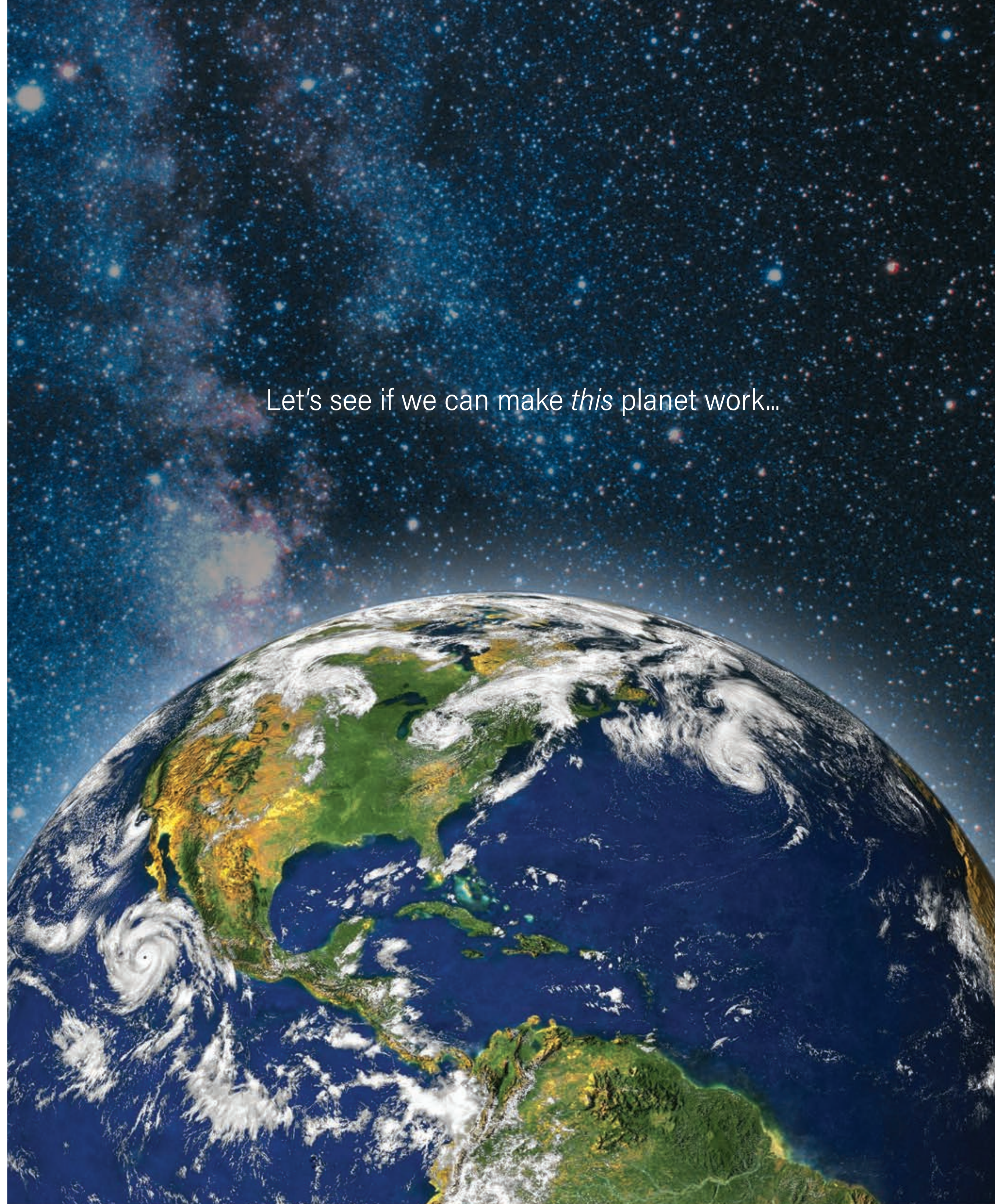
TELL THEM *PASSIVE HOUSE BUILDINGS* SENT YOU!



B.C.'s ENERGY STEP CODE: *Driving Market Transformation*

In 2017, British Columbia introduced what might be North America's most innovative beyond-code standard for energy efficiency. The B.C. Energy Step Code is an opt-in regulation that enables local governments to pursue improved levels of performance for new homes and buildings. The code allows cities and towns in B.C. to require or incentivize one of five levels of improved building performance, from current code performance all the way to net zero energy ready.

The Pan-Canadian Framework on Clean Growth and Climate Change, Canada's buildings strategy, and the B.C. Climate Leadership Plan have set targets for all new buildings to meet net zero energy ready standards by 2030 or 2032. B.C.'s Energy Step Code is the first provincial road map to achieving this goal, providing much-needed clarity to the industry and to authorities having jurisdiction. The code is performance based, with compliance assessed through energy-modeling software and on-site testing, simplifying the permitting process while also ensuring design flexibility.

LOCAL GOVERNMENTS STEP UP

As of July 2018, 28 municipalities in B.C. have signaled their intent to use the Energy Step Code—together accounting for over half of the province's population. (The city of Vancouver has already taken measures to incentivize steps to net zero energy ready buildings—see "Vancouver Strides Toward Zero Emissions." The city has committed to creating equivalencies between its building bylaws and the Energy Step Code.) As each municipality considers its options for incentivizing or requiring higher building performance, the question arises, What step should be first?

An extensive costing study, completed in 2017, offers some insight. It costed thousands of simulations for ten archetypes, representing a range of possible design choices that could comply with each performance step in the six climate zones of B.C. A first of its kind in Canada, this study revealed that significant reductions in energy use, carbon pollution, and utility costs already can be achieved at very moderate additional construction costs for the first three steps. For example, the lowest capital cost designs meeting step 3 for homes and apartment buildings in most parts of the province result in at least 20% energy savings and 50% emissions reductions (in some cases up to 90%), for less than 2% incremental construction costs. The designs needed to meet these performance criteria are familiar to the industry, which already regularly builds to this level under a series of voluntary programs.

Given the existence of low-cost solutions and the market's readiness, many local governments are opting to adopt step 3, either as a requirement or as a minimum threshold for access to added density or other incentives. Metro Vancouver's three North Shore municipalities, for example, have been requiring step 3 for new low- and midrise residential buildings since last July. Burnaby, New Westminster, and Surrey are also considering requiring or incentivizing step 3 for residential buildings.

The potential carbon pollution reductions from adopting step 3 are significant— and make a strong case for dispensing with the first two steps in many areas. For single-family homes, for example, the marginal cost for builders and consumers of moving from step 2 to step 3 is about a 1% increase in capital costs. Going up the step decreases emissions by another 20% to 25% below base code while maintaining energy costs at the same level. If all of the major municipalities in Metro Vancouver adopted step 3 for residential buildings, over one million tonnes of carbon pollution would be avoided cumulatively between 2018 and 2030.

Photo by Stephen Hui, Pembina Institute

STEPPING OUT BEYOND B.C.

Such innovation need not be limited to B.C. Developing a multitiered framework in other Canadian provinces would allow municipalities to start building the industry capacity and experience required to smoothly transition to net zero energy ready construction.

All around the country, energy-efficient buildings are being built and recognized for the multiple benefits they provide, including better air quality, reduced mold and moisture, and lower energy costs. A national energy step code could help accelerate this market transformation. Why wait?

—Tom-Pierre Frappé-Sénéclauze

Tom-Pierre Frappé-Sénéclauze *is the director of the Buildings and Urban Solutions Program at the Pembina Institute, and a cofounder of Three for All B.C., a coalition working to inspire and inform local government action on energy efficiency through judicious use of the B.C. Energy Step Code.*

Vancouver Strides Toward Zero Emissions

In 2018 the city of Vancouver adopted a Zero Emissions Building Catalyst Tools policy for mixed-use and multiunit residential buildings. This policy is focused on advancing multifamily buildings designed to the Passive House or International Living Future Institute Zero Energy standard. To offset the costs of high performance construction, this policy allows for up to a 5% floor area increase for buildings developed under a district schedule. The policy also gives the Director of Planning broad discretion to relax city regulations and policies, such as frontage requirements and floor plate limits, in order to facilitate the construction of near zero emissions buildings.

This policy is part of a larger Zero Emissions Buildings Plan established by Vancouver in 2016 to achieve zero emissions in all new construction by 2030. The city has planned a phased approach with interim targets of 70% emissions reduction in newly permitted buildings by 2020 and 90% by 2025. This plan would make Passive House thermal performance a requirement for rezoning applications by 2020, and for all low-rise residential development permits in Vancouver by 2025.

This 2016 plan also states that Passive House certification will be required for all new city-owned buildings, unless it is deemed unviable. In response, a new fire hall is being designed to achieve Passive House certification. The Vancouver Affordable Housing Agency has also incorporated a requirement to assess projects against the Passive House standards as part of its request for proposal process.

Other regulatory actions include requirements for rezoned large commercial and multiunit residential projects to meet strict thermal energy demand targets or the Passive House standard. This policy affects 60% of the square footage being developed in Vancouver. Previous actions had allowed, for all building types, the exclusion of the area used for insulation levels that exceed minimum code levels from floor space ratio calculations.

Vancouver also launched in 2018 a program providing homebuilders some incentives to document their near zero emissions projects and to offset some of the additional design costs. The city also offers discounts on Passive House training courses for trades active in its jurisdiction.

Connecticut REAFFIRMS Passive Affordable Housing

Passive affordable housing might have been the exception to the rule, except for a relentless outreach campaign initiated by Tim McDonald, principal of Onion Flats. McDonald's efforts, first in Pennsylvania and gradually in other states, included numerous phone calls and in-person presentations to a slew of state housing finance agencies on the way to successfully making the case for Passive House. At last report, 16 states now include some type of incentive for Passive House in their low income housing finance process.

The Connecticut Housing Financing Authority (CHFA) was one of the earlier state agencies to follow the Pennsylvania Housing Finance Agency's lead in incorporating points for Passive House design and construction into its Qualified Allocation Plan (QAP), which defines how the 9% Low-Income Housing Tax Credits (LIHTC) can be earned. The LIHTC application is a point-based system, and competition among developers is fierce for these tax incentives, as they often determine whether an affordable housing project pencils out.

When CHFA designated six potential points for Passive House design in its 2016 QAP, developers took note; half of the total applications submitted in the subsequent LITHC round set Passive House as a goal, and ultimately three Passive House projects were approved. In the 2017 LITHC round, three more Passive House projects were approved, and Connecticut seemed poised for further growth in affordable Passive House developments.

Other promising signs of Connecticut's burgeoning Passive House movement in 2017 included the debut of the newly minted Connecticut Passive House (CTPH), which offers resources, education, and outreach to promote the awareness and adoption of Passive House principles. CTPH, along with other regional Passive House organizations, cosponsored the inaugural New England Passive House Multi-Family conference in early spring 2018 to an at-capacity crowd. The day was filled with dynamic presentations and speakers, including a compelling keynote address delivered by McDonald on affordable passive housing, entitled "Leverage Points." In his address, McDonald called the adoption of Passive House points in the QAP the embodiment of the phenomena described by Donella Meadows in *Leverage Points: Places to Intervene in a System*, "where a small shift in one thing can produce big changes in everything."

But soon after the widely acknowledged success of the New England multifamily conference, the music stopped in Connecticut, as CTPH board members learned the disappointing news that CHFA was considering a reduction in the number of overall points in the sustainable-design section of the QAP, plus revisions to the text pertaining to Passive House. If adopted, these revisions, would kill off the incentive for developers to pursue this path.

Photo by Caryn B. Davis

To prevent this potential setback, CTPH, alongside other organizations, including the Connecticut Green Peer-to-Peer network, spurred a multipronged coalition of various stakeholders to express their support for affordable Passive House, either in person at a public hearing or in e-mails and letters submitted to the CHFA staff and board, or both. CTPH's outreach campaign recognized that the majority of decision makers who approve these tax incentives are individuals with expertise in public policy, banking, and law. They are not design and building professionals with specialized knowledge about sustainability in the built environment, let alone Passive House. Bearing this in mind, an organizational statement was drafted on behalf of CTPH to be delivered at the public hearing with the intention of presenting a narrative that would evoke the broad landscape of benefits to the state delivered by Passive House.

The narrative linked the state's recent passage of S.B. 7, An Act Concerning Climate Change Planning and Resiliency, and the United Nations' endorsement of Passive House as the best way to achieve the 2015 Paris Accord targets. The rationale of support was simple. By incentivizing Passive House affordable housing, Connecticut will ensure that buildings contribute to meeting the state's reduced greenhouse emissions and decarbonization targets: 80% below 2001 levels by 2050.

Evidence for the impact of the growing Passive House community on the states' clean-energy economy was provided with both quantitative and qualitative data. CTPH has attracted more than 60 members in less than a year and experienced attendance of over 300 participants at informational events, including a recent one that featured case studies of award-winning zero-energy passive homes in Connecticut. To showcase the fact that Passive House activity in the state is established, multiple copies of the Low Carbon Productions publication *Passive House Buildings: New England Forges Ahead* were distributed at the hearing, bookmarked to the introductory page of Connecticut's section. This assured the CHFA board that embracing Passive House places Connecticut in good company with its neighbors.

To acknowledge the leadership already on display in the state, CTPH's statement captured two highlights from the New England multifamily conference: CHFA was hailed at the conference for its visionary embracing of Passive House in its QAP, and Connecticut was the only state from New England invited to present a case study of an affordable Passive House project. To underscore the impact of Passive House on Connecticut 's clean-energy economy, the fact that the three-member presentation team also happen to live and work in the state was mentioned.

As the final component to make the case for Passive House, CTPH's statement included a section outlining how Passive House inherently provides a unique constellation of benefits to occupants, developers, and owners. For occupants, quality of life benefits, including healthier indoor air quality and superior indoor comfort, were mentioned. The ability to comfortably shelter in place when power has been lost—a level of resiliency that can bring deep emotional benefits—was also described. Yet another benefit is the confidence that, regardless of how energy prices change, the building would be locked in to the lowest levels of energy use. Since Connecticut has the second-highest electricity rate in the country, this energy security is particularly relevant for affordable housing's vulnerable populations. Finally, owner benefits, including less maintenance and increased durability of the building, were also mentioned.

The statement delivered by CTPH also included a request for desired action relative to the QAP: Increase the maximum points for sustainable construction in the 2018 QAP from the six allowed in the 2017 QAP to seven, by retaining the additive structure in the 2017 QAP as is and including one additional point to be awarded to the two most cost-effective Passive House projects.

CTPH encouraged other stakeholders to weigh in by drafting a template of turnkey letters that contained a synopsis of the case for Passive House and providing contact information and deadline dates for responses.

The net impact of this multipronged outreach campaign was wildly successful. During the period allotted for public comment, a total of 44 comments were submitted, which in and of itself is noteworthy. Of that pool, a staggering 80% of respondents opposed the reduced incentives for sustainable design, while the support for Passive House was overwhelming. As a result, the CHFA board voted unanimously to adopt a QAP for 2018 that increases the total number of available points for sustainability to seven and preserves the pathway for Passive House as a tool to earn those points.

—Alicia Dolce

Alicia Dolce *is a Climate Reality Leader and the communications director for Celebration Green Design & Build.*

WINDOWS AND DOORS
Schuco AWS75 by
European Architectural Supply, LLC

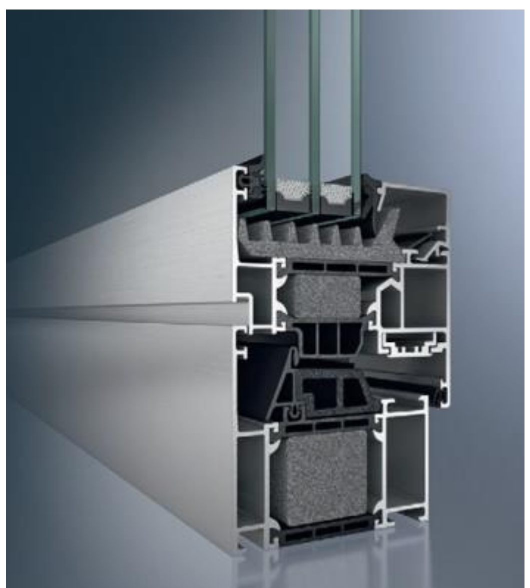
ARCHITECT
Chris Benedict, RA

DEVELOPER
Synapse Development Group

Multi-unit Passive House Window Installation

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

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



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Full-Service Passive House Windows Procurement, Delivery and Installation

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

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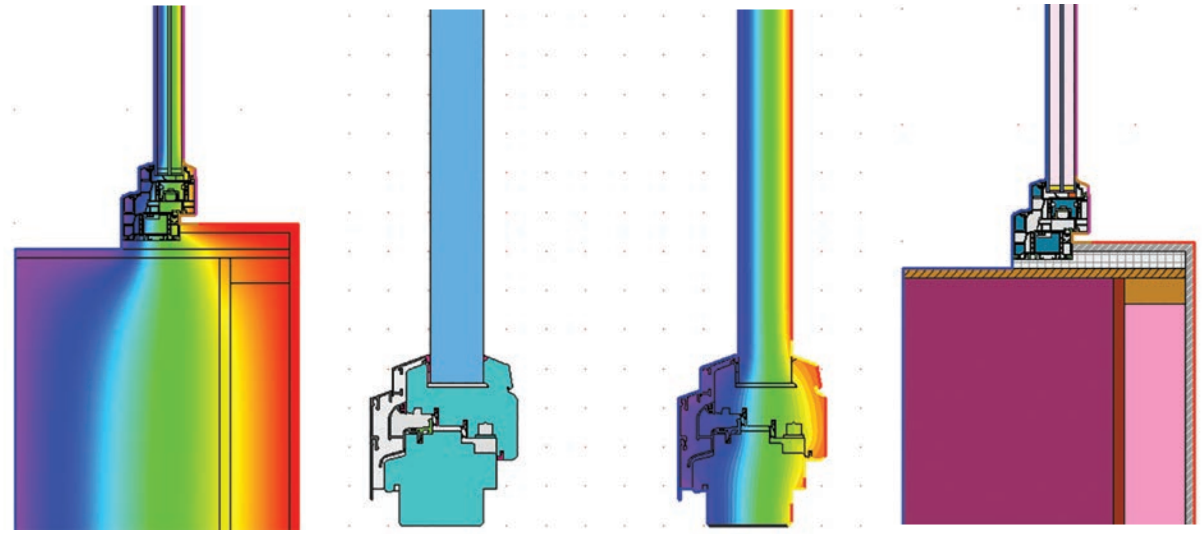


Peel Passive House Consulting

North American Passive House WINDOW STUDY

Passive House consultants in North America have long faced a shortage of domestically manufactured Passive House-certified windows. A significant barrier is the fact that North American windows are typically rated using methods developed by the National Fenestration Rating Council (NFRC). The resulting specifications do not align with the performance parameters needed by the Passive House Planning Package from the PHI. In addition, generating the data to meet both rating methods is expensive and time consuming for manufacturers.

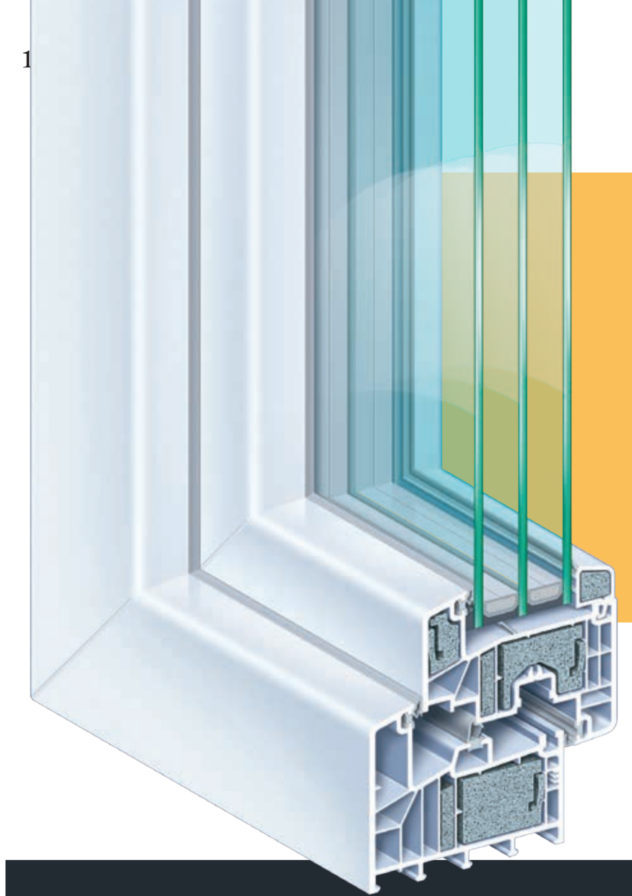
In 2017, the Fenestration Association of British Columbia decided to fund a project to help Canadian window manufacturers increase their share of the growing demand for Passive House windows. The goals of the project are (1) to provide a comprehensive guide and supporting tools to derive Passive House window data from existing NFRC simulation data; (2) to support North American manufacturers in developing PHI-compliant windows; and (3) to validate the use of existing tools familiar to North American window modelers for PHI modeling. The guide is being developed as a collaborative effort between RDH Building Science, Peel Passive House Consulting, and PHI.

The major difference between NFRC and PHI windows is one of detail. A NFRC window is typically rated according to the U-factor and the solar heat gain coefficient (SHGC) of the whole window assembly, not the individual components. A PHI-certified window requires individual values for the U-factor and the SHGC of just the glazing, the U-factor of the frame, the thermal bridge of the window spacer (Psi-spacer), and the thermal bridge of the installation (Psi-install). The heart of the project involves evaluating commonly available North American modeling software to determine its fit for producing PHI-compliant window specifications.

The guide delves into the details of various international standards and popular North American software tools that, despite not being officially validated to the appropriate international standards, might be used to comply with those standards. It concludes that WINDOW and THERM Version 7 software, both developed by Lawrence Berkeley National Laboratory, can be used to calculate glazing and frame U-factors, glazing SHGC numbers, and Psi-spacer and Psi-install values that adhere to PHI's official calculation methodologies.

The guide, which should be released by the end of 2018, will include background information on the related Canadian policies and Passive House window parameters, step-by-step modeling instructions, specific software pointers, climate-specific requirements, modeling reference sheets, and a reporting template. Armed with the details in the guide, Passive House consultants will be able to derive PHI-acceptable values for windows that are not officially certified. In addition, window manufacturers will be able to design products that more closely meet Passive House requirements.

—Steve Mann



INTRODUCING

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PASSIVE HOUSE CERTIFIED
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we believe in exceeding performance standards

And so do our building partners.

The new Defender 88PH System combines decades of fenestration knowledge to deliver a robust window system that exceeds the industry's toughest performance criteria. Manufactured in Canada, the Defender 88PH System is a PHI Certified Passive House Window that is engineered and tested for single family, low to high-rise multi-family, and commercial projects in the Pacific Northwest.

Learn more about the Defender 88PH System at innotech-windows.com/passive-house

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PentaCare from Minotair. No magic, just science.

The first autonomous and most compact all-in-one HVAC solution for multifamily Passive House buildings in the market (and other markets)

"The Battery" by Onion Flats in Philadelphia. Onion Flats will be using 28 PentaCare V12 units in its upcoming "Bank Flats" project this fall.

A revolutionary product on many levels: the PentaCare V12© is a compact, quiet, and self-contained unit being installed inside of each apartment. It fulfills the duty of 4 useful machines: heat recovery ventilator (HRV) + heat pump + HEPA high efficiency air filtration device (MERV15/F9) + dehumidifier. The mission: taking care of people providing unrivaled levels of healthy indoor comfort. To do so, it provides 5 important things which are fresh air, heating, cooling, humidity management and air filtration. So the PentaCare was born.

Installed indoor: contrary to bigger rooftop-installed HVAC units, it leaves intact building rooftops making space for PV panels and garden-style terraces. Another unique feature when maintenance or repair is needed: a PentaCare unit can be swapped in less than one hour by 2 persons. So each multifamily building keeps ready an extra unit on the premises in the janitor's closet as it's so useful to have a unit nearby. Again, another first by Minotair.

PentaCare V12 is a real achiever: regarding its balanced fresh air ventilation HRV performances, the PentaCare V12 had been tested recently for HVI certification, which is still pending at the time of printing. That certification process went through the third-party lab per excellence in the industry, Exova Lab in Toronto, ON. Exova tested the PentaCare V12 successfully in full compliance under the most largely used HRV/ERV standard in America: CAN/CSA C439-09.

The first and only HRV in North America to be Net Zero Positive in certain conditions: with the best verified heat recovery performances in America as tested by Exova, one of the results is the PentaCare V12 can provide 100 CFM of fresh air entering the building around 102˚F when it's 32˚F outside and 72˚F inside. Here's the tech data for the energy scientists: SRE of 116% when providing 100 CFM @ 32˚F outdoor air with an ASE, a.k.a. the "thermal efficiency", of 178%. In plain English it means that it's making more energy than it's using. Minotair: no magic, just science.

"No magic, just science."

Triple HEAT Recovery System©

The PentaCare V12 achieves above 100% in heat recovery efficiency but how? It uses Minotair's unique innovative Triple HEAT Recovery System© to recover heat from the stale air, heat contained in moisture, and heat generated by the compressor work. All that plus the fact that it's using the laws of thermodynamic in the mix. Again: no magic, just science.

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Commercial-grade VOC, CO² and PM 2.5 pollutant sensors made by renown and specialized manufacturers available in helping precise location IAQ sensing like monitoring a newborn bedroom in priority *(option)*.

It can control some other products like heat pumps, humidifiers, duct heaters, motorized dampers and forced air systems *(option)*.

With BACnet™ & Modbus® connectivity multifamily building managers are able to remotely monitor and control up to 207 units through BMS software *(option)*. Plus the included "Tenant Mode" provides control to the subset of features of your choice.

COMPLIANCES:

Heat Pump: ANSI/UL STD 1995 and STD CAN/CSA 22.2 No. 326

HRV and Ventilation: ASHRAE 62.1, 62.2 versions 2010, 2013 and 2016, CAN/CSA C439-09

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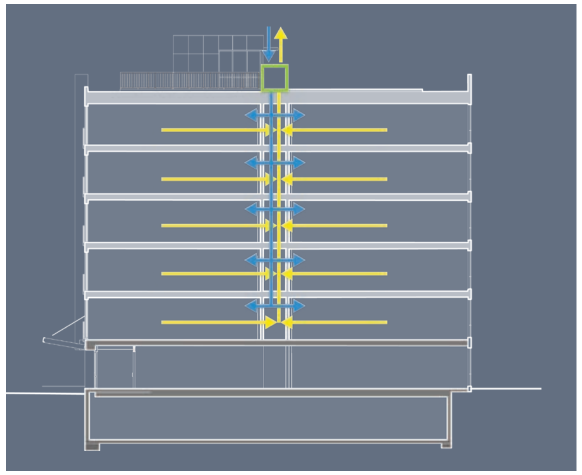
Ventilation OPTIONS *Expanding*

High-performance ventilation choices expanded rapidly in 2018 with several new products that are targeted specifically for supplying continuous fresh, filtered air to airtight, efficient Passive House buildings. Many of the ventilation products now available have undergone independent performance testing regimens, ensuring comparable predictions of energy use intensity and quality. Apples-to-apples testing also cuts through manufacturers' performance claims, which can be challenging to parse.

In North America there are a variety of options for manufacturers considering ventilation equipment testing and certification. The Home Ventilation Institute (HVI) and the Air Conditioning, Heating & Refrigeration Institute (AHRI) have established third-party industry-led performance testing programs. Since 1998 the Passive House Institute (PHI) has run its own independent performance testing and certification program tailored to the requirements of ventilators for high-performance Passive House buildings. And, now the Passive House Institute U.S. (PHIUS) is in the pilot phase of developing a similar program.

The Passive House multifamily market, which has seen strong growth in both affordable and market-rate housing, is especially benefitting from this spate of ventilation product developments. Three approaches predominate: distributed, semi-distributed, and centralized. Distributed ventilation relies on one or more small-volume ventilators to bring fresh air to each individual apartment. The equipment may be through-wall HRVs, traditional ducted HRVs or ERVs, or ventilators integrating air heating and cooling. The semi-distributed approach assigns an HRV or ERV of sufficient capacity to service a cluster of multiple units that are in sufficient proximity to minimize duct lengths.

Centralized ventilation with rooftop H/ERV



Courtesy of NK Architects

The centralized approach relies on a single large HRV or ERV with sufficient capacity for all of the units.

These different approaches tend to blur the traditional distinction between small and large capacity HRVs and ERVs, allowing for more choices when specifying ventilation equipment for even large buildings. Regardless of capacity, the equipment's thermal and electrical efficiency are essential facts for Passive House design and construction professionals.

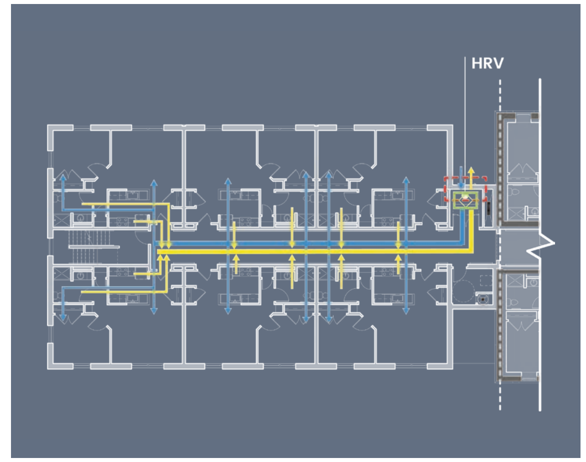
CERTIFIED FOR PASSIVE HOUSES

Last winter, Ontario-based Green Giant Design Build began importing the Futura whole-house ERV for cold climates for distribution throughout Canada. Futura is produced by **Jablotron,** the Czech Republic home security system giant.

Adam Cronk, owner of Green Giant, explains that the Futura can operate continuously without frosting up at temperatures as low as -12°C. And, with a glycol ground loop, pump, and air handler prewarming air entering the ERV, it can operate at even lower temperatures without costly electric preheating. For night flush cooling during hot, humid summer conditions, the Futura can operate in bypass mode. The Futura comes with a complete ventilation system package including proprietary insulated pipe to the building exterior and a flexible polyethylene interior ducting system.

Although Cronk will remain Jablotron's sole Canadian distributor, he is building a dealer and installer network to handle sales, installation, and commissioning the Futura in much the same way as Zehnder America operates. This service is particularly important, because in Canada's harsher climates only a trained installer can optimize the Futura's operation for a given climate and building.

Semi-distributed ventilation—horizontal (floor-by-floor)



Courtesy of NK Architects

PHI has certified the Futura ERV, expanding the choices for independently tested ventilators with validated performance for Passive House buildings.

Cronk is not sitting still; he hopes to begin importing additional Jablotron ventilation products in 2019. Stay tuned!

Zehnder America offers a number of PHI-certified HRVs and ERVs for single-family homes, small buildings, and semidistributed ventilation systems for larger buildings.

In 2018, Zehnder America introduced its new ComfoValve Luna S125 supply air diffuser, which adjusts airflow and can distribute it from 240 to 360 degrees with airflow parallel to walls and ceilings.

Ventacity Systems of Portland, Oregon now offers rooftop-capable 1,000 and 3,000 CFM HRVs and ERVs for medium and larger Passive House buildings. Ventacity's ERVs are the first PHI has certified for large buildings.

Sal D'Auria, CEO of Ventacity Systems, notes their ERVs are both UL and CSA-certified as well. By adding ERVs to their existing line of HRVs, they now have high-efficiency ventilators for every North American climate.

Ventacity's ERVs have permeable polymer counter-flow cores instead of the HRV's aluminum core. A simple difference; however, the development process was not so simple. It took over a year of design and engineering of both mechanical components and electronic sensors and controls.

Networked sensors and smart controls are other major 2018 innovations. Ventacity collaborates with Fujitsu General to optimize HVAC systems by combining Ventacity's HRV or ERV and Fujitsu's Airstage line of variable refrigerant flow (VRF) commercial heat pump air heating and cooling systems. They operate together

Distributed ventilation with through-wall H/ERV

Courtesy of NK Architects

as a system with an integrated, wireless electronic monitoring, reporting, and control system that is typically found only in buildings larger than 100,000 square feet.

And these integrated units are ready out of the box. Without add-ons or expensive programming. For Jonathan Moscatello of Ventacity, the partnership with Fujitsu is simple. They are "ready to rock." "Smarter controls for occupancy, schedules, thermal settings, and CO_2 will optimally leverage their high HRV and ERV core efficiency."

Swegon also offers a range of choices for medium and large Passive House buildings. Eleven models of Swegon's Gold RX HRVs manufactured in North America are PHI-certified and bear North American safety listings. Swegon's largest PHI-certified HRVs have a ventilation capacity of up to 5,297 CFM. Swegon also offers its REACT line of dampers which include actuators and controls and operate without a building management system (BMS).

MORE HIGH PERFORMANCE CHOICES

Among the large number of North American manufacturers of ventilation systems of all shapes and sizes, there are several manufacturers and distributors that specifically market their systems for Passive House buildings—but do not have either PHI or PHIUS component certification.

475 High Performance Building Supply is expanding the line of Lunos ventilation equipment it imports from Germany and distributes in the U.S. to meet the demands of the growing Passive House market. With this additional Lunos equipment, 475 can offer Lunos-based distributed HRV systems for multifamily projects in various climates zones.

475 calls these systems hybrids, because they combine Lunos e2 and eGo regenerative thermal core ductless ventilators with heat transfer and demand-controlled intake and exhaust ventilators without heat transfer. Together they supply sufficient fresh air and exhaust sufficient stale air even though some of the air bypasses heat recovery. Floris Keverling Buisman, CEO and technical director explains, "This compartmentalized solution avoids issues normally seen with continuously run rooftop fan systems."

Although the Lunos e2 does not have HVI or PHI certification, 475 reports the German federal agency DIBt testing established an average heat recovery efficiency of 90.6%. Additionally, 475 provides performance data for use in the ventilation sheet of the PHPP energy balance software.

Tempeff North America, now operationally separate from its Swedish parent, expanded its line in 2018 with its new RGN configuration for installation within a confined space where both exhaust and supply ducts must be connected to the same side of its ERV.

Tempeff's field mechanical engineer Andy Kebernik explains that Tempeff has supplied ventilators for both PHI and PHIUS-certified buildings in Canada. Tempeff met with PHI in Germany in 2017 to discuss plans for testing and certification, which Kebernik hopes will lead to an agreement with PHI this winter on in-house testing protocols.

UltimateAir of Athens, Ohio continues its 20-year run of leading North American ventilation innovation after pioneering electronically controlled DC motors (ECM) within HRVs and ERVs and water-to-air coils for post- and pre-conditioning ventilation air.

2018 has brought plenty of innovation. UltimateAir developed optional integrated, pulse-modulated electric preheat technology within their ERVs. Jason Morosko, VP, Engineering, explains, "For years, installers were forced to purchase and install these pre-heaters as a separate item for continuous winter ventilation. Integrating the pre-heater within the ERV allows for easier installation in the field, less expensive upfront cost, reduces the chance of condensation, and saves much needed space."

UltimateAir launched its ER80M as a prototype in 2016, but with modification of its 200DX, in 2018, UltimateAir retested and submitted both models for UL certification under new criteria and received full UL certification for both.

Luke Langhals, director of Business Development promises 2019 will offer continued improvements from the engineering department's wizardry. "We have begun the R&D for integrating an optional dehumidification accessory into our system." Stay tuned!

SYSTEMS INCORPORATING HEAT PUMPS

North America is home to two companies—Build Equinox and Minotair—that incorporate heat pumps in their ventilation equipment instead of using other means to transfer heat and moisture between air streams. Heat pump-based ventilators have the potential to reduce both equipment and installation costs, but for some projects, especially those with smaller living units, the space savings alone make this equipment highly prized.

Build Equinox, based in Illinois, celebrated its 10th anniversary by shipping its first CERV2 units, which integrate both the ventilator and heat pump heating and cooling equipment within the same box. CO_2 and VOC monitors are built into the CERV2.

Ben Newell, president and mechanical engineer, explains that the CERV1 system ventilator was in one box with the heat pump in another, but the CERV2 integrates them in a single box for easier installation. While the CERV's operation is unchanged, the new model's heat pump is more efficient. The CERV1 was UL-listed, and Newell reports the CERV2 is currently in review for UL listing.

Minotair, based in Quebec, expanded the capabilities of its PentaCare ventilator in 2018 so that now it can both ventilate as well as cool, dehumidify, heat, and/or humidify the ventilation air. Minotair co-owner and VP Alex De Gagné, announced that with an optional, compact humidifier atop the fresh air port controlled by its integrated humidity management system, the PentaCare is "even more valuable in the cold climates where winter outdoor air is so dry that it is difficult to maintain optimum indoor air humidity without humidification."

For multifamily buildings, Minotair developed a decentralized ventilation and conditioning system combining a remote whole-building control system and its PentaCare units. Each PentaCare unit provides complete HVAC for one apartment, but the building manager has the option to remotely monitor and control the PentaCare units in separate apartments.

De Gagné is in discussions with both PHI and PHIUS about PentaCare certification.

All of these innovations—from new ventilators to new systems combining new and existing equipment—are facilitating multifamily Passive House building ventilation, while continuing to meet the ventilation needs of single-family homes. As this market grows, watch this space for further updates on the whole range of ventilation options.

—Tad Everhart

Tad Everhart, *marketing manager for* Passive House Buildings, *is married to Maria Everhart, Ventacity Systems' market analyst.*

SCALABLE, EFFICIENT *Retrofit Solutions* Under Development

The New York State Energy Research and Development Authority (NYSERDA) recently awarded the first six Energiesprong-style retrofits. This announcement comes as an exciting new development to last year's article in *Passive House Buildings* about New York State's planned implementation of the burgeoning retrofit style that aims to create standardized, scalable, deep energy-efficient retrofit solutions.

NYSERDA has scheduled the design phase of these projects to last about six months, from technical solution concept development through schematic implementation plan. The finalized schematic implementation plan will include schematic architectural and mechanical designs, projected budget and schedule, a life cycle cost analysis, energy analysis, renewable-energy plan, regulatory-barrier analysis, and resiliency analysis. NYSERDA then plans to issue a solicitation to provide funding for developing and installing the designs.

One of the New York City teams is led by The Levy Partnership (TLP), a leader in the energy efficiency consulting field. In addition to TLP, the core team includes building owner Joint Ownership Entity (JOE) NYC, award-winning architecture firm CTA Architects, P.C., ecologically minded mechanical engineers Peterson Engineering Group, international structural engineers MacLaren Engineering Group, and a construction firm experienced in Passive House design, M Square Builders. Solar One, Harvest Power, Sentient Buildings, Passive Dwellings, and Rocky Mountain Institute are also providing support. Together, they are working to bring an existing 20-year-old multifamily low-income building in Harlem to near net zero energy use. The team will also address improving indoor environmental quality and the resiliency of the building, all without displacing residents during construction.

The building owner, JOE NYC, a new entity for nonprofit-owned affordable housing assets in New York City, was founded by a group of prominent New York City Community Development Corporations in response to a set of challenges confronting New York City's affordable housing stock and low- and moderate-income communities, and in particular the nonprofit community.

As JOE NYC Assistant Director of Asset Management Allison van Hee explains, "You can't expect to maintain affordability without sustainability both in terms of the well-being of building occupants and the environment as a whole. As a result, the JOE is committed to pursuing the net zero energy goals of RetrofitNY and helping to achieve New York City and New York State climate goals." RetrofitNY supports Governor Andrew M. Cuomo's goal to reduce greenhouse gas emissions 40 percent by 2030.

TLP and JOE chose an infill site that is representative of so much of New York City's contemporary low-income urban fabric and the design challenges inherent in renovating it. The midblock building consists of one floor of community facility space and five stories of apartments. The façade is a minimally ornamented brick cavity wall with concrete masonry unit (CMU) backup masonry and a bearing-wall-and-concrete-plank structural system.

The team is currently looking at how to insulate the exposed walls, given the limitations of the site and the fact that the building is built flush to three of its four lot lines. Added to that, the original building plans included vertical shafts that the team intended to use to run ventilation ducts and piping to new heating and cooling systems. Unfortunately, the shafts don't exist in the as-built conditions, so the group is busy working around these obstacles.

Thus far, the plan is to provide a significant amount of additional envelope insulation from the cellar to the roof. The exterior framed walls already have 3 inches of fiberglass batt insulation, and given the limited floor area, insulating more on the interior is not an option. The primary strategy is to use exterior insulation and finish system (EIFS) panels over the existing brick veneer and 8 inches of EPS underneath a new bituminous roof. The team is still grappling with code restrictions on expanding past the lot line toward the street, so different strategies may be implemented on the front and back sides of the building. Also in consideration as an alternative to EIFS is

Pericle Gheorghias

the use of large prefabricated panels inclusive of windows. Whichever approach is chosen, the renovations will include wholesale window replacement and air sealing.

A decommissioned trash chute and the existing corridor supply shaft may be repurposed to house ductwork going to each apartment. If these shafts are not usable, ventilation will likely be accomplished by running ductwork from rooftop ERVs down the building façade to apartments. Other options, such as cutting openings in the plank construction of the occupied apartments, were deemed too complex, costly, and disruptive to the residents. Existing exhaust shafts will be used to extract stale air from apartments and corridors. The ground floor and basement community spaces will have their own ERVs.

The project requirements include eliminating on-site fossil fuel usage, so the existing fossil-fueled space and water heating systems will be decommissioned and replaced with all-electric systems. Domestic water heating will likely utilize one or more air source heat pumps connected to the existing central recirculating system. These will in turn be outfitted with additional insulation and energy-saving controls.

The new systems also will provide space cooling, which will be a real amenity to the residents. The team is currently considering two options to assist with temperature control: a central variable refrigerant flow heat pump system with individual air handlers in each room and a hot/chilled water distribution system served by a roof-mounted heat pump.

A sizable PV array is planned for the roof level to defray the use of grid electricity, and energy-efficient appliances, lighting, and low-flow plumbing fixtures will reduce electricity usage in individual apartments. Part of the project's larger vision is to provide replicable solutions throughout New York City's multifamily housing stock, so all of the proposed systems are selected, and their implementation planned, with replicability in mind.

While the retrofit will include items directly benefiting residents, such as the new cooling system, improved ventilation, and new appliances, tenant engagement will be critical to the long-term success of the project and the replicability of the retrofit approach. For this reason, the project team is already planning a series of resident meetings to present preliminary plans and gather feedback on resident behavior and preferences. The team is dedicated and enthusiastic, and it looks forward to solving the challenges successfully, both technically and aesthetically.

Preliminary energy modeling has shown an approximately 90% decrease in site energy use based on the proposed solutions thus far, which include an extensive canopy-mounted full-roof PV array that would produce about 60,000 kWh per year. Because it is unlikely that a six-story building can achieve net zero with its limited roof area (four stories is generally considered the maximum for this goal), the building will seek to obtain the remaining 70,000 to 80,000 kWh from community solar.

In order to maximize collaboration, all the RetrofitNY teams are employing an integrative design process and have been provided a coach expert in this methodology by NYSERDA. By including M Square Builders on the TLP team, the design consultants have been able to make real-life decisions based upon its contractor's experience. MacLaren Engineering Group will advise on the additional structural loads that can be imposed on the façade and roof so that CTA Architects has the parameters within which it needs to work to implement the solutions.

Collaboration really has been key, as this process includes a fair amount of brainstorming and creativity along with technical knowledge. "It's fantastic having the full range of expertise in the room problem solving together," says van Hee. "One of the values the JOE can provide its members is brokering early adoptions of new building techniques and technologies and providing better data on ongoing operations postbuild. NYC is on the precipice of a major shift in building standards. I'm convinced that our team is developing a model that will be the boilerplate for future resident-in-place affordable rehabs. The question for me is how quickly we can solve for the trickier aspects of implementation and standardize the solution."

— Jordan Dentz and Christa Waring

Jordan Dentz *is vice president of* *The Levy Partnership* *and* **Christa Waring** *is a principal with* *CTA Architects*.

NANAIMO Aboriginal Centre Passive Housing

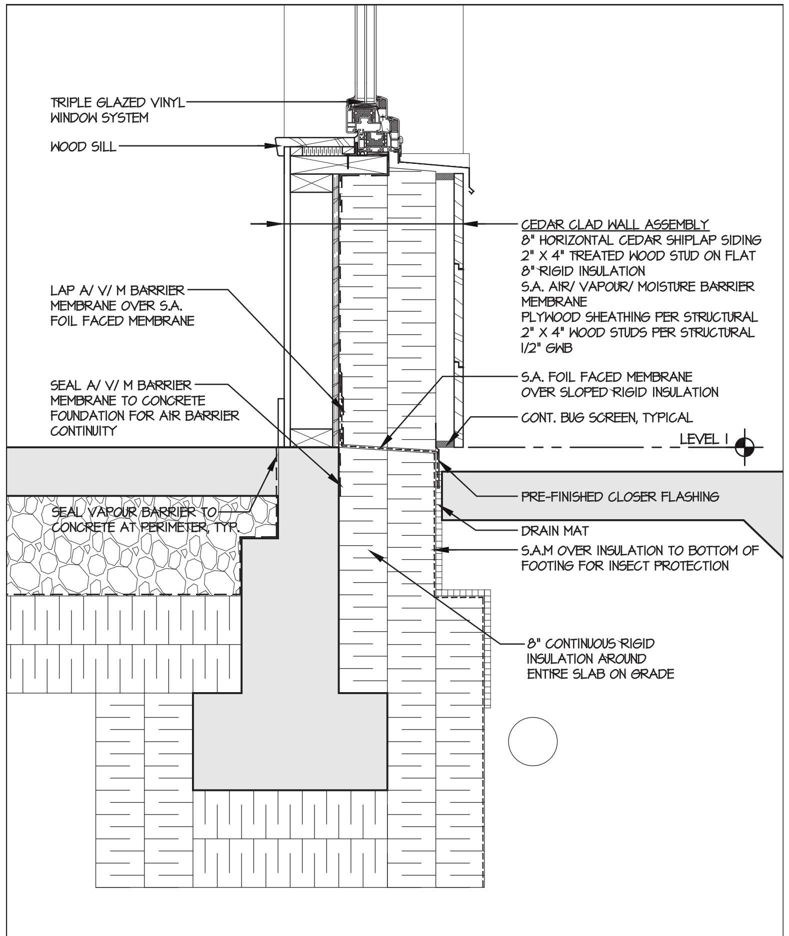
Photos by Lance Sullivan

Designed to bring affordability and community spirit to a small city on Vancouver Island's east coast, Nuutsumuut Lelum provides 25 affordable suites for youth, elders, and families in three two-story Passive House buildings. With its long and low massing, the complex's architecture references Northwest Coastal Indigenous longhouse buildings.

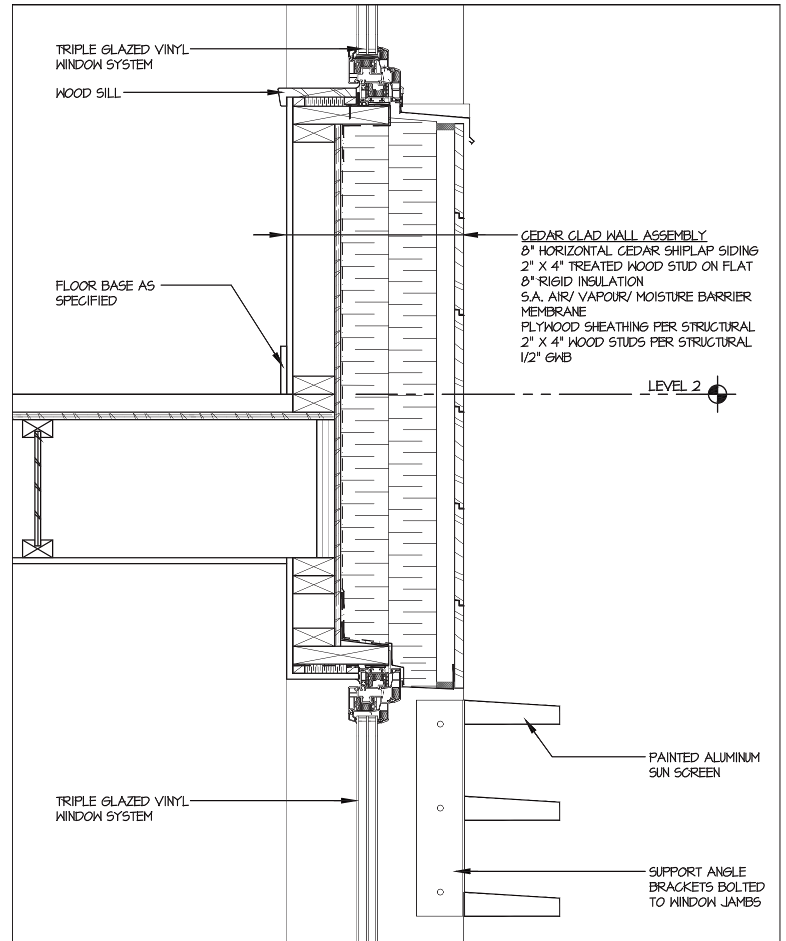
The Nanaimo Aboriginal Centre (NAC), the project's developer, is a nonprofit whose work focuses on education and family, particularly for the diverse Indigenous community there that includes First Nations, Inuit, and Metis. Its programs and services are open to all Nanaimo residents but are planned with the urban Indigenous community in mind. "The forms and materials that are traditional to Indigenous people are what drove the design," says David Simpson of dys architecture. NAC's sustainability goals for the project—particularly cutting the rental housing's energy use by meeting the Passive House standard—helped win community support.

The complex's central circular courtyard serves as its heart: Residents can gather around the fire pit and enjoy cultural entertainment on a raised, covered stage that is backed by a living wall of lattice and climbing plants. The suites' townhouse style features entrances facing the courtyard to encourage neighborly interactions. Salvaged utility poles were used as architectural features, and the fence along the back and park sides was built from reclaimed planks from the Expo '86 Folklife Village, constructed to highlight B.C.'s timber. These timber architectural features are carried inside into an amenity room that showcases recycled utility poles and Douglas fir beams.

The low slope of the roofs allows all suites to receive full sun even in the middle of December, while louvered sunshades on the south-facing façades lessen the summer heat. A minimum of 10 inches of polyiso insulation in the roof assemblies delivers an R-value of 45, helping to keep temperatures comfortable year-round and energy bills



3 FOUNDATION
dys architecture



2 WINDOW HEAD & SILL
dys architecture

affordable for the residents. The sunshades and patios—features that extend from the building—are all attached to the exterior of the building rather than through it, to minimize thermal bridging.

Each foundation's concrete slab is encased in a continuous layer of 8 inches of XPS, attaining an R-value of 40. The wall assemblies similarly rely on 8 inches of exterior rigid insulation to achieve an R-40, with a continuous air, vapor, and moisture membrane adhered to the exterior of the plywood sheathing. To manage the area's high annual rainfall, special care was given to site contouring, French drains around the buildings, and a rain screen gap beneath the horizontal cedar shiplap siding.

Carefully placed fenestration—with most of the windows on the south—combined with the superinsulated, airtight assembly yielded housing that will be heated only by the HRVs in each unit—a notable accomplishment in this climate. The HRVs have preheaters to warm the incoming air on those rare days when temperatures get quite cold. Only the amenity room, which is occupied solely during parties and other special events, has supplemental baseboard heaters. No mechanical cooling is needed.

The Passive House's primary energy target was surprisingly hard to meet for this all-electric project, given the clean hydropower in the region, says Darcy Imada of dys architecture, who became a Certified Passive House consultant during this project. The relatively high population density, and the associated hot water demand, accounts for the challenge, according to Imada. That demand is being met with individual heat pump water heaters that use CO_2 as the refrigerant.

Passive House is the highest step on British Columbia's new Energy Step Code. Working on this project gave Imada and Simpson a good understanding of how to move other projects through those steps. "It has really educated us and influenced how we do our external walls and building envelopes generally," says Simpson.

—Mary James and Sarah Brewer

Sarah Brewer *is an intern at Passive House Canada.*

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Peak heating load	Peak cooling load	Air leakage
3.9 kBtu/ft²/yr		15.5	3.0 Btu/hr/ft²		
1.2 kWh/ft²/yr	0.0	4.6	0.9 Watts/ft²	0.0	0.33 ACH_{50}
12.5 kWh/m²a		49.0	9.5 Watts/m²		

Products

Windows & Doors
Euroline

Ventilation
Zehnder America

Water Heating
Sanden

The Heights, 388 Skeen Street in Vancouver, B.C., is Canada's largest Passive House building

The Heights at the corner of East Hastings and Skeena Street in Vancouver, B.C. may look like just another apartment complex, but the recently completed six-storey, 85-unit building is Canada's largest Passive House.

Scott Kennedy, principal of Cornerstone Architecture, suggested to the developer that they could save more than half a million dollars on mechanical systems by building to Passive House standard. There would be additional costs to upgrade to a more efficient HRV system and using Passive House windows, for example, but the building would be up to 90% more efficient than a comparable project built to typical building standards, resulting in lower operating costs, and allowing for a premium to be charged to recuperate additional construction costs.

The multi-use complex consists of 85 residential, and 3 commercial units

EuroLine Windows®' ThermoPlus PHC tilt & turn windows – a Passive House certified component, certified by the Passive House Institute in Darmstadt, Germany – played an integral part in achieving this.

According to Kennedy, "If I were to test an old house, I would probably get 10 or 12 air changes an hour. If I built a well-built modern house, I would probably get 5 air changes an hour. A Passive House has 0.6 air changes an hour, which is a whole order of magnitude tighter." With its multi-point locking tilt & turn hardware and a triple seal system, the 4700-series ThermoPlus PHC system was an easy choice.

For more information about EuroLine Windows and its products, visit www.euroline-windows.com

CHICAGO'S (and Illinois') First EnerPHIT

Photos by Michael R. Conners

When Mike Conners of Kenwood Construction Services, Incorporated, bought a foreclosed house in the Hyde Park neighborhood of Chicago, it was in pretty bad shape. The basement fieldstone foundation walls were not properly waterproofed and had substandard footings. The upper-floor brick walls had pronounced efflorescence and spalling, plus numerous cracks and holes. Many of the floor and roof joists were seriously compromised from aging and multiple renovations over the years. Thermal investigation revealed several bulk water penetrations. Interior humidity levels typically exceeded 75%. A mildew smell permeated the entire structure, despite the 17 ACH_{50} natural infiltration rate.

Over the next few years, Conners and his team revived this approximately 17-foot-wide, 1880s Greystone row house into a comfortable, energy-efficient Passive House. They gutted the interior to the brick, rebuilt the foundation, repaired the stone and brick walls, added 1,000 square feet of living space in the back, and topped the structure with a 200-ft^2 penthouse utility room plus terrace. The reconstituted 3,500-ft^2 four-story-plus-basement residence includes five bedrooms and three bathrooms. It has enough roof space to host up to an 8-kW grid-tied PV system that should provide enough site-based electricity to make the house net zero.

To structurally revitalize the house, Kenwood Construction tore out the old basement slab, excavated under the existing foundation in 6-ft sections, and placed new footings. Then several dozen cubic yards of sand were removed from the slab area, resulting in a finished ceiling height of 8 feet 5 inches, increased from six feet 8 inches. Seven inches of Type IX EPS were topped with a new 4-inch slab. The below-grade stone walls were repointed and covered on the outside with a dimpled rain screen

and rigid mineral wool before backfilling. Parts of the above-grade brickwork were replaced or repointed and parged. Once the walls were repaired, the side- and rear-wall exteriors were covered with a mix of insulation types, a vapor control membrane, and cladding. The classic limestone front façade, typical of Greystone buildings, was power washed and repointed.

An equal amount of work was done on the interior. The masonry walls, mortared with limestone plaster, were in disrepair. Lime plaster was applied to the surface of all the interior walls. This not only structurally reinforced them, but also created a vapor-permeable air-and-water barrier. An intelligent vapor control membrane was then layered on top of all the interior walls. Some walls were finished with 1-½ inches of rigid mineral wool, for a thermal break, topped with 2 x 4 framing and batt insulation. Others were framed with 2 x 4 lumber offset from the masonry, providing a thermal break, and the cavities were filled with dense-packed cellulose.

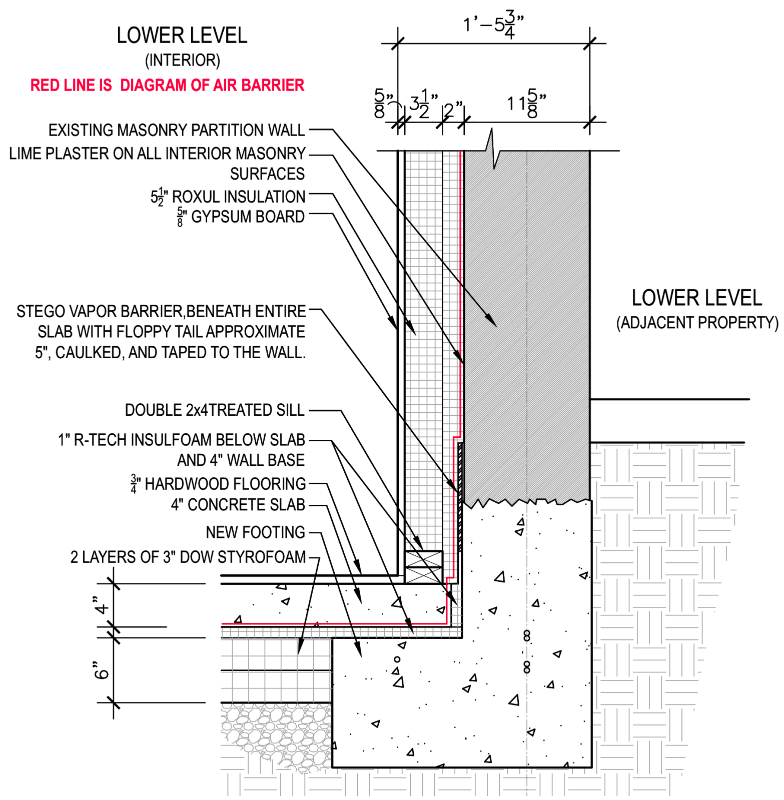
The damaged roof deck had to be removed in its entirety. It was replaced with a 7-inch layer of insulation sandwiched between 1-inch plywood layers, structurally supported by 10-inch LVLs filled with blown-in cellulose. Many of the joists between floors also had to be replaced. Wedged into pockets in the masonry walls, they were all taped at the wall junctions, prior to the addition of the interior insulation, to tie into the air-and-water barrier.

Mechanical systems and interior materials were picked to maximize indoor air and water quality. A multizone ductless mini-split provides heating and cooling. There is a separate dehumidification system to handle those days when Chicago's humidity is extremely high. A heat pump water heater provides domestic hot water. There is a whole-house water filtration system. According to Connors, the antimicrobial photocatalytic bath tiles kill a variety of microorganisms, are self-cleaning, reduce mold formation, and assist in breaking down volatile organic compounds. The drywall used throughout the house is designed to absorb and neutralize formaldehyde.

In addition to pursuing Passive House certification, the project team paid equal attention to the carbon footprint and greenhouse gas production of the project. It sourced local materials whenever possible. For instance, realizing that most hardwood floor products are made from North American hardwoods that are shipped to China for finishing and then shipped back to the United States, the team located an urban-forest mill that sources felled hardwood trees from local park districts and arborists. The mill supplied rough-sawn white oak that was finished into tongue-and-groove hardwood flooring.

The project's extensive Web site (www.kenwoodpassivhaus.com) has a detailed breakdown of utility costs and greenhouse gas emissions for potential buyers of this spec house. The calculations show that, while a typical Chicago house produces over 95,000 pounds of carbon a year, this all-electric house should produce approximately 9,500 pounds a year, including charging an electric vehicle. Based on normal utility rates, the monthly utility cost should drop from $350 to $44. If the homeowners decide to install the optional solar PV system, they can reduce both their utility costs and carbon emissions to zero—transforming their home into a net zero building.

— Steve Mann



Products

Windows & Doors
Klearwall

Air/Moisture Control
ProClima by 475

Ventilation
Zehnder America

Insulation
Rockwool

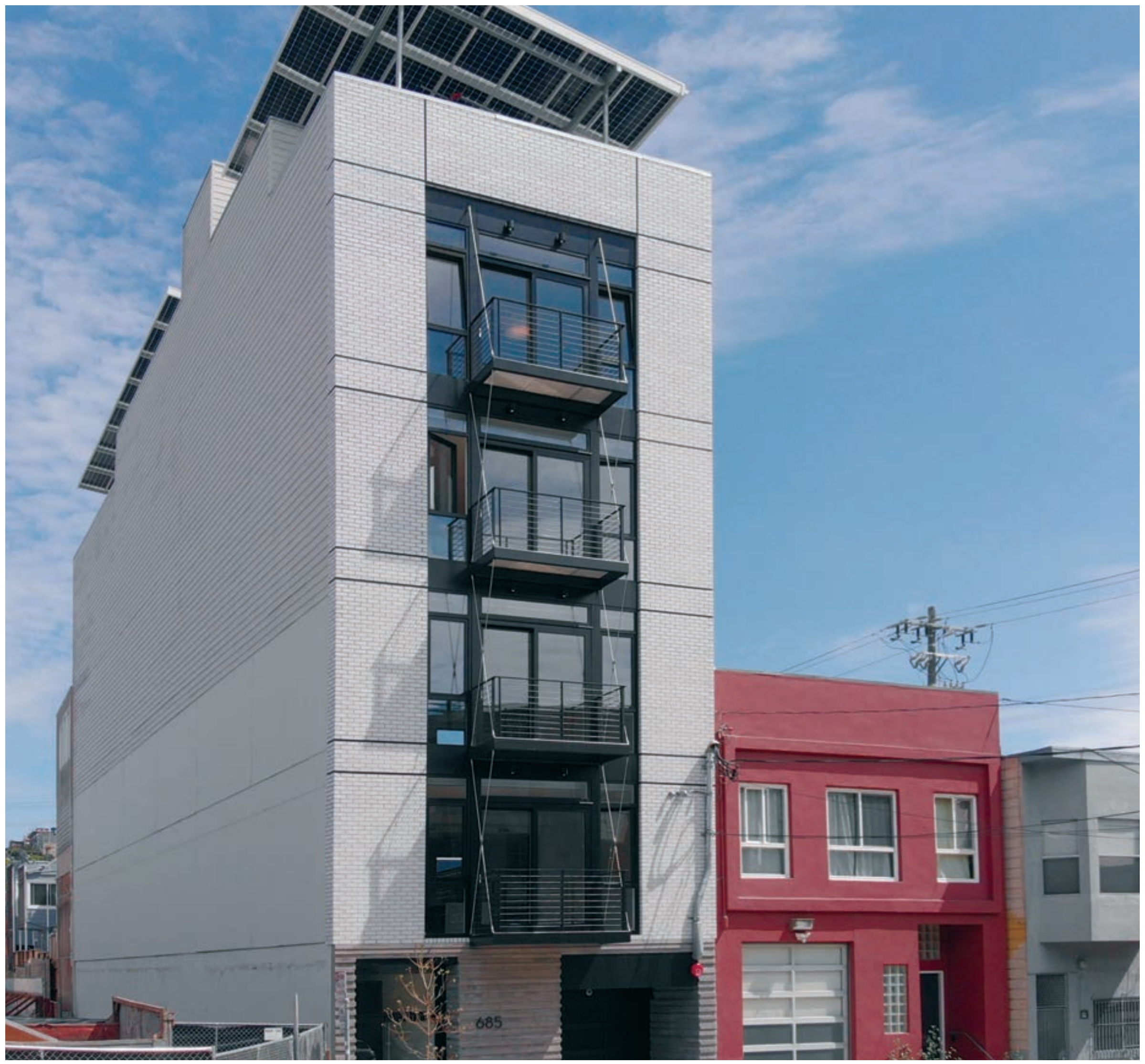
Heating & Cooling
Mitsubishi Electric

Skylights
Lamilux by 475

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Peak heating load	Peak cooling load	Air leakage
7.9 kBtu/ft²/yr	4.4	33.6	6.7 Btu/hr/ft²	4.8	0.6 ACH_{50}
2.3 kWh/ft²/yr	1.3	9.9	1.9 Watts/ft²	1.4	
25.0 kWh/m²a	14.0	106.0	21.0 Watts/m²	15.0	

Sol Lux Alpha— CARBON-NEUTRAL Nanogrid Living



Photos courtesy of Compass, Joseph Schell Photography

Sol Lux Alpha is the first Passive House certified multiunit nanogrid development in the United States. A nanogrid is a self-contained energy system that is islandable from the grid. Each of Sol Lux Alpha's four condominiums is 100% powered by renewable energy solely from the PV system over the building's roof deck. As such, the six-story building pushes the vertical limit for fully site-powered PV building design. The units are actually projected to generate excess power that can be used for electric vehicle (EV) charging, or can be paid back from San Francisco's Clean Power excess generation tariff of $.089/kWh. Each unit, plus the common area, has three Tesla Powerwall energy storage systems. These systems allow the unit to remain fully functional if the grid goes down, or if the owners simply choose to disconnect. Energy and building science experts and industry professionals have travelled from as far away as Switzerland and Australia to learn more about Sol Lux Alpha.

The initial inspiration for the Sol Lux Alpha nanogrid system came to designer-builder John Sarter in late 2009. Motivated by the Yokohama Smart City project, a citywide consortium dedicated to optimizing energy supply and demand, Sarter looked for such projects in the United States and found nothing comparable. He decided to see what could be accomplished with a single building, while also introducing the idea of distributed solar PV coupled with energy storage systems in policy, energy, and the built-environment sectors. An interconnected group of nanogrid living units, combined with community-distributed energy resources, is the essence of a microgrid community.

The first nanogrid design by Sarter and his firm, Off The Grid Design, was a passive-solar home in Marin County, California. The home was designed to provide two EV charging stations in a semidetached garage. The work he saw in Japan inspired him to reach higher than EV charging. While designing this initial project, Sarter also attended a presentation on Passive House methodology. It seemed logical to him that a larger structure with a lower ratio of internal volume to surface area would be a more economical model for a Passive House certified nanogrid building.

The partnership for Sol Lux Alpha solidified when Sarter convinced first-time developer Lloyd Klein, owner of the project's 25-foot by 100-foot lot, of the value of carbon-neutral living. Sarter said he believed he could get a 25% rear yard setback requirement waived if they brought to the San Francisco Planning Department a project with a high level of sustainability. Klein said, "If you can do that, I'll build it with you!" When Sol Lux had its community meeting prior to approval, there was initially some pushback by the local community about the project's height, the massing, and the full lot coverage. When the team told the neighbors that building would be net zero and carbon neutral, the negativity dissolved. The city was also receptive, granting the setback exception and entitlements in a record six months. By comparison, it took a developer with an adjacent property three and one-half years to receive his entitlements.

The Sol Lux Alpha team decided on Passive House certification through PHIUS, drawn by its partnership with the U.S. Department of Energy's Zero Energy Ready Home certification. The four condominiums are certified by both organizations, and the building is the first PHIUS+ Source Zero multiunit development in California. This combination of certifications enabled Sol Lux Alpha to achieve an Alternate Path of Compliance to San Francisco's rigorous Green Building Code, the only one granted to date.

Having decided on Passive House certification, the project team had to select a construction method. It ended up choosing prefabricated panels, because of the anticipated precision, schedule, and cost reductions, and because it would be difficult to build with stick framing on the relatively narrow zero lot line site. As it turned out, finding a reliable prefabrication supplier was a challenge. After two false starts, the team settled on an Oregon supplier that partially stick framed the panels on a warehouse floor, which didn't initially provide the precision the team was expecting.

The panels had to have a two-hour fire rating inside and out. From the outside in, they consist of cementitious siding, a liquid air barrier, two layers of ⅝-inch fire-rated board, ½-inch plywood, and 2 x 6 studs. They were finished on-site with dense-packed cellulose and two layers of ⅝-inch drywall. The rim joists also had to be included in the prefabricated walls. All exterior wall lumber had to be treated with liquid borate and then air dried for fire prevention. With a maximum length of 16 feet, a panel could weigh as much as 1½ tons, creating challenges when stacking panels on the floors prior to lifting and placing them with a crane.

During assembly, silicone gaskets were placed under the bottom plates and vertically between panels. A continuous bead of subfloor glue sealed the perimeter plywood edges to the envelope boundaries. Because the concrete podium was not precisely leveled and the panels were not fully constructed with precision milling equipment, some of the first panels didn't fit as precisely together as planned, creating some interesting air-sealing challenges. Sarter spent time at the facility in Oregon training the crews, which improved the precision and air sealing on the upper floors.

Because of the weight and the building height, the panels had to be placed by crane. Since the building essentially covered the site and had no side or rear access, a very large mobile crane had to be placed in the street, requiring a special permit and shutting down the street for each floor lift. In retrospect, according to Sarter, the team probably did save some time and money as intended by using prefabricated panels, but it lost those savings in the complexities of having to assemble them by crane in a dense urban environment.

The remainder of the project is a fairly typical Passive House building, configured as four stacked condominiums over a garage. The efficiency created by a lower interior volume- surface area ratio, plus the mild California climate, helped the project reach Passive House certification using standard platform framing. Additional benefits included double-pane Passive House certified European windows and an absence of exterior insulation. The kitchens are all-electric, including an induction cooktop. Each unit has two ducted mini-split coils for heating and cooling and a heat pump water heater. The building and power systems are simple and reliable. You can set it and forget it, or customize the way the energy storage system interacts with the grid. Owners can take advantage of time-of-use rates and EV tariffs to generate income from the excess generation or use it for nighttime EV charging. The elevator and stairs are outside the conditioned space. This presented some challenges locating airtight ADA- and fire-rated doors that didn't complicate the blower door testing.

A major goal of the project is to show off the multiple advantages of a carbon-neutral lifestyle. The units are very quiet and have excellent indoor air quality, due to Passive House-level air sealing and energy recovery ventilation. All have the accouterments of a luxury San Francisco condominium, in an 1,800-ft², three bedroom, three-bath unit. The elevators open directly into each unit with an electronic fob, creating a very private feeling.

The roof deck, which includes kitchen, dining, and lounge areas, is bathed in filtered sunlight from a bifacial solar array. Bifacial technology boosts the 380W nominal output by up to 30%, to almost 500 watts per panel. Each unit's batteries store up to 41.5 kWh, which can power a condominium for two to three days without recharging, due to the efficiency of the building's systems. Since the PV is recharging the batteries daily, the units can potentially run off-grid indefinitely. As a test, the entire unoccupied building ran off-grid for over three weeks, generating a substantial excess of energy every day. It will be interesting to see the yearly results of a fully occupied structure. The common areas and elevator are powered by a separate set of batteries capable of storing 24 kWh. They provide commercial-grade three-phase power for the elevator through a triple-inverter configuration.

This ambitious project realized a series of firsts: the first multifamily building and Certified Passive House for Sarter, who had been designing and building single-family homes for years; the first ground-up construction project for codeveloper Klein; the first Passive House project for the architect; the first Passive House certified multifamily nanogrid project in the United States; the first San Francisco project allowed to use an Alternate Path of Compliance Passive House certification; and the first PHIUS+ Source Zero multiunit development in California. Having faced and solved significant design and construction challenges, all the team members are gearing up to work on new Passive House and nanogrid projects in the Bay Area and beyond.

Now that the world is witnessing devastation due to global climate-related events, the value of combining

renewable energy and storage is becoming more evident. The vision of the Sol Lux Alpha team and others is slowly becoming a global reality. Adoption in the United States is lagging behind many other parts of the world, but there are now many projects in development across the country. Sarter's goal is to help the United States become more of an innovative and technological leader, moving the ball forward in the areas of building efficiency and microgrid development.

—Steve Mann

STEVE MANN *worked with John Sarter on the preparation of this article.*

Products

Windows & Doors
Klearwall

Air/Moisture Control
Siga

Sto

Insulation
Rockwool

Water Heating
Sanden

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Peak heating load	Peak cooling load	Air leakage
4.1 kBtu/ft²/yr	0.6	31.4	2.5 Btu/hr/ft²	0.3	
1.2 kWh/ft²/yr	0.2	9.2	0.7 Watts/ft²	0.1	$0.5\ ACH_{50}$
13.0 kWh/m²a	2.0	99.0	8.0 Watts/m²	1.0	

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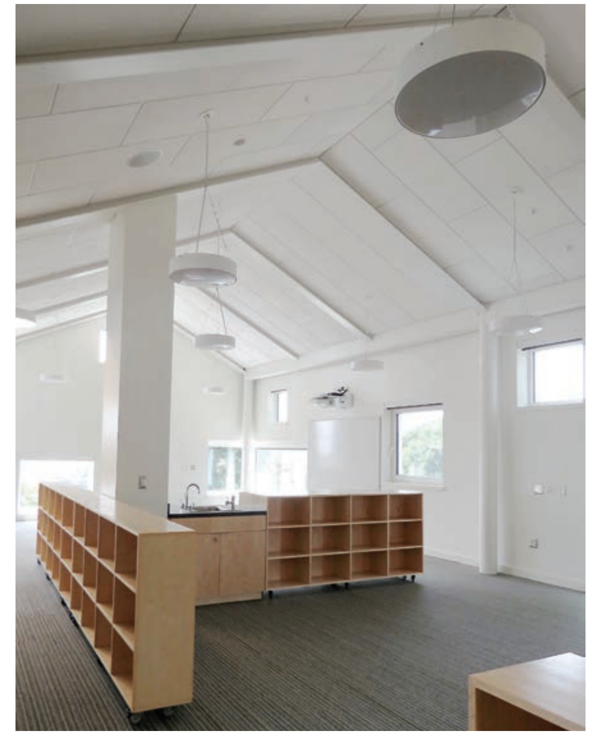


WAYNFLETE Lower School

Photos and rendering courtesy of Scott Simons Architects

The Waynflete School, in existence since 1897, now inhabits a 3-acre campus in a historic district in Portland, Maine. The independent school's students range from early childhood to 12th grade. Over the past couple of decades, Waynflete's Middle and Upper Schools have undergone renovations and additions, but the Lower School spaces had yet to be similarly transformed—until this fall. The new 23,000-ft² Lower School facility, designed and built to meet the Passive House standard, opened its doors this past August.

Architects Austin Smith and Julia Tate of Scott Simons Architects worked with the school's building committee to help them define the overall project goals and their sustainability goals in particular. Early on in the process, the architects brought in sustainability specialists from the engineering firm Thornton Tomasetti. These specialists were instrumental in developing a sustainability grid to compare and contrast different certification programs and standards, as well as a cost analysis of the premium for Passive House over a conventionally built facility. "Passive House was appealing, because it is targeted, tangible, comfortable, and you can't game the system," says Smith. Further analysis revealed that the cost premium for Passive House would pay back through energy cost savings in just six years and three months. "That was a no brainer," he adds.

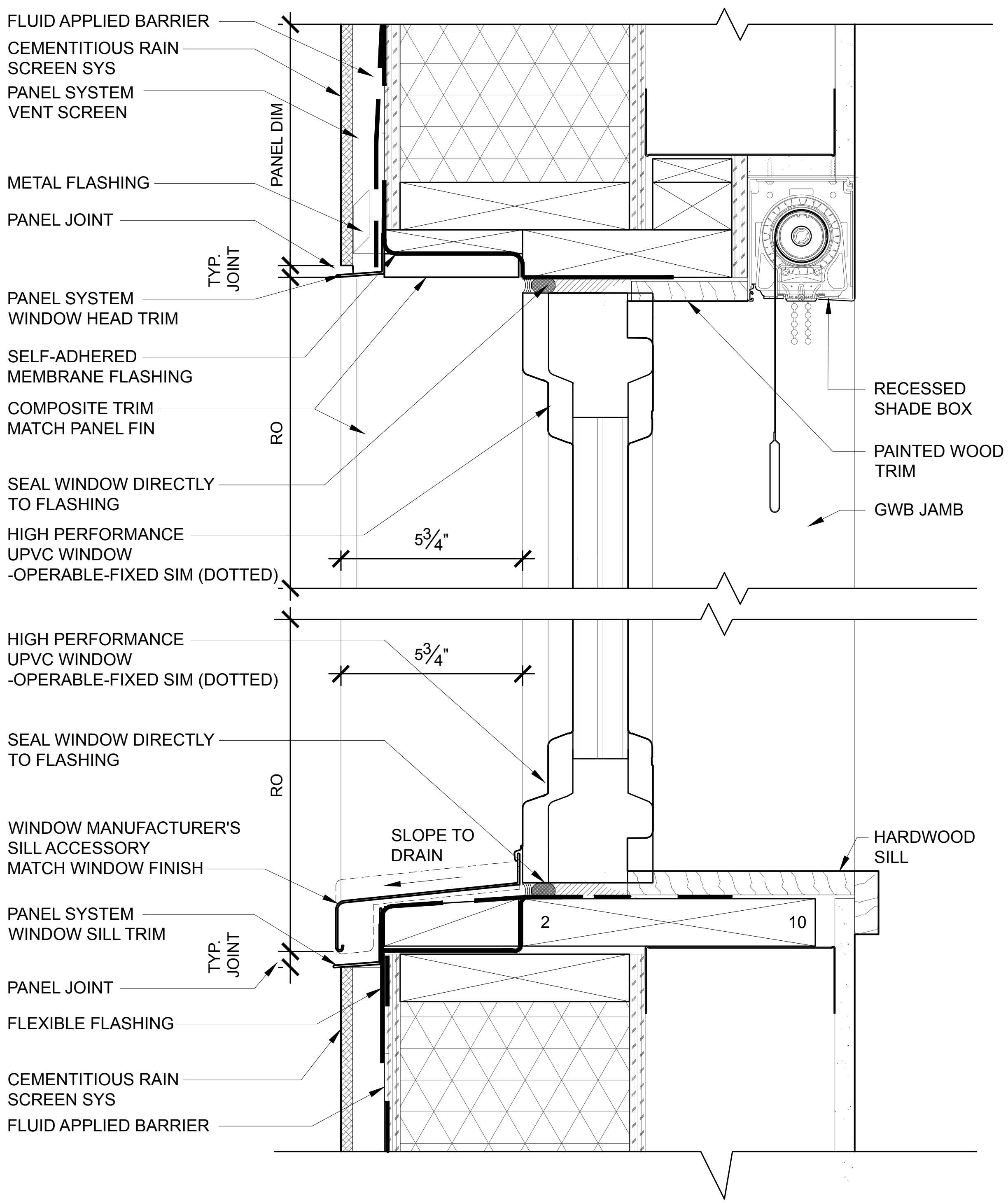
The building's design took shape based on Waynflete's teaching philosophy, which emphasizes a small teacher-student ratio, and the neighborhood's mostly residential, historic aesthetic. Its white coursed exterior and gabled elevations echo nearby forms.

The shapes of the four classrooms, which house an average of 50 students in each combined-age class, accommodate smaller groupings of 8 to 16 active learners. Each classroom area has its own form tailored to the students' ages and abilities; the kindergarten through first-grade classroom, for example, features small lofts for playing, reading, and resting. Window patterns and placement were structured so as to optimize daylighting, specifically the morning sun, while preserving eye-level views for the young occupants. The facility also includes a library, an innovation space for both class use and after-school programs, an art studio, and an amphitheater for all-school Pachangas or sing-alongs.

The new building adjoins two existing structures, augmenting the typical Passive House detailing challenges, as did the three different geometries required to create the breakout spaces. The entire design team held many meetings, especially during the construction doc phase, to work out constructible details. The design team credits much of the project's success to the input received from Wright Ryan Construction, Becker Structural Engineers, Woodard and Curran, and Allied Engineers.

The basic structure consists of an insulated steel moment frame. The largely exposed structure is enclosed with a wall assembly utilizing 8-¼-inch structural insulated panels (SIPs) of graphite-enhanced polystyrene to maximize thermal performance. These panels, along with a vapor-permeable air barrier membrane adhered to the exterior of the SIP, secure the building's desired airtightness. The foundation slab is insulated with 4 inches of rigid XPS foam to attain an R-value of 20. The R-60 roof assembly also includes SIPs topped by an insulated, vented nailbase panel and standing-seam metal roofing, chosen for its durability.

The exterior siding is masonry veneer at grade level, with the upper floors clad in a rain screen system covered with fiber cement panels. The R-values of these walls range from R-45 to R-56, depending on whether they are masonry or fiber cement clad. All of the exterior materials were selected for their longevity with an eye to reducing



WINDOW SILL AND HEADER DETAIL

or eliminating maintenance. Visual compatibility with the surrounding context of the existing campus and neighborhood was also important.

The exterior doors proved to be unusually challenging, as they had to meet Passive House requirements and Americans with Disabilities Act specifications, and accommodate the needed hardware for key card access. After much analysis, an aluminum storefront-type door was found that met all these criteria.

The all-electric building is being ventilated primarily with a centralized ERV—an approach that sounds simple but required solving various special ventilation needs. The art room includes an electric kiln, for which the direct venting had to be carefully sealed. The school's laundry facilities provoked some deliberations; it was eventually decided to use ventless condensing dryers. Venting solutions for the building's series of kitchens also took research, and the self-contained recirculation hoods that were chosen had to be preapproved by the fire department.

Supplemental heating and cooling is being provided by air source heat pumps. Heat pump water heaters supply the domestic hot water.

This facility that has been years in the planning is finally opening its doors. This state-of-the-art building is providing the structure within which Waynflete can deliver on its promised balance between communal and individual learning experiences.

—**Mary James**

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Air leakage
5.1 kBtu/ft²/yr	1.4	35.8	$0.5\ CFM_{50}/ft^2$ (design)
1.5 kWh/ft²/yr	0.4	10.5	
16.2 kWh/m²a	4.5	113.1	

Products

Air/Moisture Control
ProClima by 475
475 HIGH PERFORMANCE BUILDING SUPPLY

Ventilation
Tempeff North America
TEMPEFF NORTH AMERICA

Structural Thermal Breaks
Schöck
Schöck Innovative Building Solutions

Water Heating
Stiebel Eltron
STIEBEL ELTRON Simply the Best

Cold Climate Passive AUTO DEALERSHIP

Rendering by Cover Architecture
Photos by Lukas Armstrong and Elaine Cripps

In chilly Red Deer, Alberta, Canada, where the winter design temperature is –29°C (–20°F), constructing any type of Passive House building is a challenge. But a car dealership? With all that glass and the service bays? Fortunately Certified Passive House Designer Lukas Armstrong of Cover Architectural Collaborative and Certified Passive House Consultant Andrew Peel of Peel Passive House Consulting brought years of experience to this complex task. Key team members included architectural support from Elaine Cripps of Sublime Design Studio Inc., wood structural design by Lex3 Engineering, M&E design by 908 Engineering, and contractor Black Creek Developments.

The 1,500-m^3 (16,000-ft^2) two-story, mixed-use building was the inspiration of dealership owner Garret Scott. As Alberta is also home to the tar sands crude oil industry, Scott says that he saw the project as an "important statement to the industry and the country." More pragmatically, he understood that it would cost virtually nothing to heat and cool the building. In addition, a Passive House building fully aligns itself with Subaru's environmental strategy, which includes producing Partial Zero Emission Vehicles. The Subaru of Indiana Automotive assembly plant, the first zero-landfill factory in the United States, originally inspired Scott.

A full-service car dealership requires several distinct types of space—a showroom with adjacent sales offices, circulation, and reception areas; a service area; and a conditioned area where customers can drop off their vehicles for servicing. The sales and showroom spaces need to maintain an internal temperature of 20°C (68°F), while the service and drop-off areas need to be kept at 18°C (64°F). In order to accurately model the building, Peel Passive House Consulting had to create three separate PHPP models.

In addition to the challenging climate, architect Armstrong had to work within Subaru's corporate design guidelines, which mandated 55% glazing on the west façade with no external shading to mitigate solar heat gains. "Architecturally, probably the requirement to meet the design and branding expectations of Subaru Canada, while achieving certifiability, was the biggest challenge," Armstrong says. "The building does not look significantly different from other Subaru dealerships, but performs very differently."

Cold climates present design challenges that are magnified when designing a building that meets Passive House standards. Every decision, especially when it involves airtightness, has a significant impact. Frost protection and low humidity can be problematic. Mechanical equipment and products such as doors need to be suitable for a cold climate. These challenges can be amplified even further when deployed in an unusual space like an automobile service area.

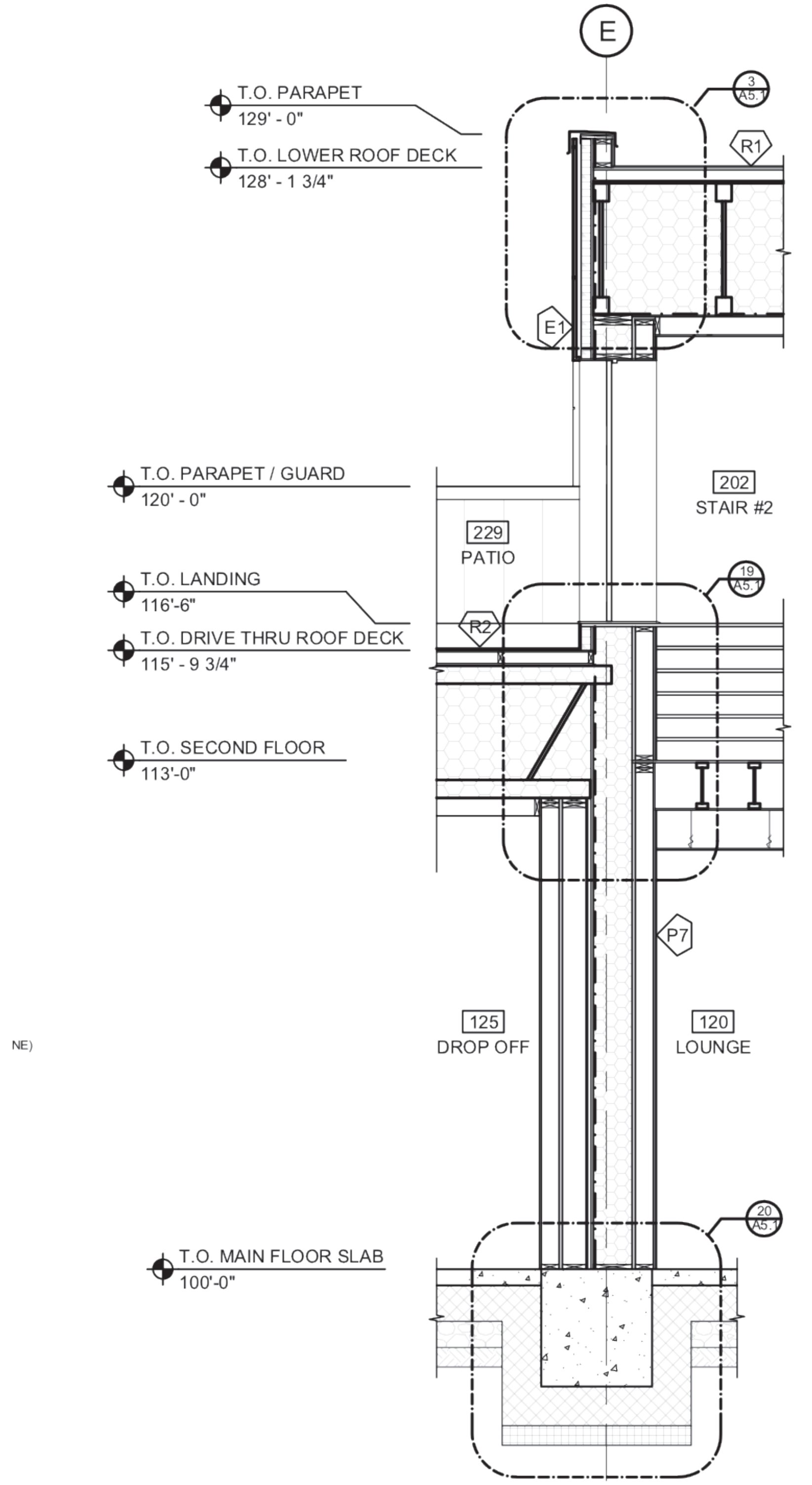
One of the biggest challenges was glazing, particularly on the west façade. Meeting Passive House space heating demand without overheating required paying special attention to irradiance on the west-facing curtain wall. The site has very little natural shading, and tree planting was ruled out because it would block too much sun, jeopardizing the heating demand target. Operable external blinds were not feasible because the site experiences wind gusts of up to 103 kph (64 mph). Electrochromatic glazing was too expensive, and the specifications were not quite suitable. After much research, the team chose to use automated, operable internal blinds coupled with insulated spandrel panels in the top row of the curtain wall. Since there are no cold

climate-certified curtain wall windows, the Passive House comfort requirement was met by placing heating supply ducts close to the windows.

Automobile service areas require doors large enough to accommodate vehicles. This presents several challenges—heat loss from lower levels of insulation, operating heat loss, and air leakage. The original design called for seven overhead doors. The team proposed an alternative design that reduced the number of doors to two, which the client did not support. Through negotiation, the team settled on four. Investigation revealed that heat loss from a single door event was a modest 15 m3h (9 CFM). To solve the airtightness issue, the team investigated European Union (EU)-rated doors. With an airtightness target of 0.4 ACH necessary to satisfy the certification criteria, a Class 2 EU door would use up 20% of that target. The team was able to locate a Class 3 door that would contribute only 10% of the air leakage.

Automobile repair presents some interesting internal heat gain issues. The project team had to calculate gains for air compressors, hoists, and other repair equipment. In addition, car engines entering the building give off heat. All cars are washed with 60°C (140°F) water after servicing. Cars also have to be run during repairs, generating exhaust temperatures of up to 343°C (650°F). Overall, the repair shop generated 55% of the internal heat gains, 14% of that from running engines.

Mechanical system choices were driven by climate and servicing requirements. For instance, Subaru services diesel vehicles, which requires attaching a 680 m3h (400 CFM) exhaust tube to each car's tailpipe during testing. Most dealerships manage this exhaust by running a large fan that evacuates all service bays even if only one requires exhausting. For the six service bays in this project, that would amount to 4,078 m^{3}h (2,400 CFM), potentially generating large heat losses. The project team was able to convince the mechanical engineer to use a



8
A4.1
WALL SECTION
Scale: 1/4" = 1'-0"

separate fan for each service bay. Various options were investigated for heat recovery from the exhaust airstream, but none was feasible.

According to Armstrong, "the largest challenge was designing an HVAC system that met the safety requirements of a repair shop as well as the Passive House thresholds." Heating and cooling are provided by a variable refrigerant flow system with heads in corridors ducted into each room. The system does not operate at the coldest winter temperatures, requiring the use of electric backup heat. There were extensive discussions with the engineer about loads. For instance, PHPP estimated the heating load at 13 kW (44.4 kBtu/hr), and at 21 kW (71.7 kBtu/hr) with no internal heat gains. The engineer's initial design called for a 64 kW (218.4 kBtu/hr) heating load, or 3 to 5 times larger.

Because of the west-facing glazing, the cooling load in the showroom and office space dominated the HVAC equipment sizing. The team evaluated the cooling load under multiple scenarios, starting with PHPP's peak cooling day assuming 40% irradiance blockage from internal shades. The team then looked at higher levels of internal heat gains from people, equipment, and lighting during the worst three hours of the day with internal blinds fully open. The normal case required a cooling load of 10 kW (34 kBtu/hr); the worst case was 52.9 kW (180.5 kBtu/hr). The engineer has calculated 57 kW (194.5 kBtu/hr).

The team also analyzed heat loss from car washing, which consumes approximately 2,020 liters (530 gallons) per day. The only viable equipment option was an on-demand gas heater. Because of the equipment choice, coupled with the high volume, high temperature, and frequent use, this function was a good candidate for heat recovery. A horizontal shower-type unit was considered, but ultimately proved unavailable. Instead, the team acquired a vertical unit and installed it horizontally.

If you really want a challenge, Peel says, design a cold-climate car dealership. You need to think through all the details early, especially equipment and all energy flows. Because project parameters may change, you should build some buffer space into your calculations—a wise suggestion for any Passive House project. Use the simplest approaches possible for all aspects of the project, and find engineers who are willing to explore options.

— Steve Mann

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Peak Heating load	Peak Cooling load	Air leakage
4.8 kBtu/ft²/yr	0.6	41.8	7.0 Btu/hr/ft²	2.2	
1.4 kWh/ft²/yr	0.2	12.3	2.0 Watts/ft²	0.7	0.6 ACH_{50} (design)
15.0 kWh/m²a	2.0	132.0	22.0 Watts/m²	7.0	

Products

Curtain Wall, Windows & Doors
Wicona by Fenster Tek

Air/Moisture Control
ProClima by 475

Ventilation
Swegon

Insulation
Rockwool

Structural Thermal Breaks
Armatherm

Heating & Cooling
Mitsubishi Electric

Water Heating
Sanden

The CARRICK Library

Renderings courtesy of Thoughtful Balance and NK Architects

The Carrick neighborhood in south Pittsburgh had been making the most of its branch library for decades. Granted, the small one-story building carved into a slope was cramped and cavelike, with the only natural light filtered through the glass block of the library's front façade. But that didn't stop library staff from developing innovative programming for local youth and adults and establishing the library as a hub of the community.

When it came time for the Carnegie Library of Pittsburgh to invest in a new Carrick branch, the Carrick staff and community knew exactly what they needed from the new building: light, space, and views to the outside. The tight site made this tricky, though.

"We found a way to create a two-story scheme on the existing site," says Laura Nettleton, owner of Thoughtful Balance and the design partner on the project with NK Architects. "But the community felt they were being shortchanged. It still felt too small, and it didn't really flow. They weren't happy."

In response, the library purchased the adjacent corner lot and tore down the building on it. That allowed for more space for the new library, although the site's slope still put the ground floor several feet underground at the building's back edge.

"We saw this rebirth of the Carrick branch as a chance to offer library users and staff a transformation in indoor air quality, comfort, and energy use," Nettleton says. The concept of Passive House was not new to the Carnegie Library of Pittsburgh. Nettleton had worked with its Director of Facilities Development Ron Graziano, to apply Passive House design principles to the recent renovation of the nearby Hazelwood branch. Though Hazelwood did not quite make certification, Graziano liked the outcome: 16% less energy use despite a doubling of space, lots more light, and peace and quiet. Despite a tight budget for the Carrick project, Passive House design got baked in early.

Value engineering discussions later in the process did reexamine this commitment to Passive House, but it was discovered that it would be more expensive to excise Passive House from the project than to keep it, because all systems would need to be reengineered. That was a useful lesson learned: There is a point of no return once you have committed to high performance for your project.

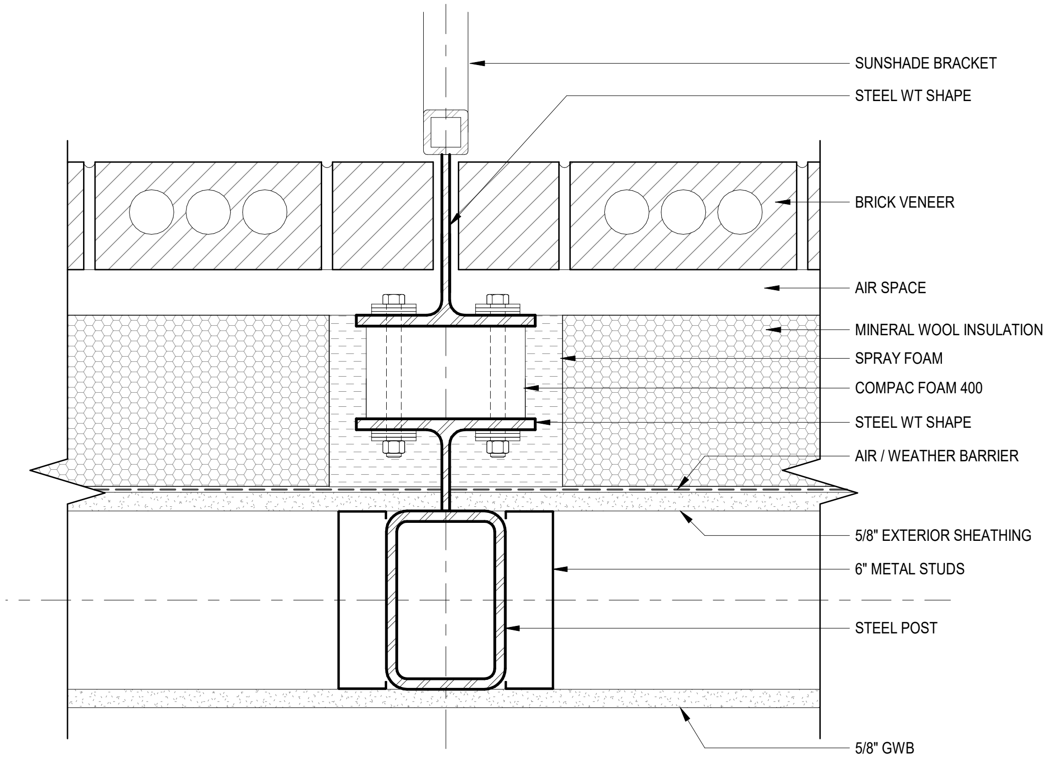
"So we knew we had a bigger site to work with. We knew the building would be Passive House. We knew the library wanted lots of light, space, and views to the outside. But we also knew that budget constraints meant an elevator was off the table. Given the slope of the site, a single-story building would have been like a pancake dug into a hillside," according to Nettleton.

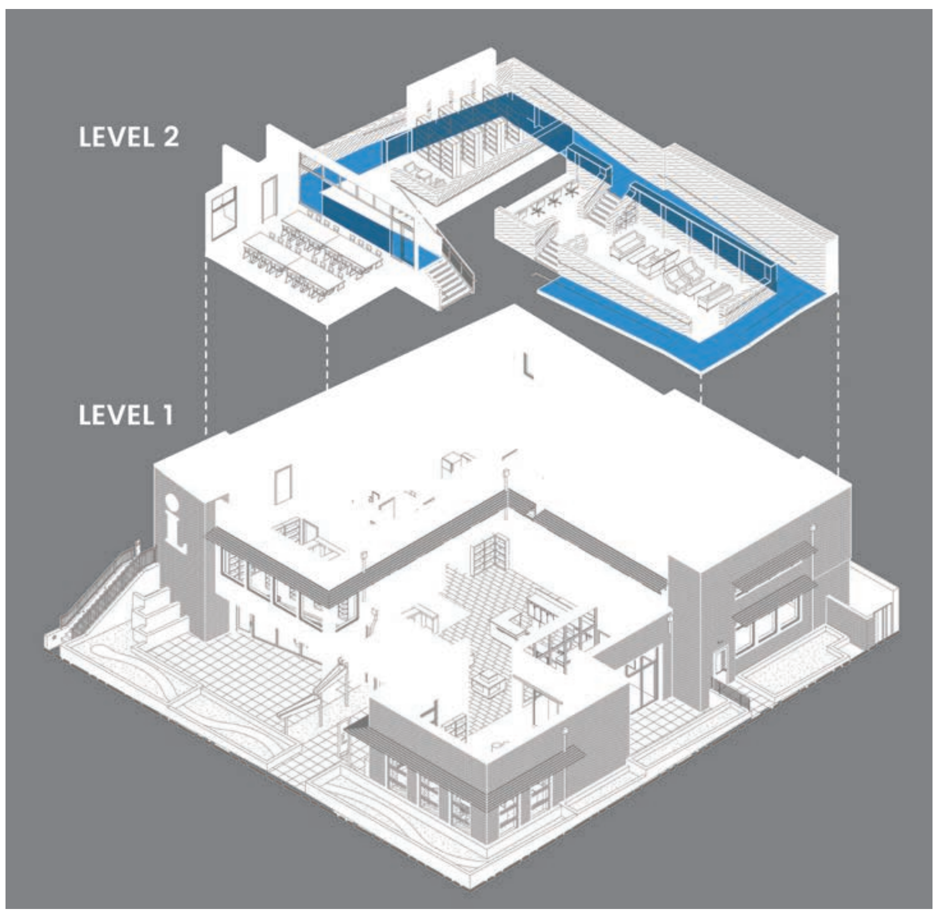
A second story was needed, and so was accessibility. Enter NK Architects principal Steve Fischer.

"Steve came up with the brilliant idea of tying it all together with an interior ramp," says Nettleton. "We had enough space inside to wrap a ramp with sufficient length to negotiate two stories. It meant we could build the library on different levels."

The bookshelf-lined ramp starts at grade just behind the circulation desk. It then takes patrons up to the periodicals room, perched several feet above the circulation desk. Winding further up the ramp, you arrive at the adult stacks, which overlook the main reading room and are naturally lit by a clerestory overhead, fitted with sunshades to protect from western and southern light. As you take the ramp further, you arrive at the main meeting room, which overlooks the street.

Thanks to the staggered heights of these rooms, each has its own direct access to natural light and views outside. This design also allowed the team to really set the youth gathering space apart, sited in the southern corner of the first floor. The library's teen programs have become a treasured community resource, with a popular videography program and creative community-building activities, and the library wanted to give them their own dedicated space. Nettleton's interior design helps make the space work for both teens and younger kids. The Sett In Stone carpet introduces a biophilic theme to the space. Larger, adult furniture occupies the teen section of the youth area, while smaller, kids' furniture inhabits the younger area. A story corner will feature a graphic describing the water cycle and the process of photosynthesis. Larger windows look out onto the entry plaza, with its rain sculpture cascading off the front of the





building. Swales capture storm water on-site, a critical feature of the site design, given that the closest storm water outlet is 250 feet down the street.

Despite the design breakthrough of the interior ramp and its success at solving the aesthetic and daylighting challenges posed by the site's slope, the design team still had to address the thermal and structural challenges of retaining all the dirt against the building. The team was not confident that the existing retaining walls were up to the task, so before the old library was demolished, new retaining walls had to be built inside the old building. NK's Todd Demangone worked with Skylar Swinford of ESCO to build the PHPP model for the project, assessing the thermal implications of the retaining walls and determining the best way to offset them. The building's windows turned out to be the most powerful lever for the Passive House design team, which selected a package that met the library's desire to use U.S.-made components for the building.

During Carrick's design, the team discovered a thermal isolation pad that worked very well for its needs: a compressed foam sheet that thermally isolates structural elements cost-effectively. The sunshades for the clerestory are being hung using this product to avoid thermal bridging there.

If all goes as planned, Carrick will be North America's first Passive House-certified library. But more importantly, this centerpiece of Carrick community life will be a light-filled, healthy, and cozy space to read, learn
, and connect.

—**Zack Semke**

Zack Semke is chief marketing officer at NK Architects.

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Air leakage
4.2 kBtu/ft²/yr	4.9	36.3	
1.2 kWh/ft²/yr	1.4	10.6	0.6 ACH_{50}
13.2 kWh/m²a	15.4	114.4	

Products

Windows
Alpen

Ventilation
Renewaire

Insulation
Rockwool

Structural Thermal Breaks
CompaCFoam by 475

Schöck

Heating & Cooling
Mitsubishi Electric

WOOD INNOVATION Research Lab

Photos by Bree-Ann Orser

The Masters of Engineering in Integrated Wood Design program at the University of Northern British Columbia (UNBC) equips design and construction professionals with the knowledge needed to apply wood use, building science, and sustainable- design principles to future projects. The program is hosted in Prince George, British Columbia, at the Wood Innovation Design Center (WIDC), an eight-story glulam post-and-beam mixed-use building with a cross-laminated timber core that was at the cutting edge of industry when it was first constructed.

As the program grew, so did the need for increased capabilities within the laboratory. First conceived of in spring 2016, UNBC's new Wood Innovation Research Lab (WIRL) opened its doors in April 2018. The lab building is constructed with engineered-wood products and received Passive House certification in July 2018.

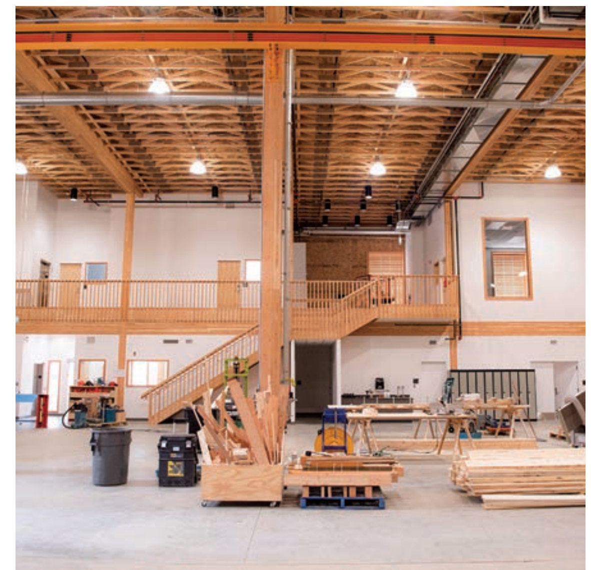
The WIRL is a 10-meter (33-foot) -tall single-story mixed-use building with a large two-bay lab space as well as a separate classroom and office spaces. The superstructure is composed of mass timber glulam columns and beams on a 6-m (20-foot) grid, and the walls are framed with wood trusses in order to achieve a high thermal performance.

The lab and classroom space is being used by UNBC faculty and students for research and testing related to wood construction and Passive House. The lab is equipped with a concrete strong wall and floor complete with anchors and hold- downs for three-dimensional testing of wooden structures. An overhead crane runs the length of one of the two bays, which allows for the safe maneuvering of large test structures or wood specimens. The shop also includes three universal testing machines, a computer numerical controlled (CNC) cutting machine, and a 34-m^2 (366-ft^2) wood-conditioning room that is equipped with ventilation and humidification in order to create an ideal environment for normalizing wood specimens to a consistent moisture content.

Meeting the Passive House standard was particularly challenging for this project for three reasons. First, Prince George has a harsh climate that swings from 30°C to –30°C during the year and has 234 heating or cooling days per year. Second, because of the need for a very tall lab space, the building envelope area is rather large compared to the small thermally treated floor area—the denominator in all Passive House energy consumption calculations. Third, the building's program requirements created some very complex challenges. A large bay door was needed to afford access for semitrucks. The cutting machinery throws off significant dust volumes, which in turn require a large dust extraction system, posing significant airtightness challenges. And the hydraulic pumps for the structural testing equipment generate massive interior heat gains when operating.

The building envelope was framed using dimensional-lumber trusses that were prefabricated into one-side-open wall panels. Due to the thermal performance requirements, the 10-m (33-foot) -tall wall panels were required to be over 500 millimeters (19.7 inches) thick. Framing the panels with upright trusses rather than studs accommodated this thickness in a cost-efficient way and reduced the resulting thermal bridges.

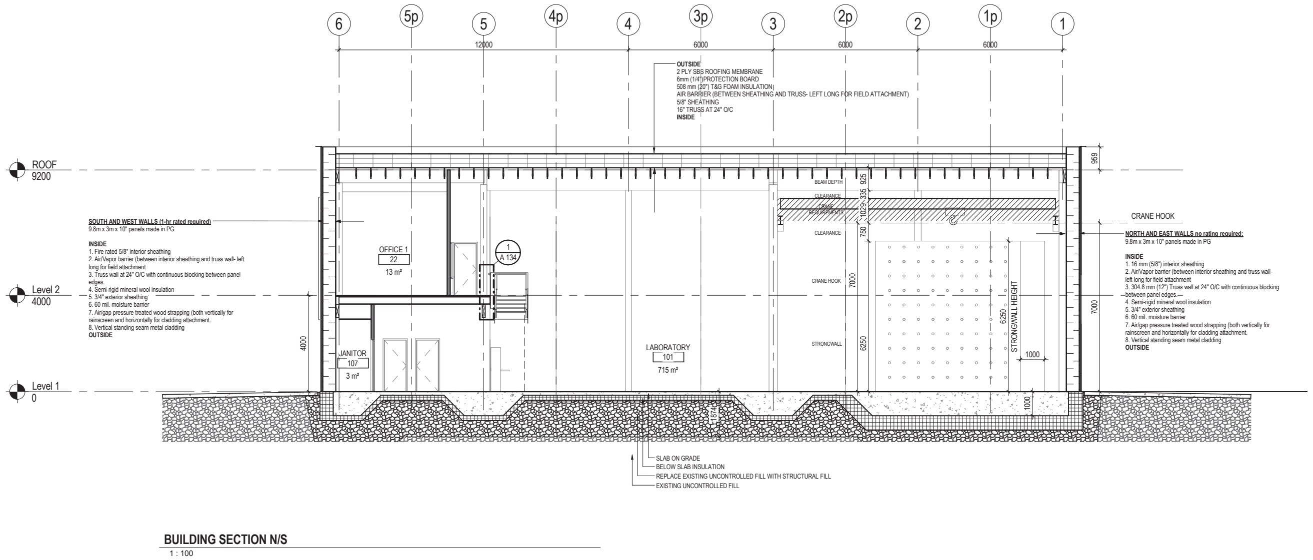
The wall panels were designed with prefabrication in mind, but the local industry—in this case, Winton Homes Ltd., a Prince George-based company that procures the raw materials from a local sawmill—was not yet capable of producing complete panels. Instead, the shipped panels consisted of OSB on the inside, followed by a smart air and vapor barrier membrane for airtightness and vapor diffusion control, and then the 500-mm-thick truss structure. The outside of the panels remained completely



open when lifted by crane into place. The builder was able to then seal the seams of the airtight layer by reaching through the wall to the membrane. Once sealed, the panels were closed from the bottom up with another layer of OSB on the outside and simultaneously filled with blown-in mineral fiber.

Exterior to this OSB was a layer of building wrap, then strapping to form a rain screen gap, and the siding. The siding is mostly painted metal with cedar accents. The interior layer of OSB was left exposed as the finishing for the lab portion of the building.

The majority of the windows are located on the south-facing wall, and the window area was optimized to allow for sufficient daylight and views while limiting the overall frame length, as the frames represent the biggest thermal weakness. The aluminum-clad wood-framed,



triple-pane windows were placed strategically—about midway through the panels—to minimize thermal losses. Because of the cold climate, the windows selected had a U-value for the installed window of between 0.70 and 0.87 W/(m²K), depending on the size.

Heat losses through the roof were managed by applying an average thickness of approximately 610 mm (2 feet) of sloping EPS insulation. EPS was chosen over the initially designed polyurethane because it has a significantly lower embodied carbon impact.

Reducing thermal losses through the 30-m by 30-m (98-foot by 98-foot) concrete raft slab foundation was quite challenging , because a portion of the foundation is a strong floor: a high-capacity 1-m (3.3-foot) -thick section of reinforced concrete that will be used for structural testing. A high-strength and -density EPS insulation had to be special ordered for installation below this portion of the building, which would be experiencing higher than normal forces. Underneath the foundation 215 mm (8.5 inches) of EPS was applied continuously.

As for airtightness, careful design and planning and meticulous implementation during construction resulted in an impressive achievement that was well above expectations: 0.07 ACH_{50}. The compactness of the building and the simplicity of the envelope worked in our favor, but there were also significant pitfalls.

An overhead shop door was a lab requirement in order to receive materials via a flatbed truck, but it presented a logistical challenge, as these doors aren't typically airtight or well insulated. The solution was a German-manufactured door that fully seals, thanks to rubber gaskets pressed airtight between each panel and the surface where the door meets the floor, and to an ultra-high-molecular-weight polyethylene profile and track that reduces friction when the door is being opened or closed. The door was tightened against the track after installation to ensure a tight seal while maintaining minimal resistance for raising the door.

Wood dust is an unavoidable by-product of working with wood and can represent a significant health and safety risk if not properly cleaned up, as the dust can be small enough to irritate the respiratory system. Removing it involves moving large volumes of air, leading to unavoidable heat losses. To reduce those heat losses as much as possible, a dust extraction system with a recirculating function was installed. The air is transported out of the building and the dust is removed through a large cyclone filter. Then the air comes back into the building, passes through very large 1-micron pocket filters, and is eventually distributed back into the laboratory. The system can be operated in bypass mode, in which case the exhaust air is not recirculated. This mode is only used when cedar or hardwoods are processed. As the extracted air volume is very large, a door has to be opened to allow for enough airflow. These wood species are rarely used in the laboratory, and a limitation to process them only during the summer months was acceptable to the user and the certification team.

For continuous ventilation the WIRL relies on an HRV with a heat recovery efficiency of 80%. The building's small heating requirement of only 9.8 W/m² is met using a 35-kW gas-powered furnace, which is roughly the same capacity as a furnace serving a code-compliant single-family house. The heating power needed according to the modeling and the current measuring results suggests that a furnace with a power of 10 kW would have been sufficient, but availability and safety margins made the builder opt for the installed system. The expected energy costs for the heating system are around $1,000 per year, leading to expected savings on energy costs alone of more than $10,000 per year. For an incremental increase in the operating budget, the natural gas will be replaced by renewable biogas, which will reduce the already very low emissions associated with the building heating by another few percent to about 10% compared to a code- compliant building. The heat is distributed using in-floor radiant heating with a highly efficient, low flow temperature of approximately 22°C.

A comparative life cycle assessment (LCA) was conducted on the WIRL to estimate the impact of materials versus operational energy on the overall building emissions over its lifetime, and to identify the materials and components within the building that contributed most to the emissions. In the majority of buildings, operational energy impacts far outweigh the embodied energy of the materials used in the building. However, in Passive House buildings that ratio can shift, as operational energy is minimized. We were surprised by the LCA results, which showed that by drastically reducing annual energy use, the ratio of operational to embodied energy over the lifetime of the WIRL would be roughly 60 to 40. These results emphasize the importance of first reducing the operational energy of a building. Once high performance standards have been achieved, the material selection for the superstructure and the building envelope becomes increasingly important.

—Guido Wimmers

Guido Wimmers is chair and associate professor of the Integrated Wood Design Department at the University of Northern British Columbia.

Passive House Metrics

Heating energy	Total source energy	Peak heating load	Peak cooling load	Air leakage
3.8 kBtu/ft²/yr	36.8	3.2 Btu/hr/ft²	0.3	
1.1 kWh/ft²/yr	10.8	0.9 Watts/ft²	0.1	0.1 ACH_{50}
12.0 kWh/m²a	116.0	10.0 Watts/m²	1.0	

Products

Windows
Zola

Air/Moisture Control
ProClima by 475

Ventilation
Swegon

Heating and Cooling
WaterFurnace International

Water Heating
Stiebel Eltron

Passive House Under the RADAR

Photos by Kaplan Thompson Architects

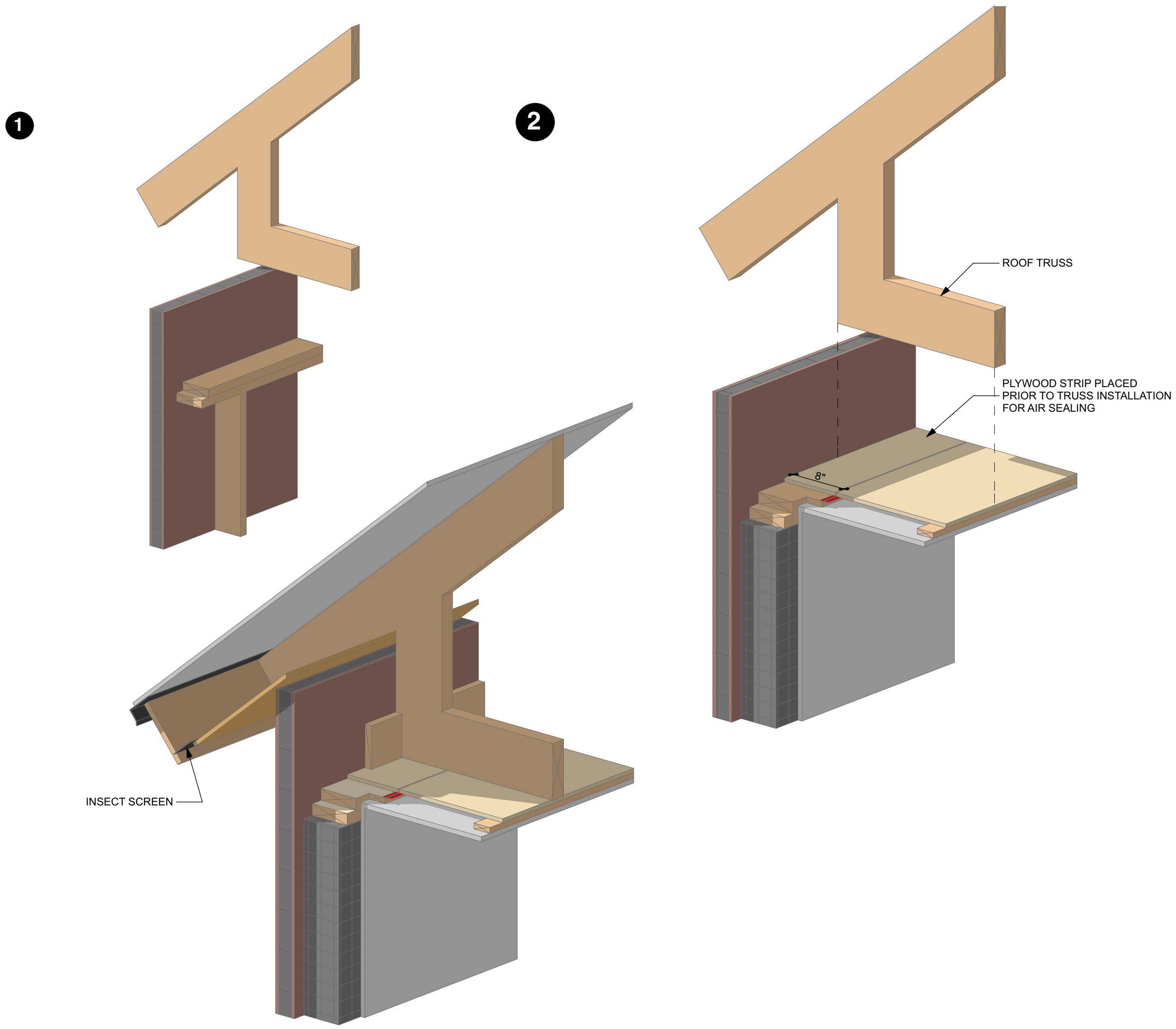
On the gradient between splashy and subtle Passive House projects, Blackstone Apartments, a 19-unit affordable housing development in Portland, Maine, falls so far toward the subtle end as to fall off the graph completely. "We did not discuss Passive House with the client," says Jesse Thompson of Kaplan Thompson Architects. "Passive House was never a project goal, but the project should be able to meet the PHIUS metrics." The property owner found out that the project was likely Passive House compliant only after the final blower door test.

"Early-stage, high-profile Passive House projects often launch with integrated teams, lots of fanfare, and extensive lists of consultants," notes Thompson. For many projects, though, that approach isn't realistic. Kaplan Thompson Architects has been pushing the envelope on its recent projects, exploring the question: How do we take Passive House strategies to mainstream multifamily construction when the budget doesn't allow for extra consultants or pretty much extra anything? Or when the owner perceives Passive House as a luxury good?

When working within a constrained budget, the firm strives to prioritize the most critical Passive House elements, balancing improved ventilation, airtightness, and insulation in order to make the best possible building. For this project, Thompson pushed the team on airtightness and ventilation, while keeping a low profile on insulation specifications. "Our multifamily work has shown us the effectiveness of having at least 85% efficient ventilation," he says, "which does more than a foot of insulation." Besides, he adds, developers have had decades of experience at cutting back on insulation to shrink project costs, so they're very skilled at it.

High-quality airtightness, on the other hand, is still a novelty and, more importantly, can be accomplished without raising costs, if it is designed in right. If it doesn't cost extra, it's not likely to be cut. Thompson had two advantages in this arena. Firstly, his own Passive House experience allowed him to draw details that he knew the building contractor could successfully implement. Secondly, in Maine all affordable housing already has to meet an airtightness requirement, albeit one that is 5 times leakier than PHIUS's. The builder was familiar with this type of requirement and was confident the team could meet the specification of .05 CFM_{50} per square foot. No mention was ever made that this was a Passive House goal, which contractors tend to think of as difficult to achieve and therefore worth raising bid prices over.

The buildable air-sealing details that Thompson specified for the Blackstone Apartments started with a thick vapor barrier under the slab. Nothing unusual there. Subslab insulation—in this case 3 inches—is also fairly routine. The wall assembly includes a nailbase sheathing adhered exterior to the studs and air sealed from the outside with the manufacturer's proprietary tape. "We could inspect this from the outside and easily see any spots that were missed," says Thompson.



ROOF INSTALLATION - 3D DETAIL
1' = 1'-0"

The airtightness layer in the roof assembly was a proprietary sheathing installed under the roof trusses and then taped from the inside. Although this approach was new to the builder, it wasn't a big stretch, and the panels' advantages were evident. They provided a hard surface that subcontractors could walk around on without damaging it. Once the wiring and plumbing chases were installed, blown-in cellulose filled and insulated the attic spaces.

The windows are standard casement types with vinyl frames and are triple-pane. Locally manufactured, they have an overall U-value of 0.22—not rock star performers but good enough, and they survived the value engineering process. The solar heat gain coefficient (SHGC) was also midrange; higher SHGC glazing can easily lead to overheating in multifamily projects.

Ventilation dominates heat loss in multifamily buildings, according to Thompson, because the requirement to deliver 50 CFM to each of 19 units adds up to a big wind blowing through the building all day long. Thompson chose two centralized HRVs with an 85% heat recovery efficiency, one for each of the two floors.

Supplemental heating and cooling is being supplied by heat pumps, with one head in each unit and only two evaporator units on the exterior. The building's only gas appliance is the hot water boiler, designed with an efficient distribution loop that includes smart recirculation pumps controlled by timers and a thermostat. As the housing is intended for seniors, the hot water demand tends to be lower than it would be for the general population.

Thompson told the developers at the end of construction that the project had met PHIUS's metrics—while staying within its stated budget of $180 per square foot. "They were surprised and excited," he says. Kaplan Thompson Architects' achievement refutes the sometimes-expressed concern that Passive House is a boutique program.

—Mary James

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Peak heating load	Cooling load	Air leakage
6.4 kBtu/ft²/yr	1.6	38.0	4.6 Btu/hr/ft²	3.7	
1.9 kWh/ft²/yr	0.5	11.1	1.2 Watts/ft²	1.1	0.05 CFM_{50}/ ft²
20.2 kWh/m²a	5.0	120.0	14 Watts/m²	11.8	

Products

Air/Moisture Control
ZIP System Sheathing and Tape

Ventilation
Ventacity Systems

Insulation
GreenFiber

Heating & Cooling
Mitsubishi Electric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testing platform
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• Square corners reduce leakage by 75%
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AFFORDABLE Multifamily Housing in Cambridge

In many parts of the world, the sweet spot for Passive House construction is affordable multifamily housing. This is particularly true in the northeast United States. Although Passive House construction techniques and details are becoming familiar to architects and builders, there's always the question of cost. Can a multifamily Passive House building be constructed for the same cost as a code-built building? According to architect and Certified Passive House Consultant Michelle Apigian of ICON Architecture, the answer is a resounding Yes! It's all about priorities, integrated design, and focus on long-term value. Concord Highlands, in Cambridge, Massachusetts, is a prime example of how this can be done.

When Cambridge-based owner and developer Homeowner's Rehab, Incorporated, first talked to ICON Architecture, the goal was to work toward attaining Passive House performance, as long as it didn't seriously impact the budget. The project had multiple potential funding sources, and maintaining the budget was critical to nailing down the financing. As design work progressed, the team eventually realized that it could reach its goal. Success was due to a combination of a design team that had previous Passive House experience and the owner's motivation, including a willingness to spend a bit more money in the beginning to investigate high-performance options. These early investigations led to decisions that saved money, ensuring performance and cost optimization. Construction started in May, shifting the team's focus to ensuring execution that delivers on the design intent. To that end, on-site trainings are being conducted for both the general contractor and the strategic trades.

Renderings by Icon Architecture

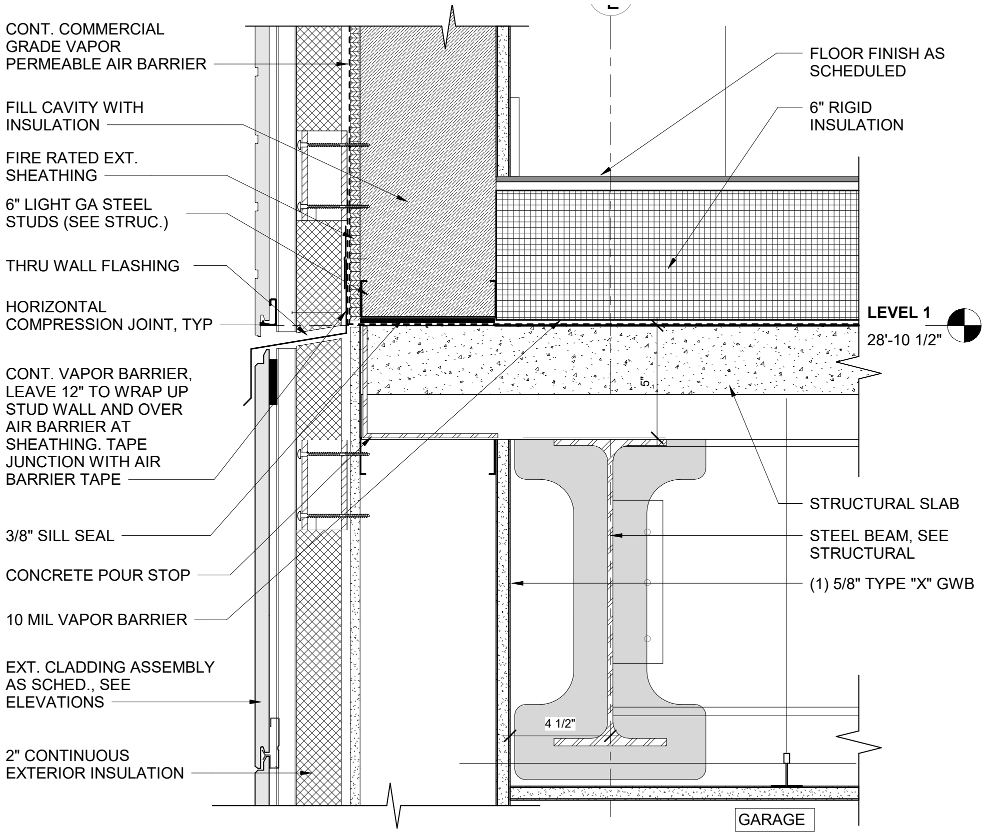
Concord Highlands contains one floor of podium level parking and 98 one-, two-, and three-bedroom apartments on six floors. In addition to 12 apartments, the first floor contains a lobby; property management offices; and spaces for mail, for maintenance, and for residents to gather. The top floor contains shared laundry facilities, a community room, a community kitchen, and a roof deck. Current programming ideas include a roof farm on the deck, managed by an outside service. The building was designed using Active Design principles, promoting light-filled stairwells and interior common spaces that invite resident engagement. The top-floor spaces have the best views of the adjacent Fish Pond Reservoir, a green space and part of the water supply for the city of Cambridge.

Homeowner's Rehab builds projects that are community and resident oriented, with a targeted tenant mix representing various income levels. More than half the units are for families making less than 60% of the regional Adjusted Median Income (AMI). The remaining units are for families making no more than 100% of the AMI. Five percent of the units are accessible; 2% are for hearing-impaired residents.

The project is located in an evolving industrial area, sandwiched between a high-density residential neighborhood of single-family homes and a retail-oriented zone. There is walking access to food shopping and other amenities. There are 67 parking spaces (a 68% ratio) and 103 resident bicycle parking spaces (100%+). The location is closely connected to Cambridge's extensive bicycle network; it is 1 mile from the closest subway station and adjacent to bus stops.

One way to keep costs under control is to design using familiar assemblies. The building has two levels of concrete deck construction. The lower floor above-grade walls are 2 x 6 metal studs. The upper-floor walls are fire-treated 2 x 6 lumber. All exterior walls are being filled with blown-in fiberglass and wrapped in 2 inches of mineral wool over a combined air and water barrier applied to the sheathing. The cladding is being attached using fiberglass clips to minimize thermal bridging. The roof is a 20-inch truss cavity, also filled with fiberglass, and covered with a minimum of 2 inches of sloped rigid insulation. Due to significant ventilation requirements, the laundry room is outside the conditioned space. The trash rooms and the management offices are also outside the Passive House space.

Concord Highlands is not actively pursuing Passive house certification, but it is adhering to Passive House design principles. WUFI modeling was done early on. It showed that, counter to the design team's intuition, overheating would not be a problem if the team eliminated shading on the building's east-west axis—a significant savings. The team also did thermal bridge calculations to make sure there were no significant problem areas. The one significant bridge, at the intersection of steel columns and beams at the podium level, was eliminated with a structural thermal break material. Cambridge typically requires LEED certification, but the project was granted a variance to pursue



2 TYPICAL LEVEL 1 SLAB EDGE DETAIL
3" = 1'-0"

Passive House Metrics

Heating energy	Cooling energy	Total source energy	Peak heating load	Peak cooling load	Air leakage
4.1 kBtu/ft²/yr	2.8	4,566 kWh/ person/yr	2.9 Btu/hr/ft²	3.1	0.05 CFM_{50}/ ft² of envelope area (design)
1.2 kWh/ft²/yr	0.8		0.8 Watts/ft²	0.9	
12.9 kWh/m²a	8.7		9.1 Watts/m²	9.6	

Enterprise Green certification instead, because of its focus on affordable multifamily projects. As part of that effort, there is a dedicated sustainability consultant on the project, and there will be extensive commissioning, including infiltration and ventilation. Thanks to all these efforts, the residents will be enjoying low utilities, great air quality, comfort, light-filled public spaces, and ready access to the vibrant Cambridge community.

—Steve Mann

Products

Structural Thermal Breaks
Schöck

Heating & Cooling
Mitsubishi Electric

Mixed-Use Building Rises in MIDTOWN MANHATTAN

Rendering (opposite page) by Stasis 3D
all other photos and graphics courtesy of ZH Architects

This 24-story mixed-use building embodies the challenges and risks in developing an urban site with neighboring tall buildings, a tight zoning envelope, and a mid-block location with limited light, air, and access. The owner and developer, Bernstein Real Estate (BRE), wanted to bring the highest and best use to an empty lot that they owned, which had been being used just for parking, as well as expand their portfolio to include residential programming with a focus on energy efficiency.

The site was adjacent to a building also owned by BRE, which depended on windows installed right on the lot line as the only source of daylight for scores of offices. Therefore, the initial challenge that ZH Architects had to tackle was developing a floor plan and a building section that preserved the majority of the neighboring property's windows while creating apartment layouts that would meet current market demands.

The design they developed preserves this daylight at the upper floors of the existing building by creating an intentional gap between the facades of the new and existing buildings. To maintain the privacy between existing commercial and new residential tenants, the east façade of the new building was not punctured and the south- and north-facing façades of the new building were designed with ample glazing.

The restriction on the placement of the windows on the new building, as well as the added exterior wall surface area on the east façade, complicated the process of meeting Passive House performance targets and made it challenging to find room for 55 well-lit apartments. "It required some creative work in plan layouts," says Stas Zakrzewski, one of ZH's two principal architects, as it was important to reflect the changing needs of this neighborhood, which is a mix of students, creative professionals, and longtime garment and fur distributors. In the end, the building will provide a variety of apartment layouts ranging from studio to three-bedroom units with 20 percent of the units designated as affordable housing and the remaining market-rate.

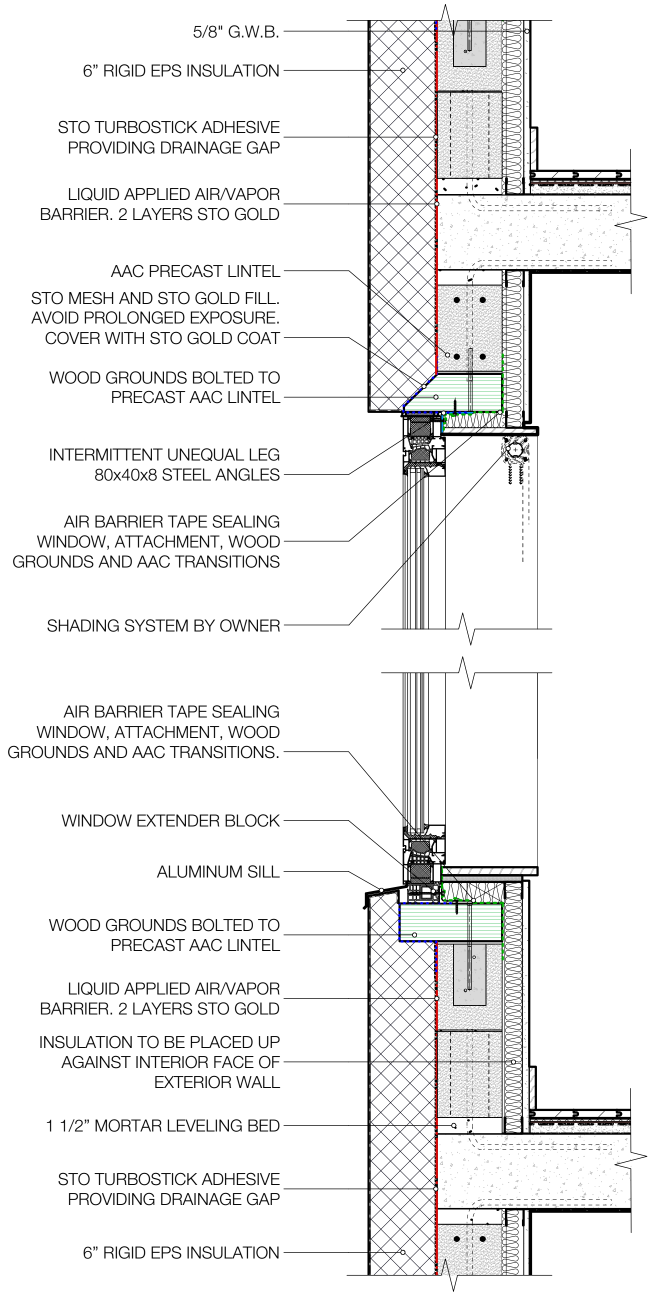
The foundation had its own peculiar trials, thanks to the site's subsoil conditions.. "These resembled a black diamond ski slope," recalls Zakrzewski. In places the bedrock lay just below the cellar, and leveling this area required extensive chopping away at the schist before construction. Elsewhere the building rests on grade

beams and piles that extend down to stable rock. Exterior insulation was added around the foundation's entire perimeter where possible but was only installed below the non-loadbearing foundations, as a building this size can lose heat in discrete places and still hit the performance targets.

The mix of apartment types, and varying building widths and height setbacks, required focused coordination between the mechanical, plumbing, electrical, and sprinkler trades in order to preserve the Passive House envelope. ZH was fortunate to have JBS Project Management and KSK Construction, with Steven Winter Associates as the Passive House consultant, working together to ensure this project's success.

To maximize space in the apartments, the wall assemblies were carefully evaluated for a balance between the preferred R-value and the corresponding depth of the proposed exterior wall assembly. After much consideration, autoclaved aerated concrete (AAC) block was chosen over CMU as it provided the highest R-value with the slimmest wall section and gained measurable square footage per floor—translating directly into usable space for the tenants. Other advantages of AAC block are its light weight, excellent fire resistance, and quick installation process. The front façade will be completed with a water and air barrier membrane adhered directly to the exterior of the AAC, 5 inches of mineral wool, and a ventilated rain screen façade. The remaining facades will rely on an EIFS system.

Building in an urban environment, where space comes at a high premium and each floor is tightly packed with apartments and building amenities, usually means that cooling is the dominant energy load on the building. Site conditions dictating that the prime elevation faces south also added to the cooling requirements. To mitigate for these factors, all the south-facing windows will feature accent brows that double as shading devices to reduce summertime heat gain. Cooling, heating, and dehumidification will be supplied by a variable refrigerant



flow air source heat pump with individual air handling units in each apartment, allowing each tenant to have control over its heat and air conditioning. A centralized ERV is being installed on the top bulkhead of the building. It will provide all the residential units with a continuous flow of filtered air, another advantage of Passive House construction.

The double-height lobby and retail spaces on the ground floor are both located within the thermal envelope. The lobby entry will feature two sets of high-quality airtight double doors to create a vestibule—a cost-effective solution compared to custom air-sealed revolving doors that were initially considered for ease of traffic flow. White box commercial spaces are often not included in a Passive House envelope as their future use is unknown, but for this owner/developer bringing energy efficiency to the commercial component of the project was a priority. Due to the different usage patterns of retail spaces, a second ERV was specified for that space, and occupancy sensors were added to reduce ventilation to the retail spaces when unoccupied.

—**Mary James**

Passive House Metrics

Heating energy	Cooling energy	Total renewable source energy	Air leakage
2.1 kBtu/ft²/yr	4.3	37.7	
0.6 kWh/ft²/yr	1.3	11.1	0.6 ACH_{50} (design)
6.6 kWh/m²a	13.6	119.0	

Products

Air/Moisture Control and Insulation
Sto

Ventilation
Swegon

Structural Thermal Breaks
Armatherm

Schöck

NUTHATCH Hollow

Renderings courtesy of Ashley McGraw Architects

At Ashley McGraw Architects, our ambitions encompass creating a regenerative and resilient world where humans live in alignment with, and contribute to, the natural systems all around us. That's why, when approached by Binghamton University to design a 3,000-ft^2 environmental learning and research facility located on a 70-acre nature preserve in Binghamton, New York, we set an ambitious agenda. The Nuthatch Hollow facility is being designed to meet both the Passive House and the Living Building Challenge (LBC) standards.

Developed by the International Living Future Institute, the LBC is one of the most aspirational and rigorous holistic building standards in the world today, with only 20 projects to date achieving full certification. Passive House, both the U.S. and the German versions, is based on the need to make drastic energy reductions in our buildings to mitigate the devastating effects of climate change. PHIUS has developed a set of criteria that takes into account climate-specific variations and cost considerations, and we chose to work toward that standard.

A DOUBLE STANDARD OF A GOOD SORT

Understanding and complying with the requirements of these two systems together has required an iterative approach to decision making—reviewing the features of each system, component, and material on multiple levels and evaluating the benefits or disadvantages of the part relative to the whole. Adding to the complexity of the project is a paradox of compliance: In many instances, the guidelines prescribed by PHIUS and LBC are at odds in practice, if not in purpose. Holistically resolving these differences requires a careful patchwork of cross-checked resources and systems.

As one example, gas-fired, rather than electric-resistance, water heaters can be a desirable solution for a Passive House, due to their higher energy efficiency; however, LBC prohibits the use of on-site combustion, which necessitates a different approach. To mutually address these guidelines, we chose to locate tankless electric water heaters at the fixtures, which virtually eliminates the potential distribution losses and makes this option a highly efficient one.

Although the combination of these standards is complex, we know that the benefits are worth the effort. The energy reduction strategies of Passive House allow us to meet the net positive energy requirement of LBC with the limited area of photovoltaics we can fit on the roof, and provide a level of resilience that will only become more important as time goes on.

MATERIALS RESEARCH BENEFITS FROM INCLUSIVE TEAM

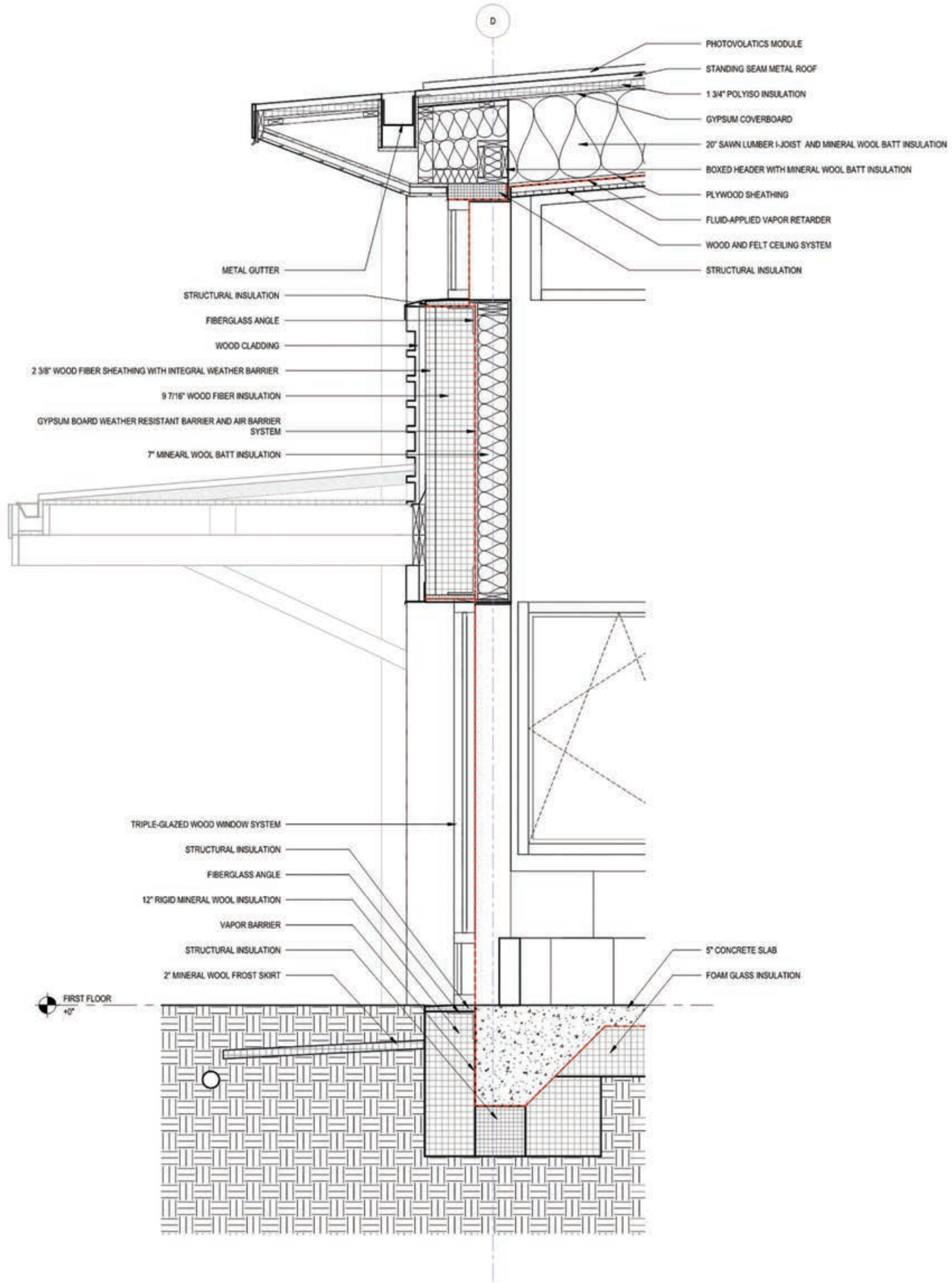
Finding components and materials that can meet the rigorous thermal and airtightness requirements of Passive House, as well as satisfy the toxicity elimination goals of LBC, is a key part of the process of making a better building and a healthier planet—but it can be an arduous exercise, to say the least. Satisfying LBC's mandates can require contacting hundreds of manufacturers, reviewing extensive statements of chemical ingredients for LBC's Red Listed (or worst in class) items, searching for alternative products, and advocating for change in manufacturing processes.

At the kickoff meeting for Nuthatch Hollow, we engaged students and faculty to play significant roles in the project, including the intensive task of materials research. The process has evolved over the last 18 months, starting out with a special class built around material research as part of the coursework. The students made the initial contacts with manufacturers of products under consideration and identified manufacturers who were open to adjusting their components to meet the requirements. When the course was completed, the university appointed a student materials-vetting specialist, who has been responsible for researching alternative manufacturers of materials already vetted, to help comply with the public bidding process. The students' involvement has been a significant learning experience for them as well as a huge help to the design team in making material and component selections, and will continue to be a critical component of the process as we move through construction documents toward bidding this fall.

The team has researched materials that can fulfill multiple functions, such as the use of a specific type of wood fiber insulation that serves as a vapor-open weather-resistive barrier in addition to providing insulation value. Because regular truss joist I-beams could not meet the Forest Stewardship Council requirements set forth by the LBC guidelines, sawn lumber joists were used for the roof design instead, with mineral wool batt insulation tightly fitted between structural members, both sourced from nearby Eastern Canada. In an effort to keep the assemblies as foam-free as possible, foam glass gravel made from recycled glass is being considered as an alternative to below-slab rigid foam insulation.

NAVIGATING SOLUTIONS

Another area where we faced complexity in integrating the two standards was at the washrooms. Living Building Challenge requires net positive water, meaning that the water that falls on the defined LBC project site in the



course of a year determines the project's allowable water use per year, and all wastewater must be processed on site and returned to the environment. Composting toilets are commonly used to help achieve this level of water use reduction, as the composting process allows water to be saved from use as a carriage medium. For this project we are specifying foam flush composting toilets with a composter beneath, which requires continuous ventilation. Exposure to constant airflow is necessary to allow the mixture of toilet waste and bulking material to convert to usable compost and liquid fertilizer. The continuously operating composter fan creates negative air pressure at the toilet fixtures for odor control. Our challenge is to accommodate this continuous exhaust within a balanced ventilation system and still meet the stringent heating limitations of Passive House.

At first, we saw two potential solutions to the situation. The first approach would keep the composter ventilation separate from the building's main ERV by installing a secondary HRV unit to provide dedicated service to the composting toilets. The second approach would integrate the composting toilet exhaust into the overall ventilation system. We ultimately chose the first solution, deciding that the risk of dispersing toilet room odors throughout the entire building was too great. The dedicated HRV will be a very high-efficiency unit that will supply into the washrooms and exhaust directly from the composter unit, thereby containing most, if not all, odors within the washroom ventilation loop.

Passive House Metrics

Heating energy	**Cooling energy**	**Total source energy**	**Peak heating load**	**Peak cooling load**	**Air leakage**
6.4 kBtu/ft²/yr	1.6	38.0	4.6 Btu/hr/ft²	3.7	
1.9 kWh/ft²/yr	0.5	11.1	1.3 Watts/ft²	1.1	0.05 CFM_{50}/ ft² (design)
20.2 kWh/m²a	5.0	120.0	14.0 Watts/m²	11.8	

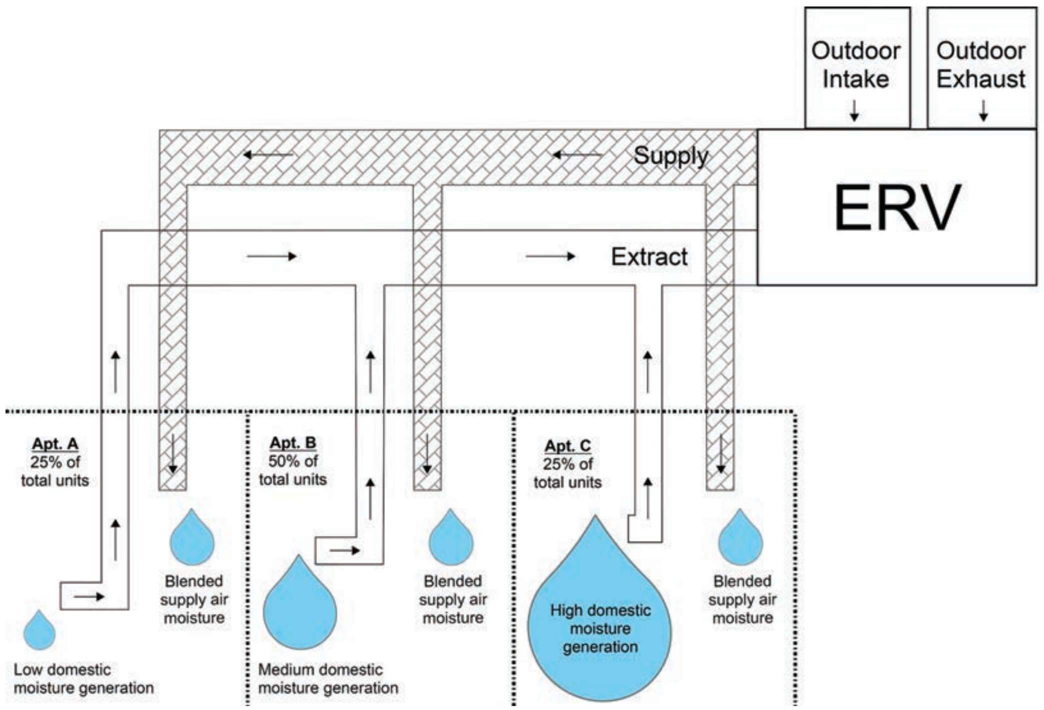
A VISION FOR ENVIRONMENTAL STEWARDSHIP

The primary function of Nuthatch Hollow will be as a teaching and research facility for Binghamton University's environmental studies program. The facility will also be available for other gatherings and may be used during the summer months for community-based educational programs as a hub for collaboration and community engagement. On a symbolic level, the building will act as a physical manifestation of the school's core values and mission, especially as they relate to preparing students to live effectively in a time of change and actively create a more sustainable, resilient world.

Combining standards from these two programs has not been easy, but we hope that by taking on this challenge, we will make the path clearer for others, and that the myriad of sustainable building standards out there will ultimately work together to allow for an integration that's even greater than the sum of its parts. As we move through this process, we know that with every ambitious project we push toward a future of abundance, symbiosis, and regeneration.

Matthew Broderick *is president of Ashley McGraw Architects,* **Nicole Schuster** *is an associate principal/project architect, and* **Christina Assmann** *is a project architect at the Syracuse, New York-based firm.*

MULTIFAMILY *Moisture Control*



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Most of us are familiar with the feeling of a humid apartment after taking a hot shower. Some of us kick on an exhaust fan, perhaps unfog the bathroom mirror, or even open a window to get the moisture out. Domestic moisture generation—moisture from human activity—is a major factor driving the humidity levels in our residential buildings, especially in superairtight Passive House construction. Before diving into just how much of an impact domestic moisture has in our buildings, let's first look at average daily moisture generation rates of a typical family of three:[1]

- Breathing and transpiration—6 to 9 lb of water vapor per day.
- Ten-minute shower in the morning for each individual—3.6 lb of water vapor.
- Cooking fried eggs and bacon for breakfast—0.5 lb of water vapor.
- Cooking steamed vegetables with pasta for dinner—0.5 to 1.0 lb of water vapor.
- One small dog and a few plants around the house—0.5 lb of water vapor per day.

This brings the daily total to between 11.1 and 14.6 lb of moisture generation per day, or about 1.5 gallons of liquid water.

Where does all of this moisture go? In a typical code level apartment building with moderate to high levels of air leakage, water vapor has two year-round exit pathways: exfiltration through the façade and dedicated kitchen or bathroom mechanical exhaust. In the summer, moisture is also removed via condensate from the cooling system.

Let's now put this in the context of a highly energy-efficient apartment with very low levels of air leakage (about 5 to 10 times less than the code-compliant unit), and balanced ventilation with energy recovery. The first means of moisture removal, façade exfiltration, is virtually nonexistent given the building's superior airtight design. Next is mechanical exhaust ventilation in the kitchens and bathrooms. Because the unit has balanced ventilation and energy recovery, the exhaust airstream in a Passive House project typically passes through the energy recovery core. Depending on the core selection, a large percentage of the interior moisture may be retained in the apartment air despite the constant mechanical air exchange.

There are two basic types of core:

- HRV, in which a certain percentage of sensible heat is recovered (transferred from the exhaust airstream to the supply airstream) while no moisture is recovered.
- ERV, in which a certain percentage of sensible heat and a certain percentage of moisture in the air is recovered.

Table 1 breaks break down the moisture-related pros and cons of ERVs and HRVs in the context of a high-density Passive House building.

Traditionally, the key factor in deciding between an ERV and an HRV for a high-efficiency building has been the project's climate. However, as internal moisture loads begin to exceed exterior moisture loads in high-density projects, the decision between ERV and HRV must be looked at more closely for each project regardless of climate.

Our Passive House team at Steven Winter Associates, Incorporated, closely studied this dynamic relationship between interior humidity levels and the ERV vs. HRV decision for a 277-unit high-density, affordable housing Passive House project in New York City. The project team originally elected for decentralized ERVs, one unit per apartment, to reduce summertime cooling loads, resulting in utility savings for the buildings' tenants. Given this decision, we underwent a major modeling effort to assess the risk of high wintertime interior humidity levels, an ingredient for increased condensation potential on the project's windows. Two primary questions needed to be answered:

- Will interior relative humidity (RH) levels get high enough in the wintertime to cause condensation potential on the windows?
- Is the ERV's airflow boost capacity enough to mitigate high interior humidity levels?

This modeling exercise yielded the following takeaways:

TAKEAWAY #1: Weekday interior RH levels will peak anywhere from 50% to 63% in the morning and early evening. The largest peak will occur during the morning breakfast hours.

TAKEAWAY #2: Weekend interior RH levels will remain between 50% and 70% over the course of the day.

TAKEAWAY #3: Boost flow on the ERV during high-humidity conditions will only slightly reduce peak humidity levels.

TAKEAWAY #4: Due to high predicted interior humidity levels, localized supplemental dehumidifiers may be required.

TAKEAWAY #5: Some ERV cores can have a much greater moisture recovery rate in the winter season than in the summer. These seasonal differences are not typically reported by manufacturers and should be confirmed for each project.

As the project progressed, a decision was made to switch to four centralized ERVs. The model was then revised to account for a normalized amount of air mixing that would occur with the centralized design. See Figure 1 for a schematic of this concept. In other words, not all apartments will be generating high levels of moisture at any given time. Therefore, the supply air going back to

Table 1. Moisture related pros and cons with ERVs and HRVs in high efficiency, airtight construction

	ERV	**HRV**
Pros	Summer – prevents high exterior air moisture load from being supplied to interior air; cooling loads are minimized	Winter – flushes high internal moisture load out of building; humidity levels reduced
Cons	Winter – if internal moisture generation is high, interior moisture load is not flushed out of apartment; humidity levels increase	Summer – allows exterior air moisture load to be supplied to interior air: cooling loads increase

[1] Anton TenWolde and Crystal L. Pilon. "The Effect of Indoor Humidity on Water Vapor Release in Homes." In *Proceedings, ASHRAE Thermal Performance of the Exterior Envelopes of Whole Buildings*. Washington, DC: U.S. Department of Energy, Oak Ridge National Laboratory: Buildings X Conference, December 2–7, Atlanta, Georgia, 2007.

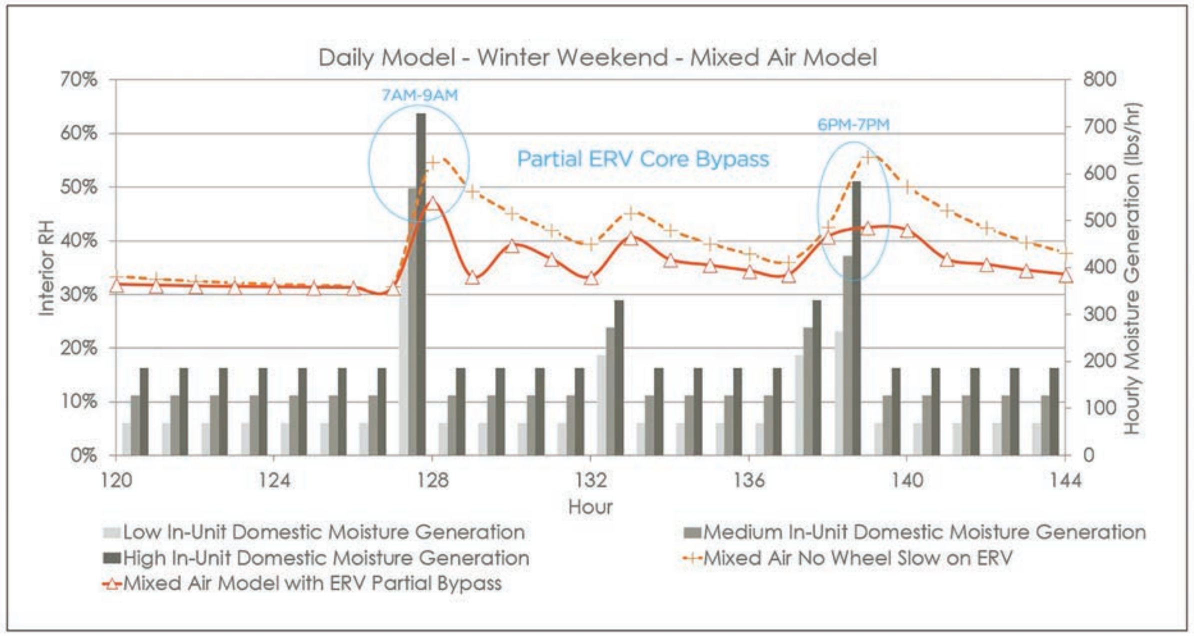


Figure 2. Moisture model on a typical weekend day in winter.

each apartment will result from a blending of the average humidity conditions across the project's 70 units that each centralized ERV services.

The revised moisture model, which was based on using centralized ERVs, yielded a noticeable reduction in apartment interior RH when compared to the decentralized model. On a typical weekend day in winter, the model was predicting that average apartment interior RH percentages would remain in the low to mid-50s for only a few hours during those times when domestic moisture generation peaks.

While the centralized ventilation approach largely reduces the risk of high moisture levels in the apartments, additional controls are being specified for the centralized ERV units to further alleviate this risk. During periods of cold exterior air temperatures and high return air humidity levels, the ERV will have the ability to partially bypass the enthalpy wheel to flush the moisture out of the apartment air. Figure 2 depicts the substantial effect of incorporating this ERV cotrol.

Our modeling shows that this approach of utilizing partial core bypass controls on the ERV effectively mitigates high interior RH levels in the wintertime, and reduces the risk of condensation on the project's windows. However, this approach is certainly not ideal. During periods of partial core bypass, heating loads will increase, due to the reduced rate of sensible heat recovery from the exhaust airstreams.

It is rare to find a perfect solution to a problem. Because we have very little control over domestic behavior, we'll likely need to lean on engineered solutions to grapple with unpredictable behaviors and interior humidity. Cooling systems are a good place to start. Cooling systems that better match the low loads in Passive Houses could enhance their dehumidification potential in the summer, thus making HRVs more favorable for projects. HRVs will completely flush moisture out of the apartment air during the winter months when a risk of condensation may be present. Another thought is to take a page out of Intel's book and incorporate dual-core technology in our ventilators. The potential solution could be a ventilator that automatically switches from an ERV to an HRV core from season to season. Whatever the actual solutions may be moving forward, it's critical that we begin to think about them. This issue will become more prevalent as we design tighter, denser multifamily buildings.

—Dylan Martello

DYLAN MARTELLO *is a senior building systems consultant and CPHD at Steven Winter Associates, Incorporated.*

Electrification, Decarbonization, and the Leapfrogging of Zero Net Energy

CALIFORNIA'S NEW PATH to a LOW-CARBON FUTURE

In February of 2018, the city of Palo Alto released what I regard as a groundbreaking report, *Buildings Baseline Study and Roadmap for Zero Net Energy Buildings*.[1] This report, while valiantly attempting to adhere to the state's previously outlined Zero Net Energy (ZNE) goals, quietly subverts them and subtly reveals our more urgent priority of reducing carbon emissions.

Palo Alto's report arrived one month before the California Energy Commission's (CEC's) proposed updates to the 2019 Title 24 Building Energy Efficiency Standards were announced.[2] This CEC announcement made headlines nationally due to a new requirement to include solar panels for all residential buildings by 2020. However, more significant than the bling of the required PV was a careful adjustment from an earlier push toward ZNE buildings to a beyond-ZNE target.

This nimble leapfrogging over ZNE targets was easy to miss, as it was almost apologetically tacked onto the very end of the FAQ, disguised under the subtitle Do the 2019 Residential Standards Get Us to Zero Net Energy? The answer concludes: "Looking beyond the 2019 standards, the most important energy characteristic for a building will be that it produces and consumes energy at times that are appropriate and responds to the needs of the grid, which reduces the building's emissions."

LEARNING FROM PALO ALTO

There's much to unpack in these two documents. The Palo Alto study, based as it is on measured data supplied by the municipally owned utility, gives a detailed look at current building energy use—and provides good insight into which policies would most impact the building sector's carbon emissions. An introductory graph illustrating overall source energy use for Palo Alto's buildings shows that natural gas accounts for just over half of total energy use. Figure 1 breaks Palo Alto's building energy use down into its end uses, showing commercial buildings consuming the lion's share of this energy.

While Palo Alto may not be average in terms of cost of living, its built environment could certainly be considered typical. For this reason, this report provides good generalized insight into the energy use of Every City, California.

THE BIG REVEAL

By far the most eye-opening information exposed in this report is in the bar chart graphs illustrating annual building energy use, electricity use, and carbon emissions (see Figure 2). Applying the frameworks of Zero Net Carbon, Zero Net Energy, and Zero Net Electricity to these graphs forces us to ask: *What is the target we're really aiming for with our buildings?*

This is precisely where the CEC's move away from ZNE in favor of a carbon reductions focus starts to make sense. This graphic comparison enables us to see that if we look only through the total Electricity Use lens (right side of Figure 2), we'll be led toward heavily promoting daylighting and lighting efficiency measures, which will probably do little to reduce carbon emissions.

The total Energy Use (middle) lens, the basis for ZNE, would encourage a broader distribution of possible policy incentive options, with improved impact on carbon emissions reduction. However, it's clearly the total Emissions lens (left) that we simply cannot ignore. This shows—even in the mild climate enjoyed by Palo Alto—that the highest building carbon emissions are from energy used for space heating,[3] with water heating following closely behind. This means that if we focus only on reducing these two end uses, we'll significantly reduce our carbon emissions from buildings.[4]

So how do we achieve this most effectively?

Fortunately for us, the CEC's FAQ already has much of this covered. Special mention is made of the new residential standards encouraging "demand responsive technologies including battery storage and heat pump water heaters."[5] This is big. It signals a clear move toward the electrification of buildings—a big step for California, where gas has been the fuel of choice for many years. With this combination of electrification, storage, and heat pump technology, hot water energy use will mostly be covered by renewable energy.

Less clear in the CEC's FAQ is a solid plan for how California will be reducing building space heating demand. Not too coincidentally, space heating demand happens to be a particular specialty of the Passive House standard, which makes it a great approach for meeting the CEC's policy goals to encourage buildings that best match renewable-energy production capacity, place least strain on the grid's resources, and quickly and substantially reduce building emissions.

TARGETING LOADS

To illustrate how the Passive House approach plays out in a reasonably typical residential building situated close to Palo Alto, let's take a look at the measured energy use of a home I designed with One Sky Homes. This single-family home has a treated floor area of 2,342 square feet, R-28 walls, an R-46 roof assembly, windows of R-3.3, a floor slab of R-14, and an airtightness reading of 0.3 ACH_{50}. It's an all-electric home, utilizing heat pump technology for both hot water and space conditioning, and boasts a 7.5-kW PV array installed on the south-facing roof, which powers both the house and an electric vehicle.

TIME OF USE MATTERS

The daily energy use of this house has remained remarkably stable, with a net annual use well into plus energy territory. However, the bigger picture of energy use versus generation provides the most insight here, and points to the same conclusions for energy use priorities as those in the Palo Alto report's bar graphs comparing total Electricity Use, Energy Use, and Emissions.

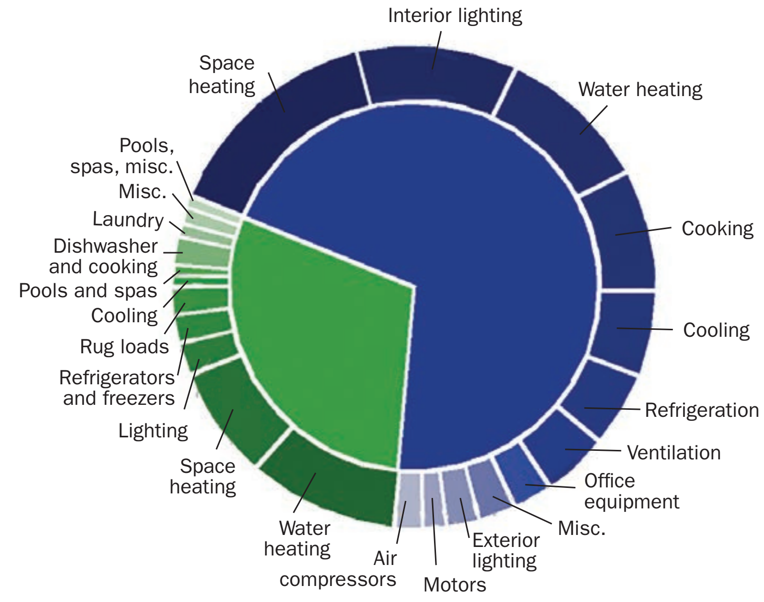


Figure 1. Palo Alto Utilities Data 2016 (inside pie chart), with Residential Appliance Saturation Study 2009 (RASS) and California Commercial End-Use Survey 2006 (CEUS) used to determine end use breakdown by building sector. Source: DNV-GL.

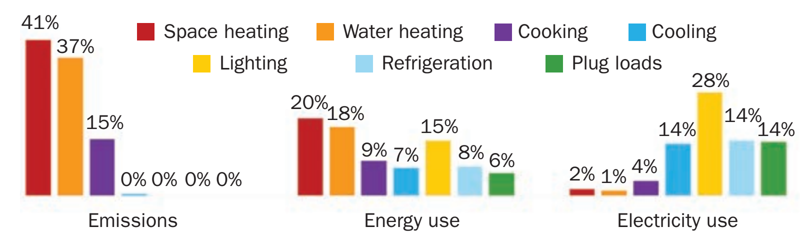


Figure 2. Summary of Building Energy Usage (Total BTU). Source: Data compiled from RASS and CEUS data by DNV-GL.

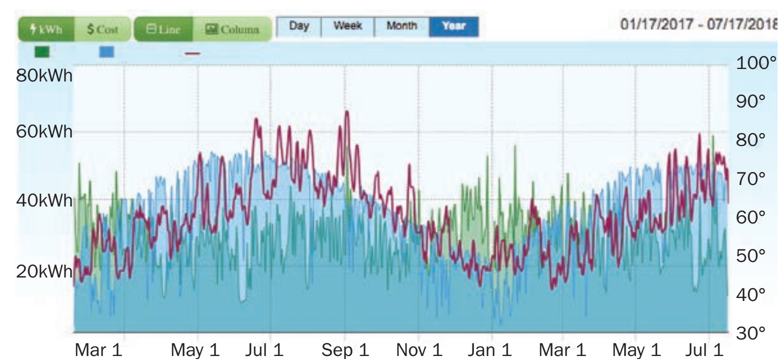


Figure 3. Alamo Passive House Total energy demand vs energy production, courtesy of One Sky Homes.

A full year's worth of daily outdoor temperature, electric usage, and energy production (see Figure 3) shows that without battery storage, this house-and-EV package still requires a utility. Even in our sunny California climate, despite an incredibly low overall demand (and an electric vehicle), the 7.5-kW array is unable to meet all of its energy needs between the months of November and February. (Imagine how much larger the wintertime gap between production and demand would be if the house were not so well insulated and airtight!) This not only means that time of use matters, but that seasonal use matters. As the Palo Alto report corroborates, our most critical variable is in fact winter space heating demand, which cannot be covered by short-term battery storage.

Photo Courtesy of One Sky Homes

REFOCUSING ON EMISSIONS REDUCTIONS

Given the information shared in the Palo Alto report, and bolstered by the data collected on the One Sky home, I'm encouraged by the CEC's shift away from total building energy use to carbon emissions reduction. Piecing all this information together, it's clear that aligning our energy code with the targets set by the Passive House standard would help California to meet our long-term carbon emissions reductions goals.

—Bronwyn Barry

Bronwyn Barry *is a registered architect and a Certified Passive House Designer.*

References

Herrschaft, Blake, and Betty Seto. Buildings Baseline Study and Roadmap for Zero Net Energy Buildings. *Palo Alto, CA: City of Palo Alto Development Services, February 2018.*

*California Energy Commission.*2019 Building Energy Efficiency Standards, Frequently Asked Questions. *California Energy Commission, March 2018.*

California Energy Commission. 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. *California Energy Commission, June 2015, 255–56.*

1 www.cityofpaloalto.org/civicax/filebank/documents/63492.

2 www.energy.ca.gov/title24/2019standards/documents/2018_Title_24_2019_Building_Standards_FAQ.pdf.

3 Space heating demand is also the highest energy user in commercial buildings, challenging the commonly held notion that commercial buildings in this region are cooling load dominated.

4 Early projections indicate that this same approach applies equally to our warmer southern Californian climates, where summer peak load reduction offers the same opportunities for full electrification.

5 www.energy.ca.gov/title24/2019standards/documents/2018_Title_24_2019Building_Standards_FAQ.pdf.

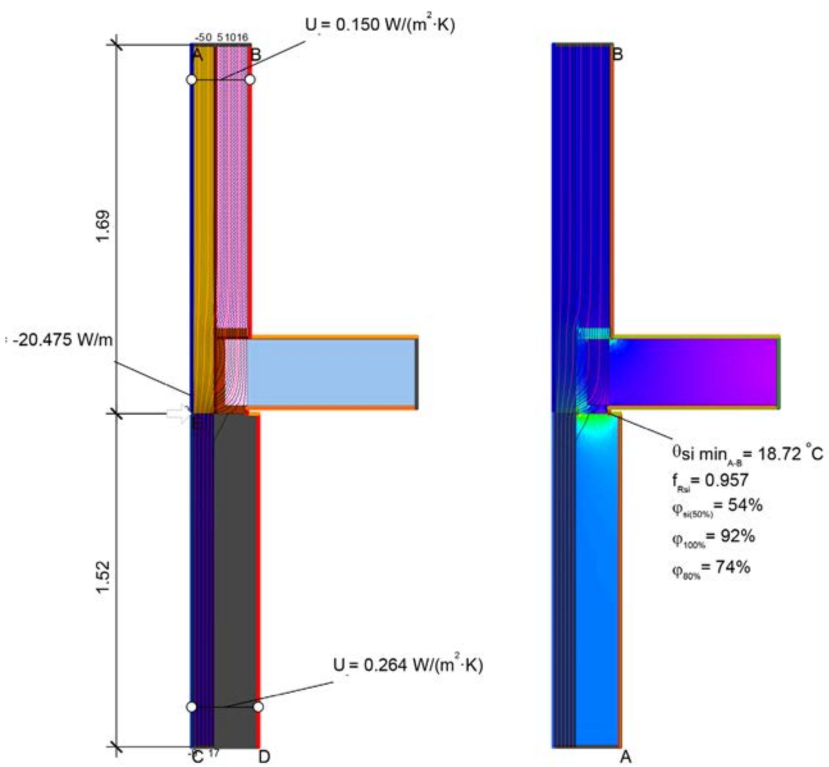
FLIXO

A Learning Curve Worth Navigating

For most people in the building industry, thermal bridge calculations are a far-distant concern—if they even know what they are. But for Passive House practitioners, calculating psi values is often a painful fact of life. While high-quality instruction is increasingly available, the commonly available software, THERM, seems stuck in the mid '90s, with hard-to-use drawing interfaces, finicky geometry imports, and severely limited calculation functions that require using additional spreadsheets.

Wouldn't it be nice if you could simply identify a detail in a computer-aided design (CAD) drawing, and with a few clicks of a button, the psi value would automatically pop up, complete with report and documentation? While nothing like that exists currently, there is software that comes surprisingly close.

Europe has seen a raft of two-dimensional thermal-modeling software developed in recent years. One of those programs—Flixo—is relatively unknown in North America, but offers considerable promise for Passive House practitioners. Let's look at some of the features—good and bad—of this software.



$$\psi_{A\text{-}E\text{-}C} = \frac{\Phi}{\Delta T} - U_1 \cdot b_1 - U_2 \cdot b_2 = \frac{20.475}{30.000} - 0.150 \cdot 1.686 - 0.264 \cdot 1.524 = 0.026\ \text{W/(m·K)}$$

Material	λ[W/(m·K)]
Air layer, unventilated, horizontal, thickness 1m	5.420
Concrete, reinforced (with 1% of steel)	2.300
EQ 2x6 24in oc w Blown fiberglass R4.0/inch	0.041
EQ TJI 24in oc w Blown fiberglass R4.0/inch	0.040
Gypsum board R0.9/inch	0.160
Mineral wool R4.0/inch	0.036
OSB R1/inch	0.144
Timber 450 kg/m3 (softwoods)	0.120
XPS R5.0/inch	0.029

Boundary Condition	q[W/m²]	θ[°C]	R[(m²·K)/W]
Exterior, normal		-10.000	0.040
Exterior, ventilated		-10.000	0.130
Interior, heat flux, downwards		20.000	0.170
Interior, heat flux, upwards		20.000	0.100
Interior, normal, horizontal		20.000	0.130
Symmetry/Model section	0.000		

Pre-formatted Flixo report page showing a rim joist condition with a psi value calculation on the left (with model showing materials, boundary conditions, and iso-therm lines) and an fRsi calculation on the right (with model showing heat flux). Credit: CSBR (Center for Sustainable Building Research, a University of Minnesota research center)

The first thing people generally notice about Flixo is how easy it is to draw geometry. It has a thoroughly modern drawing interface, with a host of intuitive, smart snap settings, copy-and-paste options, and transformations. For experienced THERM users, Flixo is refreshingly forgiving when geometry doesn't line up perfectly. In fact, one of the coolest features of Flixo is the ability to overlap and layer polygons. If a beam needs to be thickened, it can simply be stretched, without the need to redraw or reposition every piece of geometry that touches it. This makes testing different versions of the same model with slightly different insulation thicknesses a snap, for example.

Another nice feature of Flixo is the customizable component database. Particular pieces of geometry that can be time intensive to draw, such as I-joists, can be created once and saved to the component database. When incorporated into a project template, they become available for every modeling project with a few clicks of a button.

Drawing angled geometry is a pain, however. Would you like to draw a line segment exactly 6 inches along a sloped roof? Prepare to get creative. Flixo expects horizontal and vertical line segments. Its intuitive parallel and perpendicular drawing guides and direct-value entries don't help much when the geometry is canted. This means that a sloped roof, for example, is best drawn with horizontal and vertical geometry and then rotated.

One way around this limitation is to import complicated geometry from a CAD program. Here Flixo really shines. When importing a Drawing Exchange Format (DXF) drawing, the program automatically opens an import wizard. Before dropping the geometry into your model, the wizard zooms you around the object, automatically identifying extra line segments, unclosed polygons, and other little errors that usually cause fits. You can delete or fix these, one after another, until the wizard finds no more issues and drops the cleaned-up geometry into the Flixo drawing. The ease of this import process is one reason why Passive House window manufacturers, such as Zola, are switching to Flixo for their thermal-modeling needs.

Once you've drawn an object, Flixo provides a vast database of materials and associated thermal properties and boundary conditions to complete the model. Currently, all of these databases use European standards such as ISO and DIN, which makes compliance with PHI Passive House standards straightforward. There is currently no ASHRAE-based material database.

While we're on the topic of American versus European standards, Flixo's method of dealing with unit conversions is more nuanced than that of most programs. Rather than offering an either/or proposition, Flixo lets users select IP or SI units for specific properties and calculation results. For example, you can draw in inches and feet, but view results in metric units. One sorely missed feature is a pop-up converter for quickly converting R-value per inch to metric units.

Flixo is a tab-based program. Once you complete a drawing on one tab, called a Model tab, you calculate heat flow with a button click. Results pop up on an associated but separate Report tab. These two pages are now linked, so changes to the model on one page transfer over to the Results page, where both geometry and calculations are automatically updated. You can configure a Report page to display a host of different results and calculations. Depending on the Flixo version, a Report page can include different types of heat flow visualizations, psi values, U-values, heat flux values, and even fRsi factors.

Report calculations can be displayed alongside both dimensioned views of the model and graphic keys, such as material properties. In this way, all the important assumptions and values going into the calculation appear together. You can set up these pages as minireports, with page numbers, labels, company logos, and other text. A Master Report page adds these features to every Report page, vastly simplifying both the calculation and reporting procedures that are so time consuming for THERM users. Each of these pages can be exported separately or combined in a multipage PDF report. If you only want a snapshot of the heat flow through a detail, you can copy that picture onto the clipboard and paste it into other word-processing or spreadsheet documents.

Perhaps the best feature of Flixo is its ability to model complex windows. All of the Flixo versions (with the exception of the most basic version, Flixo Energy) come with a DXF import feature. Two versions, Flixo Frame and the top-of-the-line Flixo Pro, provide several tools that can cut at least in half the time spent modeling windows. With Flixo Frame, you can create glass unit objects, eliminating the need to create separate glazing models that must be imported. Flixo Frame also comes with an air cavity wizard. Simply click your mouse around a group of air cavities, and the program automatically identifies and fills them with the appropriate thermal conductivity and emissivity, calculated for each, depending on their specific size, geometry, and surrounding material. This feature doesn't help window manufacturers calculate National Fenestration Rating Council (NFRC) values, which are done according to a different set of rules, but it does come in handy when calculating window frame U-values and psi-install values for Passive House certification.

Flixo Frame provides a special window frame boundary condition that automatically adjusts the frame's surface film coefficient at different points along its interior surface, according to ISO 10077-2. When it comes time to perform the thermal simulation, experience shows that Flixo has a much more stable calculation environment than THERM. Crashes are rare even for complex window frames. Taken together, these features make Flixo Frame a hands-down favorite for window manufacturers.

Unfortunately, not all of these cool features are available in every Flixo version. Flixo Frame and the expensive Flixo Pro are the only versions that come with the specialized window-modeling features. None of the other Flixo versions comes with the air cavity wizard, glass unit object, or special frame boundary condition, meaning that they cannot calculate official window frame U-values. And if a window manufacturer opts for the cheaper Flixo Frame, there is no psi value calculation tool. This confusing and frustrating functionality split is probably the worst feature of Flixo.

If you're using Flixo Energy Plus, the psi value calculation tool is standard, but there are no specialized window-modeling features. While you can create and evaluate window models, psi values incorporating a window may or may not be accurate—it depends on the type of window frame. Frames such as North American vinyl and fiberglass windows are most affected, because they have a large number of air cavities. Solid-frame wood windows with a small number of cavities are least affected.

Where does that leave Passive House folks? In essence, Flixo Frame is for window manufacturers that are modeling windows and calculating certified window frame U-values. Flixo Energy is for Passive House consultants calculating heat loss via psi values. If you need both sets of values, some creativity (or extra money) may be required, depending on the desired accuracy. Note that both PHI and PHIUS allow estimates of psi-install values for windows—as long as the values are on the "conservative side."

For most Passive House consultants occasionally tasked with calculating thermal bridge coefficients, an upgrade to Flixo makes great sense. Users say the experience is akin to going from the horse and buggy to the automobile. The time saved on the first project alone typically more than covers the cost of the software. If new users get stuck, there are a number of high-quality animated tutorials available and good product support from the manufacturer. In Flixo 8.1, coming soon, users will be able to import old THERM files into Flixo projects to get fRSi, psi value, and other calculations directly in the software. Welcome to 2018.

—Rolf Jacobson

Rolf Jacobson *is a research fellow at the Center for Sustainable Building Research at the University of Minnesota. He also consults for CertiPHIers, which sells Flixo.*

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