CHAPTER 14

Passive House Standard: A Strategic Mean for Building Affordable Sustainable Housing in Nova Scotia

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This chapter discusses the approach taken by Housing Nova Scotia (HNS) between 2014 and 2016 to address the need to build more energy-efficient housing. Working with Passive House (PH) consultants, HNS has designed and completed the construction of three PH affordable housing pilot projects.

Following a brief background on HNS including the main challenges it faces in managing its existing housing portfolio, the chapter describes HNS's greening strategy adopted in 2008. This contextual information is followed by a description of how the PH standard was adopted and expanded on the experience of working with the multidisciplinary teams involved in the design and construction of these buildings, as well as the lessons learnt through this process.

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1 Housing Nova Scotia

HNS mandate is "To ensure all Nova Scotians can find a home that is right for them, at a price they can afford, in a healthy and vibrant community that offers the services, supports, and opportunities they need" (HNS, 2013, p. 13). Specifically, HNS provides housing solutions for low- to modest-income Nova Scotians, offers programs throughout the housing continuum from homeless shelters to home ownership, and, while HNS does not fund or provide ongoing support services to clients, it works with others who may offer them. Since housing need is a complicated/complex issue, HNS therefore recognizes that cooperation and collaboration with a multitude of other players from government, private, and non-profit sectors is required (HNS, 2017, p. 2).

HNS is the largest residential landlord in Nova Scotia with CAD 13 billion in real estate assets. It owns, maintains, and operates 12,600 social housing units for low-income families and seniors that are managed by 5 regional housing authorities across the province. The HNS portfolio of buildings is built primarily for rental public housing that includes near-single family dwellings (duplex, townhomes, etc.), and low-, mid-, and high-rise Multi-Unit Residential Buildings (MURBs). Seventy five percent of the units are for seniors over the age of 58 and are typically one- to two-bedroom rental units. The rest of the units are for low-income families which are typically three to four bedrooms. Tenants pay rent geared to income, no more than 30% of gross household income, and HNS in most cases pays for energy costs which are included as part of the rent. Housing is often concentrated in a small geographic area and easily identifiable and is concentrated in urban areas where demand is higher, while there is excess supply elsewhere.[1]

Key initiatives that are being undertaken by HNS include:

1. increasing affordable housing opportunities for lower-income families, seniors, and persons with disabilities;
2. preserving existing affordable housing stock;
3. playing a key role in breaking the cycle of homelessness; and
4. reducing our impact on the environment (HNS, 2016, p. 7).

[1] Information in this section is from internal HNS sources.

2 Affordable Public Housing Challenges

The affordable housing challenges facing low-income individuals and families in Nova Scotia include an aging housing stock, an aging population, the rise in the number of people with disabilities, homelessness, low incomes, the lack of affordability for a large segment of the population, rural to urban migration, rising energy costs, changing housing types leading to more complex housing needs, and the lack of long-term federal funding for housing. Since the Province of Nova Scotia has a responsibility for providing safe, affordable housing, these challenges have a direct impact on its finances.

Sixty percent of HNS's aging housing stock was built between 1954 and 1978. This has had a severe impact on building performance since "Building envelope performance is strongly linked to the age of the housing stock. Inferior products and methods (by today's standards) used in the original construction result in excessive air infiltration and heat loss" (NS DCS Greening Strategy, 2008, p. 2).

In addition, several hindrances impact HNS and drive up its operational costs. First, are the rising costs of utilities (electricity, oil, propane, natural gas, water) which range between CAD 20 million and CAD 30 million, amounting to 15–20% of HNS annual budget. Second, energy prices are volatile. Third, tenants who pay for heat and electricity have a limited capacity to absorb utility price increases. Fourth, it is difficult to reduce heating and electrical demand due to the type of tenancy composed of mostly seniors who spend most of their time indoors and, anecdotally, have a tendency to keep higher temperatures in their homes. Fifth, since HNS pays for most of the utilities, tenants do not benefit from any energy savings. Sixth, the increase in operational costs reduces any savings that could go toward capital investments or to increase the supply of affordable housing. Lastly, allocated budgets do not dedicate funding specifically for energy efficiency projects making it a challenge to devote resources for sustainability run initiatives. Given the list of obstacles, focusing on improving energy efficiency and construction quality to reduce the energy costs for the housing units will benefit HNS indirectly through utility cost savings, thus making funds available for other areas of housing.[2]

[2] HNS internal documents.

3 HNS Sustainability Initiatives

Despite these challenges, HNS made a commitment to sustainability and has been improving the energy efficiency of its portfolio for over 30 years. In 2008, HNS authored a greening strategy that set out to reduce costs and increase efficiency by improving five key energy usage drivers:

1. building envelope performance;
2. mechanical and electrical systems;
3. maintenance and operations of the portfolio;
4. raising energy conservation awareness among building occupants; and
5. products and services and information systems

In early 2014, the Building Design Team (BDT) at HNS put forward a proposal (Energy Reduction Initiative [ERI] (HNS, 2014a)) aimed at improving the performance of its buildings. The plan focused on strategies to improve building envelopes and targeted reductions in space heating loads and increased efficiency. In November of 2014, HNS signed a Memorandum of Understanding with Efficiency Nova Scotia (ENS) (HNS, 2014b) to benefit from their expertise and rebate programs. ENS is a franchise operated by EfficiencyOne, an independent, non-profit organization which manages energy saving programs and services for Nova Scotians. Lastly, the ERI explored the possibility of using PH standards as a potential path to achieve sustainability and affordability for HNS and the private-sector.

Since one of the pillars of the HNS's housing strategy is building "healthy vibrant communities," it developed a pilot Neighborhood Revitalization Initiative (HNS, 2013, p. 19) to upgrade the condition of dwellings and, where feasible, build new ones through residential infill construction in targeted neighborhoods across the province. The stated purpose of this pilot program was to vitalize areas in need of stabilization due to adjacent or internal pressures that may include development pressures, high crime rates, or general need to upgrade the visual appearance. The first targeted neighborhood (Alice Street) was designated in collaboration with the Town of Truro and included one or more of the following characteristics: older residential properties in need of exterior building improvements, much of the properties being owner occupied and having predominantly low- to modest-income homeowners and tenants. Accomplishments of this program are documented in HNS's *Annual Accountability Report 2015–2016* (HNS, n.d.).

4 The Passive House Standard

According to the PH Institute, "Passive House is a building standard that is truly energy efficient, comfortable and affordable at the same time" (Passive House Institute, n.d.). The focus of the design standard is to conserve energy by reducing heat loss through the building envelope and maximizing solar heat gains. A building constructed using PH principles is very well-insulated, airtight, and primarily heated by passive solar gains and internal gains from people, electrical equipment, and so on. Energy losses are minimized, and any remaining heat demand is provided by a source that is smaller than what would otherwise be required for a conventional home. Cooling loads are limited by minimizing heat gains through shading and window orientation. An energy recovery ventilator (ERV) provides a constant, balanced fresh air supply and excellent indoor air quality.

The key principles of PH are:

1. Superinsulation: Installing a continuous layer of thick insulation below the foundation, on the walls, and in the attic.
2. Airtightness: 0.6 Air Changes per Hour (ACH) which is at least two times tighter than the R2000 standard which is "no greater than 1.5 air changes per hour" (Natural Resources Canada, 2012).
3. Minimize thermal bridging: Avoiding "cold spots" by designing thermal breaks in the building assemblies.
4. High-performance windows and doors: Triple-glazed, argon-filled, custom low-e coatings, airtight. This insures more solar heat and reduces transmission losses.
5. Use very high-efficiency heat recovery ventilator (HRV): Installed with best practices, the HRV will provide adequate fresh air while reducing heat losses.

The benefits of building to PH standards are as follows. First, it helps cut energy costs since "Passive Houses allow for space heating and cooling related energy savings of up to 90% compared with typical building stock and over 75% compared to average new builds" (Passive House Institute, n.d.). Second, a PH does not require a conventional heating system as it relies on passive heat sources of solar and internal heat gains. Third, having an airtight envelope minimizes outside noise. Fourth, the quality of indoor space is improved with careful ventilation and natural daylighting.

Fifth, according to the "majority of costing studies and construction estimates report that the cost increment of building to Passive House standards is less than 10%, with the average value being around 6%" (Pembina Institute, 2016, p. 52). Sixth, even though there is a significant increase in the embodied energy of added insulation layers in the envelope and other building elements, the operational cost of the building is reduced and "the measured energy use reductions in passive buildings compared to typical construction ranges from 40% to over 80% when considering total energy use intensity" (Pembina Institute, 2016, p. 34).

According to a recently published research by the Pembina Institute, there are "several reasons to prioritize an enclosure-focused approach to energy efficiency:

- Building enclosures are long lasting and costly to refurbish, unlike other systems that can be more easily replaced as better technologies become available.
- Enclosures are simple systems; their performance does not depend on complex energy management systems and they are more tolerant to delayed maintenance.
- Reducing heating and cooling demand early in the design process allows for reduction of the size of space conditioning systems, reducing construction cost and ongoing energy demand.
- High-performance enclosures also offer significant non-energy benefits, such as thermal comfort, acoustic isolation, durability, and increased resiliency to power outages and extreme temperature events" (Pembina Institute, 2016, p. 1).

In providing affordable housing, HNS strives to identify efficient and cost-effective solutions. Therefore, the focus of PH on simple conservation aligns with HNS's corporate philosophy. There are two standards commonly used: The PH Institute Standard and the PH Institute US (PHIUS). These two standards are the basis for acquiring certification or a PH building. The advantages of certification are quality assurance and guarantee that the building has met the defined criteria set out in the standards. For HNS, this was doubly important because it was building pilot projects using PH standards for the first time using public money.

Table 14.1 summarizes these requirements.

Table 14.1 Passive House certification standards

	PH institute standard	*PHIUS climate adjusted standard*
Thermal performance of envelope	≤15 kWh/SM	Varies by climate (≤7.1 KBTU/SF/yr. in NS)
Total energy consumption	≤120 kWh/SM	≤6000 kWh/person/yr
Airtightness	≤0.6 ACH @ 50 Pa	+ ≤0.05 cfm/SF @ 50 Pa

5 Passive House Case Studies: Passive House Pilot #1: 74 Alice Street, Truro

5.1 Project Context

In mid-2013, the first area chosen for revitalization under the Neighbourhood Improvement Initiative pilot program was the Alice Street neighborhood. This area is located near the Town of Truro's Eastern boundary. In addition to upgrading existing buildings, HNS planned the demolition of a provincially owned two-story single family dwelling at 74 Alice Street that was deemed structurally unsafe. The plan was to redevelop the property into two new affordable family dwellings that were to become part of the first subsidized affordable pilot housing project built and certified to PH standards in Nova Scotia.

In early 2014, a feasibility study was conducted to verify the viability of applying these standards to the Alice Street project. This was particularly important since HNS's BDT had already designed a three-bedroom duplex for the site and had obtained a development agreement (DA) from the Town of Truro's planning department. An immediate challenge facing the project was the fact that the south-facing windows were shaded and solar incidence, one of the PH principles, was minimized, making them energy neutral. While this meant that the building could not achieve certification under the PH International (PHI) standard, it was still deemed possible to move ahead to achieve certification using the climate adjusted PH standard developed by PHIUS.

5.2 Project Design

Shortly following the decision to pursue certification through PHIUS, a tender was issued for consulting services to apply these design principles to the new units. A certified local PH consultant who had completed 14 projects brought extensive PH knowledge and construction experience in the Nova Scotia climate to this project. Next, the PH consultant conducted the energy modeling required using the proprietary PH Planning Package (PHPP) (Passive House Institute, n.d.). Based on the results of the modeling, the PH consultant worked closely with the BDT to incorporate PH design principles and provided recommendations to execute the requirements to achieve certification as set out by the PHIUS. The consultant also specified assemblies and mechanical systems that have been successfully installed in projects built in Nova Scotia. Finally, the consultant was engaged to provide construction administration technical services, support, and training to the contractor and quality assurance from the tendering, through construction, till the end of the contractor's warranty period.

The first step in designing the Alice Street redevelopment project was to leverage the site's natural solar gains by strategically orienting its windows and doors, while at the same time maintaining an aesthetic that compliments the neighborhood and creates a pleasing space for the occupants to live in. the building's orientation facing the street is north-south. The existing street had a specific building pattern which the new design respected and made sure that it fit within. The proposed building was close to maximum buildable area with each housing unit of 2030 Square Foot (SF). Thicker walls required redesign and filled remaining space in the allowable footprint. There was a need to shift some rooms and walls for more usable space but it still followed the original design.

5.3 Project Construction

In mid-2015, through a public tender that specified tested and reliable assemblies, a construction contract was awarded to a local construction firm with a cost of approximately CAD 125/SF. As part of the project, the consultant was contracted to provide hands-on training and construction support to the contractor on the project. At appropriate times during the construction schedule, the consultant worked hands-on to demonstrate the techniques necessary to build the PH assemblies correctly. The site training was scheduled for specific crucial tasks for the project.

As part of the support that this project received from ENS, there was an instructional video made with a professional crew that captured the major milestone steps in the construction process (Picture 14.1). The purpose of the video was to raise awareness among HNS staff and the construction community about PH. The video covered the following six key steps:

Picture 14.1 Truro Passive House video documenting air-sealing walls and penetrations

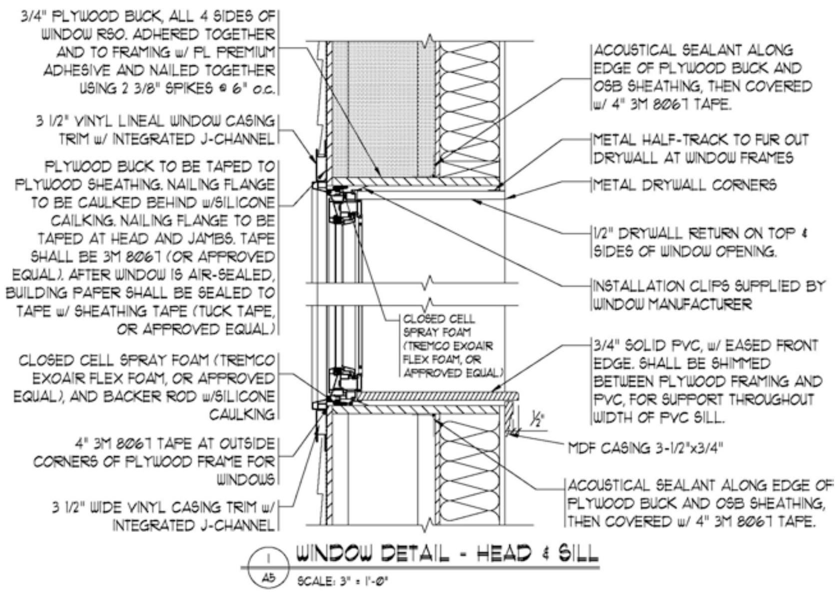
1. laying sub-slab insulation and vapor barrier installation;
2. installation of exterior walls and air-sealing exterior walls and penetrations;
3. installation and air sealing of windows and doors;
4. electrical rough in, plumbing rough in, heat pump rough in, ventilation rough in;
5. blower door pre-drywall, final blower door, and ventilation commissioning; and
6. summary of completed home—review of costs and savings.

The following sections describe the building process documented in the video which applies to any PH construction project.

Vapor Barrier and Slab Foundation Insulation: The Alice Street house had a full basement built using insulated concrete forms (ICF) walls. A significant amount of foam insulation was added below the foundation.

ICF walls just meet National Building Code (NBC) requirements for thermal performance, but additional foam inserts were introduced to increase the R-value of the wall. PH principles can be applied to a full basement like this project as well as with slab-on-grade construction. Careful attention was given where penetrations were made in the foundation; for example, sealing toilet penetrations.

Wall construction: Two walls were constructed: an interior, 2x6 load-bearing wall and an exterior wall built from Truss I-Joists (TJI) to provide a significant amount of additional insulation. Conventional construction only calls for the single interior 2x6 wall. The exterior wall was taped as it is the airtight layer. To ensure the building is airtight, transitions to other building components and assemblies required careful detailing. For example, where the window was mounted, where the wall meets the foundation and where the wall meets the roof. Windows used were triple-pane, argon-filled, insulated fiberglass frames, with custom coatings to maximize solar gains (Picture 14.2).



Picture 14.2 Truro Passive House window detail

Penetrations: It was crucial to take extra care around mechanical and electrical rough in work. The contractors were asked to run everything they can inside the plywood box and once they leave the box, they had to use a controlled penetration. Even if the project does not plan to install a security system, it is good to rough in the wiring for the system so that if a system is installed in the future, no additional penetrations are needed.

Blower door testing: Two tests are done: one "pre-drywall" test and one final test when the home was complete. The purpose of the pre-drywall test is to evaluate the airtightness of the building while there is still an opportunity to identify the location of the leaks and seal them before finishes are applied.

Ventilation: Once the building enclosure was addressed and a very airtight home was achieved, the crucial next step was to provide proper ventilation to insure good indoor air quality for the occupants and, at the same time, minimize heat loss to ventilation. All new construction requires mechanical ventilation; this is especially important in a PH as the home achieves very high levels of airtightness. For comparison, the airtightness target for a PH is almost three times higher than an R2000 home. A very efficient HRV is installed in a PH, with careful attention paid to the penetrations and system balancing.

Mechanical Equipment: The next biggest source of energy use in the home was domestic hot water. To address this, a heat pump water heater was installed, which is much more efficient than any conventional water heating appliance. Since the home was super-insulated and airtight, much of the heating demand was met by solar gains and internal loads such as appliances, lighting, and the heat generated by the occupants themselves. As such, only a simple, inexpensive heating system was needed, and electric baseboards were installed. This led to substantial savings over a central heating system, for example, a fully ducted air source heat pump, boiler, or furnace.

Table 14.2 is a fact sheet for Alice Street.

The Alice Street project was completed in May 2016 and achieved PHIUS certification in September of the same year (Picture 14.3). The final cost of the project was CAD 519,498 and when compared with a code-built building, using the 2015 NBC of Canada, with the same specifications, the increase in costs was 16%. The calculations were based on the actual financial information obtained from the contractor who built the project.

One of the unforeseen factors that caused a cost increase was the need to raise the foundation by one foot to take into a water stream, which was encountered after excavations. On the other hand, there was no significant

Table 14.2 Truro Passive House project fact sheet

Truro Passive House Project fact sheet	
Location	Truro, Nova Scotia
Construction	New
Type	Duplex
Size	2030 SF/Unit
Treated floor area	1685 SF/Unit (156.5 SM/Unit)
Bedroom	3
Bathroom	1.5
Architect	Building Design Team, Housing Nova Scotia
Energy consultant	Passive House E-Design
Builder	Global Construction
Construction costs	CAD 519,498
Date completed	May 2016
Construction	
Foundation slab	4 in. slab over 8 in. EPS Type 2 rigid insulation
Basement wall	8″ ICF block wall with additional 2″ rigid insulation on exterior and interior 2x4 Roxul service wall
Walls	Vertical 9–1/2″ Trus Joist I-Joist (TJI) w/cellulose insulation; 7/16″ Oriented Strand Board (OSB) sheathing caulked and taped at all joints and 2x6 Roxul structural stud wall
Roof	Insulation 28″ loose fill cellulose, 7/16″ OSB sheathing caulked and taped at all joints on open-web wood trusses
Windows	Triple-pane, argon-filled, low-e, fiberglass frames
Key energy efficiency measures	
HVAC	
Heating	Electric baseboard backup
Ventilation	High-efficiency heat recovery ventilator. All bathroom and kitchen exhaust ventilation is run through switches on the HRV system

Envelope

- Wall R-Value = 53.2*
- Basement Wall R-Value: 42.2*
- Slab-on-grade R-value = 33.3*
- Ceiling R-value = 101.9*
- Windows U-value = 0.15 to 0.20
- Air sealing, ACH50 = 0.4 (tested)

*R-values come from the energy model and considers all bridging, layers and air films.

Lighting, appliances, and water heating

- A domestic hot water: heat-pump electric hot water heater, with a seasonal COP of 2.5.
- A 100% compact fluorescent lamps and light-emitting diodes.

Picture 14.3 Truro Passive House front view

reduction in useable space due to the increased insulation thickness in the walls since the building was extended in length to the back of the lot to make up for the loss in the building width (Table 14.3).

Preliminary energy data acquired from Nova Scotia Power (NSP)[3] bills showed actual average monthly electrical consumption for Unit-1 was 990 kWh, while actual monthly electrical consumption for Unit-2 was 715 kWh. The differences are attributed to tenant usage. Compared to the average household energy use by a code-built dwelling with three household members in Nova Scotia 2570 kWh/month[4] (Statistics Canada, 2015) there appears to be reduction in the range of 62–72% reduction over code-built dwelling (Table 14.4).

[3] We do not have accurate readings from the energy monitoring system and instead NSP bills were used from June 13, 2016, to June 12, 2017.

[4] This figure is from Statistics Canada (http://www.statcan.gc.ca/pub/11-526-s/11-526-s2013002-eng.pdf) Table 4–1 Average household energy use, by household and dwelling characteristics, 2011—gigajoules per m 2 of heated area (0.71GJ*156.5 SM = 111GJ per unit). This is equivalent to 2570 ekWh/month per unit.

Table 14.3 Truro Passive House cost comparison with code compliant construction cost

Truro Comparison Cost Report
December 20, 2016

Description	Passive house standard Amount ($)	Code compliant Amount ($)	Premium ($)
Exterior			
Concrete foundation	49,413	25,900	23,513
Windows	18,682	12,500	6182
Doors	6505	3580	2925
Framed wall insulation	3095	3895	(800)
TJI wall insulation	2750	0	2750
Slab insulation	4100	1300	2800
Roof insulation	2100	850	1250
Taped OSB	1500	0	1500
Vertical TJIs	8300	0	8300
Attic hatch	800	90	710
Vinyl cladding, fascia, soffit	3500	3800	(300)
Decks and porches	0	0	0
Roofing	0	0	0
Excavation	0	0	0
Interior & systems			
Sheetrock	0	0	0
Doors	0	0	0
Paint	0	0	0
Floor finish	0	0	0
Elect baseboard	5800	4800	1000
Subfloor	0	0	0
HRV & ductwork	12,200	7900	4300
Plumbing fixtures	4800	1900	2900
Stairs & railing	0	0	0
Cabinetry	0	0	0
Devices, switches	0	0	0
Wiring	2200	0	2200
Plumbing	2400	0	2400
Light fixtures	0	0	0
Total Building Costs (including taxes)	497,498	435,868	61,630
PASSIVE HOUSE CONSULTANT & CERTIFICATION (including taxes)	22,000	0	22,000
Total project costs including passive components	519,498		

(*continued*)

Table 14.3 (continued)

Truro Comparison Cost Report *December 20, 2016*		
Total project costs excluding passive components	435,868	
PREMIUM FOR PASSIVE DESIGN—VALUE		**83,630**
PREMIUM FOR PASSIVE DESIGN—PERCENTAGE		**16%**

Source: Global Construction.

Table 14.4 Truro Passive House project analysis

Truro Passive House project analysis
Total cost 1. Total, project cost for Truro = CAD 519,498 2. Additional cost related to PH cost @ 16% of total project costs = CAD 83,630 (CAD 41,815/unit)
Total actual energy consumption (per the Truro NSP bills,) 1. Actual Average Total Monthly Electrical Cost of both units CAD 277 2. Actual Average Total Annual Electrical Cost of both units CAD 3324 3. Actual Average Total Annual Electrical Cost of each unit CAD 1662
Equivalent energy consumption 1. Monthly equivalent energy consumption for code-built dwelling is 2570 ekWh. 2. Estimated, monthly, cost of energy is CAD 463 @CAD 0.18/kWh. 3. Estimated, total, annual, energy consumption cost per unit = CAD 5551/yr.
Return-on-investment (ROI) based on actual energy consumption 1. Return-on-Investment At 10 yrs. would require estimated, annual, savings of CAD 8363 (CAD 4181/unit) At 20 yrs. would require estimated, annual, savings of CAD 4181 (CAD 2090/unit) 2. Estimated, annual, electrical consumption savings due to Passive House Design = CAD 5551 – CAD 1662 = CAD 3889/yr. 3. ROI for PH costs @ 16% of total project costs = CAD 41,815/CAD 3889 = 10 Years

5.4 *Communication, Education, and Marketing*

HNS learnt tremendously from this project and made every effort to share these lessons. HNS invited interested stakeholders to visit the newly constructed duplex during an open house with BDT and the PH consultant available to answer questions. One open house was specifically dedicated to

HNS and regional Housing Authorities staff, a second for provincial government employees, and a third for the public. Specific invitations were sent to relevant groups such as the Nova Scotia Association of Architects, the Nova Scotia Home Builders Association, and Dalhousie School of Architecture and Planning, among others. There were media reports on the radio as well as interviews with HNS's chief executive officer. Finally, the video produced by ENS was shared on the internet on Vimeo (https://vimeo.com/user24834665/review/173926323/48370de629).

The Alice Street project won several awards including the 2016 ENS Bright Business Award jointly with the PH consultant and the 2017 Department of Community Services Minister's Ideal Innovation Team Award, and the 2017 Nova Scotia Premier's Excellence Award. It was also the finalist in the 2016 Smart Energy Communities Award under the real estate sector.

6 Passive House Pilot #2: 831 Highway 1, Hebron Heights

6.1 Project Context

This project involved the retrofit of an existing vacant building that was formerly used as an institutional residential care center. The property located at 831 Highway 1 in Hebron, Yarmouth County in southwest Nova Scotia, formerly known as the Hebron Resource Centre, was operated under the umbrella of the Department of Community Services who no longer used the facility and it sat vacant for many years. Since the property was owned by HNS, an evaluation study in late 2015 established the viability and suitability of converting it to a multi-residential senior complex of approximately eight units with at least 50% of the units to be fully accessible. In addition, the study confirmed that the property could also be renovated to meet PH design requirements.

The Western Regional Housing Authority (WRHA) director and staff met with the Municipality of the District of Yarmouth Planning Department who were very excited about the opportunity to see the property developed into a senior apartment complex. ADA was submitted, and due to the urgency, the process only took two months instead of the usual four to six months. During that time, work continued on tender documents, design, revenue models, and any renovations not dependent on the DA, such as demolition, windows, roof, and siding replacements.

The existing building orientation has excellent southwest exposure overlooking Doctors Lake and is situated on a large parcel of land providing an opportunity for outdoor garden spaces and offering the possibility of expansion or subdividing the land to provide additional housing units. The project is composed of two levels with a total combined area of approximately 8000 square feet and consists of 8 one-bedroom plus den units and 1 one-bedroom unit aimed at low-income seniors, singles, or families and will be operated by the WRHA. This project was realized as part of HNS's efforts to increase the supply of affordable rental housing in response to market demand for seniors' independent living, which is consistent with the provincial housing strategy.

6.2 Project Design

This project was the first affordable multi-unit apartment PH complex in Nova Scotia seeking certification. The initial conditions had several design challenges. First, the design team had to work with an existing building footprint and structural system. Second, as per the latest NBC requirement, the bedroom had to have an egress door to the outside on each level which meant that the layout of the apartment had the bedroom located on the exterior of the building. Third, there was the potential for overheating during summer months from existing large south- and west-facing windows. Fourth, there needed to be a central heating system while, at the same time, providing residents in each unit the ability to control temperature. Finally, using a central HRV in a multi-family building required fire separations between apartment units which, in a multi-family PH pose a challenge in terms of maintaining airtightness and avoiding thermal bridges.

For the design approach, the BDT at HNS worked with the PH consultant to apply PHIUS's Climate Adjusted Standard (PHCAS). Using Wärme Und Feuchte Instationär (WUFI) Passive (Passive House Institute US, n.d.) as the modeling software, the goal was to seek certification based on PHIUS+ 2015 Standard. This required an integrated design approach with WRHA, HNS BDT, external consultants, and equipment suppliers.

An initial WUFI model was created regarding the existing and schematic architectural documents provided. Several iterations of the model were created as mechanical systems and envelope components were refined in accordance with inputs from the PH consultant, equipment suppliers, and the BDT architects and engineers. The final iteration considered the best way to achieve the PHCAS on the original schematic design provided.

The design response for heating was to use an air-to-water heat pump unit that uses a hot water system for hydronic heating and domestic hot water with a propane boiler used as backup heat source. The unit was chosen with a high coefficient of performance. Low-heat baseboard hydronic units in each unit with individual thermostats were installed. Hot water is recirculated and hot water tanks are used to maintain the necessary hot water demand. The air-to-water heat pump provides the needed flexibility for controls in each unit. It also supplies space heating and cooling as well as water heating and it reduces energy and cost by producing 2–5 kW of heat energy for each kW it consumes.

Regarding ventilation, a central ERV was used, which provided ventilation, humidity control, and return air heat recovery. The ERV delivers continuous low volume supply and exhaust ventilation for the whole building and supplies ventilation based on demand per apartment with an independent high booster control. The installed unit provides 1000 Cubic Feet per Minute (CFM) supply air and 1000 CFM exhaust air, has a dual core air handling unit with a regenerative cyclic dual core heat exchanger with supply and exhaust fans, and two cores acting as heat accumulators. Heat recovery is automatically activated on request. Using a central ERV that provides heating and cooling with up to 90% efficiency offsets the cost of fire dampers.

The electrical design response included a backup generator which is typical for seniors' buildings. Each unit has its own "emergency" circuits on a generator in case utility power goes out. The boiler is on the generator for heating in case of power outage. The building was also designed to be photovoltaic solar-ready for installation of a 15 kW, 60-panel, 3-phase, grid-tied, micro-inverter-based PV system.

The project was cost shared between HNS and Canada Mortgage Housing Corporation (CMHC) with a funding of CAD 1.6 million. These funds were made available under the Investment in Affordable Housing (IAH) Agreement and were approved as part of the 2015–2016 fiscal budget. By using energy-efficient PH design, WRHA could potentially save on heating costs which would be verified once data from the energy monitoring devices is compiled.

6.3 Project Construction

The project had a very tight timeline to be completed by March 2016, the end of the 2015–2016 fiscal year. At first, this seemed to necessitate a fast track approach, whereby construction could start before the design was completed to shorten the time to completion. This would have required that the BDT issue separate construction packages. When reviewing the fast track option, it was decided that it is better to design and build instead, since the risks associated with pricing outweighed any time savings.

The construction tender was awarded to a local construction firm that had built the original building. This made the construction process easier since the builder was familiar with the elements of the existing building. Due to the reconfiguration of the original spaces, it was not possible to reuse the existing interior partitions to match the new layouts. Furthermore, the roof did not meet the new building code structural requirements and had to be replaced completely, which added to the construction costs (Table 14.5).

A detailed cost comparison for the Hebron study was commissioned to Hanscomb Limited, a quantity surveying and cost analysis firm in Halifax. The results, summarized in Table 14.6, show a 7% increase for construction built to PH standard compared to code-compliant construction. Since the Hebron pilot was a retrofit project, there were some cost savings owing to the reuse of some of the existing building elements which is not the case in the new construction (Picture 14.4 and 14.5).

At the time of this writing, no data were available to compare the modeled and actual energy use since the Hebron energy management systems has not been providing any reports (Table 14.7).

7 Passive House Pilot #3: 7–9 Brownell Avenue, Amherst

7.1 Project Context

The project in Amherst was a replacement of an existing duplex on Brownell Avenue that was damaged by fire. An assessment of the building was conducted and it was decided that a complete reconstruction would be a better solution than repairs. This was another opportunity to construct to the PH standard and to leverage the experience gained from the Alice Street project. For contractual and budgetary reasons, it was not possible to engage a PH consultant upfront and the BDT developed the design in-house based on the Truro experience. Although the project footprint was smaller (2-bedroom unit of 1000 SF each), it had similar design and specification features as Alice Street (Pictures 14.6 and 14.7).

Table 14.5 Hebron Passive House project fact sheet

Hebron Passive House project fact sheet	
Location	Hebron, Nova Scotia
Construction	Retrofit
Type	Multi-Unit Residential Building (MURB)
Units	9
Estimated occupants	18
Total building size	15,154 SF
Total treated area	7842 SF
Unit treated area	855 SF
Bedrooms	1/Unit
Bathrooms	1/Unit
Architect	Building Design Team, Housing Nova Scotia
Energy consultant	Passive House E-Design
Builder	Graham Construction LTD.
Construction costs	CAD 1,553,749
Date completed	March, 2017
Construction	
Foundation slab	2½" EPS Type 2 rigid insulation over existing 4″ concrete slab and existing, 2″ rigid insulation.
Below grade walls	Existing 8″ concreate foundation with existing 4″ insulation below grade on exterior and new 4" EPS rigid insulation above-grade on exterior.
Exterior walls	3½" Roxul Batt Insulation in 2 × 4 studs, 7/16" OSB sheathing c/w all joints caulked with acoustical sealant and taped, 5½" Roxul Batt Insulation in existing, 2 × 6 studs.
Roof	Insulation 28″ loose fill cellulose, R-3.8/in thermocell procell, 7/16" OSB sheathing c/w all joints caulked with acoustical sealant and taped.
Windows	Triple-pane, argon-filled, low-e, fiberglass frames
Key energy efficiency measures	
HVAC	
Primary heating	Hydronic, air-to-water heat pump, COPmin.3.5.
Secondary heating	High-efficiency, propane-fired, condensing boiler.
Ventilation	High Efficiency Energy Recovery Ventilator (ERV), continuous exhaust from kitchen and bathrooms in units with switch boost.

(*continued*)

Table 14.5 (continued)

Hebron Passive House project fact sheet

Envelope

- Wall R-Value = 63*
- Basement Wall R-Value: 46*
- Slab-on-grade R-value = 27*
- Ceiling R-value = 103*
- Windows U-value = 0.13
- Air sealing, ACH50 = 0.66 (tested)

*R-values come from the energy model and take into account all bridging, layers and air films.

Lighting, appliances, and water heating

Domestic hot water	Indirect hot water tanks.
Appliances	Energy Star rated, energy efficient appliances (Fridge, Dishwasher, Washer, Dryer, Oven, and Range).
Lighting	LED lamps and LED light fixtures.

Table 14.6 Hebron Passive House cost comparison with code compliant construction cost (Hanscomb, 2017, p. 10)

Comparison cost report Hebron
April 19, 2017

Description	**Passive house standard Amount ($)**	**Code compliant Amount ($)**	**Premium ($)**
1. Substructure	594	0	594
2. Structure	18,318	0	18,318
3. Exterior enclosure	93,585	32,369	61,216
4. Mechanical	110,475	126,100	−15,625
5. Electrical	0	0	0
6. Site	0	0	0
Subtotal (excluding taxes)	222,973	158,469	64,504
Taxes	33,446	23,770	9676
Total passive costs (including taxes)	256,419	182,239	74,179
Total building costs (including taxes)	1,527,134	1,452,955	74,179
Passive House consultant & certification (including taxes)	26,615	0	26,615
Total project costs including passive components	1,553,749		
Total project costs excluding passive components		1,452,955	
PREMIUM FOR PASSIVE DESIGN – VALUE			**100,794**
PREMIUM FOR PASSIVE DESIGN – PERCENTAGE			**7%**

Picture 14.4 Amherst Passive House front view

At around the same time, ENS initiated a PH Pilot project under its New Home Construction program, which "provides increased incentive levels for home builders who wish to build to the PH standard. The program eligibility allowed for the homes to be semi-detached, be registered in the pilot before construction begins, and have a site inspection performed within one year of registering. Furthermore, energy modeling services were to be performed by a certified PH consultant. Projects that meet minimum performance requirements would receive a rebate of CAD 10,000 if they achieve a modeled annual heating energy intensity of 22.4 k Wh/m^2/year. This could be realized using PHI or PHIUS certifications or using either PHPP or WUFI modeling software.

HNS registered the Brownell project with ENS and it became clear that engaging a PH consultant during the construction phase was crucial to provide quality assurance and ensure that the project was built to the minimum performance requirements to receive the ENS rebates. The tender for the construction of the project was issued in February 2016 and awarded in March with an anticipated six months' period for completion.

Picture 14.5 Amherst Passive House interior view

A change order was issued shortly after the tender was awarded to engage the services of the PH consultant as part of the contractor's responsibility.

7.2 Project Design

Even though the BDT used the same approach as in Alice Street, there were differences in the two projects requiring detailing that the PH consultant provided and had to be adjusted during the construction phase. These differences included an entrance detail which had a cantilever, the wall separating the two units, and detailing of the existing basement wall.

7.3 Project Construction

As with all provincial construction contracts, a public tender was issued for Brownell and was to be awarded to the lowest bid price. One of the construction firms submitted a bid price that was close to the BDT's cost estimate to construct the project. The same firm submitted a new price

Table 14.7 Hebron Passive House project analysis

Hebron Passive house project analysis
Total cost 1. Total, project cost for Hebron = CAD 1,527,134 2. Additional cost related to PH cost @ 7% of total project costs = CAD 100,794 3. Return-on-Investment: At 10 yrs. would require estimated, annual, savings of CAD 10,08 At 20 yrs. would require estimated, annual, savings of CAD 5004
Energy Consumption (per the Hebron WUFI model) 1. Total, floor area = 7824 SF 2. Total, annual, space heating and DHW demand for the facility = 31,350 kWh/yr. 3. Estimated, total, annual, electrical consumption cost to meet the space heating and DHW demand = CAD 3240/yr. (@CAD 0.18/kWh)
Equivalent Energy Consumption (per the Canada Mortgage and Housing Corporation (CMHC). (n.d.)) 1. Annual, equivalent energy consumption (ekWh/SM) of MURBS built between 1980 and present is 212 ekWh/SM which is equivalent to 19.7 ekWh/SF 2. Estimated, annual, equivalent energy consumption = 19.7 ekWh/SF × 7824 SF = 154,133 ekWh/yr. 3. Estimated, total, annual, equivalent energy consumption cost = CAD 27,744/yr. (@CAD 0.18/kWh)
Return-on-investment (ROI) 1. Estimated, annual, electrical consumption savings due to Passive House Design = CAD 27,744 –CAD 3240 = CAD 24,504/yr. 2. ROI for PH costs @ 7% of total project costs = CAD 100,794/CAD 24,504 =4 years

about one hour before the tender closing time with an amount of half of its original bidding price. Since it was the lowest bidder, the bid had to be accepted and the tender was awarded to this construction firm.

Once the project started, it became clear that the contractor did not realize that this was a PH project which required a higher level of care, coordination, and quality control compared to a code-built project. During the project, some of the contractor's staff took the PH Builder's Course, which added to their knowledge and appreciation of PH construction methods.

Other difficulties the project faced were due to: the construction crew having to commute back and forth to Amherst from PEI; the low bid price; a lack of consistent work on site that caused delays; as well as a long wait for the delivery of windows and doors. There were also issues with the quality of construction which did not meet the PH standard in terms of air leakage and had to be addressed on several occasions. Finally, all these delays affected the morale of everyone working on the project (Table 14.8).

Picture 14.6 Hebron Passive House south east view

Picture 14.7 Hebron Passive House south west view

Table 14.8 Amherst Passive House project fact sheet

Amherst passive house project fact sheet	
Location	Amherst, Nova Scotia
Construction	New Construction
Type	Duplex, Split-entry
Units	2
Total building size	15,154 SF
Unit treated area	965 SF/Unit
Bedrooms	3/Unit
Bathrooms	1/Unit
Architect	Building Design Team, Housing Nova Scotia
Energy consultant	Passive House E-Design
Builder	Sperra Construction
Construction costs	CAD 303,262
Date completed	April, 2017
Construction	
Foundation slab	3″ EPS Type 2 rigid insulation over existing concrete slab
Basement walls	Blueskin self-adhesive waterproofing membrane and 2″ EPS Type 2 Rigid insulation on the exterior of existing, concrete wall. 1″ EPS Type 2 Rigid Insulation and 3 ½″ Roxul Batt Insulation on interior side of the existing, concrete foundation wall
Walls	Vertical 9 ½″ TJI w/cellulose insulation. 7/16″ OSB sheathing caulked and taped at all joints and 2x6 Roxul structural stud wall
Roof	Insulation 28″ loose fill cellulose, R-3.8/in Thermo-Cell ProCell, 7/16″ OSB sheathing c/w all joints caulked with acoustical sealant and taped at all joints on open-web wood trusses
Windows	Triple-pane, argon-filled, low-e, vinyl frames
Key energy efficiency measures	
HVAC	
Primary heating	Electric baseboard
Ventilation	High-efficiency heat recovery ventilator (HRV). All bathroom and kitchen exhaust ventilation is run via switches on the HRV system
Envelope • Wall R-value = 54* • Basement wall R-value: 28* • Slab-on-grade R-value = 19*	

(*continued*)

Table 14.8 (continued)

Amherst passive house project fact sheet	
• Ceiling R-value = 105* • Windows U-value = 0.17 (average) • Air sealing, ACH50 = 0.83 (7 Brownell Ave.) and 0.75 (9 Brownell Ave.) tested	
*R-values come from the energy model and take into account all bridging, layers and air films	
Lighting, Appliances, And Water Heating	
Domestic hot water	Electric hot water tanks
Lighting	LED lamps and LED light fixtures

At the time of this writing, the Brownell project at Amherst had some remaining deficiencies including the energy monitoring systems not being hooked up, which means no energy data could be acquired. Furthermore, the cost analysis for PH construction would have required the contractor to share costs which was unlikely given the difficulties faced and the ongoing contractual deficiencies.

8 HNS PH Pilot Projects: Lessons Learnt

The focus of the PH standard is conserving energy by reducing heat loss through the building envelope and maximizing solar heat gains. Some of the conclusions were that PH is economically viable because it uses simple conservation techniques that are not complicated or expensive. By using PH standards, HNS can adapt conventional construction materials and techniques in its tenders to reduce energy needs. PH is a viable approach for housing in Nova Scotia, given the wealth of consultants' expertise which could be leveraged to create a new standard of construction. While HNS's main role is about creating affordable housing opportunities for low-to modest-income Nova Scotians, it is aware of its unique position to foster innovation and promote energy efficiency in the construction industry. Making PH more common in the province could have a positive impact by reducing overall energy costs and, over the long run, making homes more sustainable. It would also certainly contribute to consultant and contractor capacity building, which in turn could drive down the costs of PH construction and reduce delays caused by having to redo design or construction work to meet the standard.

The lessons learnt from these three pilot projects are summarized below. However, these conclusions are specific to Nova Scotia. Case studies and technical references must be used to apply these results to other Canadian or international locations.

Pre-qualification: Pre-qualify contractors to ensure that they have the minimum capability of delivering PH project requirements. HNS experienced some challenges by not pre-qualifying contractors in its Amherst PH project, which suffered in terms of quality and schedule. It is also worthwhile to research the availability of qualified products and equipment such as windows and doors to confirm availability in the market, preferably by local manufacturers. This should be done in advance of specifying materials and assemblies in tender documents for PH construction.

Predesign: Adopt the highly collaborative integrated design process which "requires that whole project team to think of the entire building and all of its systems together, emphasizing connections and improving communication among professionals and stakeholders throughout the life of the project" (US Green Building Council, 2014). This is especially effective for PH design. In addition, it is best to establish a project budget that includes PH design and construction administration fees to ensure clear cost expectations. The PH consultant should have the contract directly with the client since there are financial decisions that might affect the outcome and should include a contingency for increased PH expertise during construction.

Design: First, establish design parameters that meet the NBC of Canada and the Provincial Building Code. Second, confirm that the project meets either PHI standards or PHIUS Climate Adjusted Standard; the latter proved to be much more cost effective and achievable in Nova Scotia's climate. Third, ensure that specific client requirements, which may require special attention, are met (e.g., seniors housing has a higher heat demand throughout the year than non-senior residences). Fourth, include in the design documents a summary about PH and expectations for meeting PH targets.

Modeling: To achieve major decreases in heating energy consumption required by the PH standard, a building modeling tool such as PHPP or WUFI Passive is used to simulate the performance of the building, using such variables as solar exposure, shading, envelope assembly, window and door types, and electrical and mechanical systems. The tools allow for the PH designer to change any of the variables to optimize the building performance for best results.

Tendering: Require that contractors provide full price breakout of labor and material for all work that is considered above and beyond current NBC and Nova Scotia Building Code (NSBC) regulations; highlight PH requirements in the tender to avoid any misconceptions on what is requested; review expectations and requirements with all potential bidders ahead of tender submittals; and include time to meet with the PH consultant during construction as part of the tender package.

Construction: Provide PH supervision including field reviews at critical milestones built into the project schedule; hands-on training to the contractors as needed; reports with photos on issues and proposed solutions; and blower door testing at critical intervals. Having PH expertise on the Design Team will help save costs during construction.

8.1 Commissioning and Post-Occupancy

Ensure that commissioning is conducted by PH consultant as well as by a third party if you are seeking certification or government subsidies in the form of rebates; there is an easily understood user manual for tenants that includes a project summary and tips for optimal energy consumption in everyday living; and monitoring equipment is installed to measure total energy consumption as well as energy consumed to provide space heating separately.

9 Concluding Remarks

HNS approached these pilot projects as an opportunity to generally showcase its commitment to environmental sustainability and energy efficiency. More specifically, the aim was to evaluate the PH design and construction approach and process outcomes; document energy performance of the building and compare it to a code-built building; and track energy costs of each unit and determine obstacles toward adopting PH as a cost-effective method for HNS. In each of the three buildings, energy monitoring systems will keep track of energy uses and compare the information across projects. Early results from Alice Street were positive and showed a reduction in energy use. However, data from the other two projects was still not available at the time of this writing.

Cost increases over code-built houses averaged about 11% when weighted by total cost. PH design and oversight is one of the cost factors that should always be considered. Despite being important, they were not quantified by HNS as part of the pilot projects. As more builders adopt PH standard for construction projects, costs related to PH consultants during construction will start falling. Furthermore, certification fees increase the overall costs, which in the case of the Alice Street project was significant. ENS support had at first been tied to achieving PHI certification which was not achievable due to the location of trees to the south that reduced solar incidence. Instead, HNS achieved certification through PHIUS while ENS support was used to produce the instructional video. It is hoped that further awareness of PH may lead to supporting performance criteria, instead of specific certifications, being tied to funding. This would also lead to a higher rate of success in cases where contractors are less familiar with PH construction, as in the case of Amherst, and hopefully save on time and costs.

Scale of a project is another important cost factor. When moving from a semi-detached building to a multi-unit one, there are some advantages in the modeling due to the increased volume to area ratio, the increased number of occupants that generate internal heat, and the larger facades that provide the ability to have more solar gains. In addition, it should be noted that certification to PH standard is more economically feasible in larger projects since the costs incurred are distributed over more units. On the other hand, there are challenges related to the centralized mechanical systems that also allow for tenants to control their units through localized thermostats. This is especially true when modeling since a certain temperature is assumed for all units to simulate the energy consumption of the building, which may be different for each unit because occupants control ventilation, space heating, and domestic hot water (DHW) consumption.

The HNS PH initiative, as it was specifically implemented in Nova Scotia, was a success in demonstrating that affordable sustainable housing can be built using local materials and techniques with conventional and small building contractors within a reasonable margin of increased cost. HNS plays a role in promoting innovation in the overall housing sector. Making PH construction more common could have a significant impact on long-term sustainability, from both an economic and environmental perspective. The importance of energy efficiency and reducing the carbon footprint of buildings is increasing as the effects of climate change are being felt more rapidly on a global scale.

These PH projects have generated a lot of interest in Nova Scotia. HNS has been contacted by several local companies and service providers who expressed an interest in cooperating with HNS on demonstrating existing alternative energy technologies or piloting new innovative ones in existing buildings. HNS will continue to pursue its sustainability initiative through exploring potential energy savings in its buildings independently or through partnerships with other organizations that share the same goals.

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