Understanding Trends and Key Barriers to Scaling Zero Emissions Homes in BC

EXECUTIVE SUMMARY

Prepared by:

Rhianna Lash, UBC Sustainability Scholar, 2020

Prepared for:

Christian Cianfrone, Executive Director, ZEBx

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Introduction

The following study explores the trends and barriers expressed by high-performance homes being constructed in British Columbia as a part of the Near Zero program, administered by the Zero Emissions Building Exchange (ZEBx).

The findings focus on wall assemblies, windows, and mechanical systems due to the clear trends exhibited by the participating projects, the availability of information provided, and the expressed importance these three aspects share to the overall energy efficiency and performance of the home.

The observed trends in products, solutions, and challenges will inform opportunities to improve the cost-effectiveness of high-performance homes in Vancouver and British Columbia to both building professionals and regulators.

Background

The Near Zero Program is a green initiative sponsored by the City of Vancouver and CleanBC to gather data and encourage the construction of more high-performance homes. The following information was collected through the Nero Zero Program administered by ZEBx. Participants submitted answers to three surveys regarding their current high-performance home over the course of the project at stages of design, post-construction, and occupancy. A total of 17 of the participating projects were reviewed, comprising of data from the design stage only, with questions ranging from the intentions in choice of products, assemblies, materials and design strategies, to the overall design solutions used and barriers encountered. Further interviews were conducted along with in-person site visits over the course of 3 months to better understand the selected projects.

Summary – Table 1.

Primary data in relation to the energy efficiency of selected high-performance homes.

Project	Standard	Date	Floor Area	Energy Use Intensity	Heating Demand	Mechanical systems	HRV	Uw[i] (W/m2K)	Wall Thickness	ACH[ii] Target	Incremental Cost[iii]
Beaumont NZ	PH	2018	3869 SF	70.8 PE	12.5	Heat pump	84%	0.76	R47	0.6	5%
Knight Residence	ESC 5	2017	1959 SF	31 PER	21	Combi Unit	83-89%	0.8	R30	1	5%
Point Gray Home	ESC 5	2017	1597 SF	Unknown	Unknown	Heat pump	90%	0.8	R22	1	5%
Cambridge House	PH	2019	2553 SF	48.6 PER	12.6	Minisplit	84%	0.8	R48	0.3	5-6%
Blindheim House	PH	2016	3227 SF	41 PER	17	Minisplit + heating mats	84/93%	0.76	R65-83	0.6	5-7%
E 37th House	PH	2015	2217 SF	113 PE	15	In floor Radiant	95%	0.66	R52	0.54*	5-8%
Poetta House	PH	2017	1819 SF	45 PER	13	In floor Radiant + minisplit	93%	0.66	R55	0.6	5-8%
Turner St. PH1	PH	2016	1916 SF	52.39 PER	10	In floor Radiant	93%	0.66	R56	0.6	9%
Georgia St. Home	ESC 5	2019	3255 SF	Unknown	Unknown	Heat pump + Baseboard minisplit	65%	1	R28	1	10%
465 E 18th	PH	2017	2464 SF	55.4 PER	15	In floor Radiant	93%	0.72	R47	0.6	10-20%
Khotso House	PH	2014	2796 SF	49.2 PER	14	Heat pump	84%	<0.99	R49	0.35*	12<16<20%
Neultin House	PH	2017	4064 SF	71 PE	13.8	VRF air source Heat pump	90/95%	0.66	R46	0.6	15%
Jacob-zu Residence	ESC 5	2017	4168 SF	Unknown	Unknown	VRF Heat pump, HRV	116/95%	0.72	R52	1	15-18%
Anju Niwas	ESC 5	2018	2719 SF	Unknown	Unknown	Heat pump + Fireplaces	116%	0.86	R28	1	25%
Lilac House	PH	2016	5758 SF	116 PE	9	HRV minisplit	94%	0.79	R43	0.6	35-40%

[i] The U-Value or Uw is a measure of conductivity of the whole window (glass and frame included).

[ii] The air changes per hour (ACH) at 50 Pa.

[iii] The percentage increase difference in cost between a code-built home and high-performance home.

* Achieved ACH

Key findings:

- Wall thickness increases in correlation with the performance of the assembly.
- Windows are being primarily imported from Europe due to lack of availability and are found to be one of the costlier aspects of building a high-performance home, being 2-3 times more expensive than a window used in a code-built home. There is also a strong preference for wood aluminum-cladded windows.
- Clear trends in product choice for DHW and HRV brands Sanden and Zehnder, respectively due to a lack of product variety in the local market.
- Transition to include more active cooling (35% of projects using passive cooling only).
- Transition from in-floor radiant heating to mini split heat pump systems for heating.
- BC Energy Step Code, Step 5 (ESC5) homes are experiencing similar incremental cost increases as Passive House.
- Participants that were constructing their first high-performance home also expressed a higher incremental cost of 10-20%, reaching as high as 40% namely due to the size of the complex. No trend showed an increase or decrease in incremental costs of building high performance over time, instead was subjective to the size of the project and experience of the design team. Projects that had a square-footage below 2000 all had an incremental cost less than 10%.
- The thermal resistance of walls in Passive Homes is almost double that of ESC5 projects.

Wall Assemblies

Across all projects a variety of wall assemblies was used, including stick frame, advanced framing, double wall, SIP panels, TJI or Larsen truss, and ICF.

The stick-frame assembly was used by 65% of projects – commonly 2x6 or 2x8 wall with a 2x4 service wall – because the stick-frame 2-part wall system is thought to be a very affordable, conventional assembly with its cavities capable of being filled with additional insulation. Double stud walls were considered the most expensive assembly because of the increase in both materials. Historically, the goal for high-performance wall assemblies was to just achieve the highest R value, however general contractors are observing a transition to achieving the thinnest wall possible whilst maintaining a high R-value to both maximize floor space in urban settings as well as lower material and labor costs – and ultimately make high-efficiency homes more affordable. Some methods used to achieve this include newer wall assemblies such as structurally Insulated Panels (SIPs), or by increasing the performance of other components of the home (e.g. roofs, windows, airtightness, slab insulation, etc.). Spray foam insulation is also being used to assist in minimizing the wall thickness for its increased R value per inch.

Projects that targeted an Energy Step Code 5 (ESC5) rating all referenced the 'R22+ Effective Walls in Residential Construction in British Columbia' to determine their wall assembly; a guide published by BC Housing that illustrates traditional construction methods for standard wall assemblies. Passive homes were shown to have more innovative solutions compared to ESC5 construction because of the increased wall thickness and airtightness requirements challenging designers to maximize floor area and create new solutions to ensure the envelope was continuous.

Cost

A trend amongst SIP construction was that this wall assembly had the largest impact on incremental costs of a high-performance home compared to code-built, averaging an overall increase of 10%, but a 20-30% cost increase to the wall assembly when compared to Stick frame (including materials and labor). Prefabrication was considered by most projects to avoid complicating construction and reducing waste. Despite prefabricated members such as SIPs having a higher initial cost, some projects expressed construction cost savings in labour.

The thermal resistance required in a high-performance home far exceeds that which is needed in a code-built home, driving the wall thicknesses to as much as 18" and expected budget for insulation approximately 150% more. To increase the thermal resistance of the assembly, either more insulation was installed or products that have higher thermal resistance without the additional thickness were used.

Air Tightness

Most commonly across all projects, the air barrier was installed to the exterior of the structure as a self-adhered membrane or layer to the sheathing. Due to the high price point of self-adhering products, some projects used peel-and-stick membrane selectively, namely around openings, whilst others applied it onto the entire sheathing. Comparatively, applying the air barrier on the interior of the structure could allow for attachments like steel outriggers, shading devices and heavy claddings to be affixed to the exterior face of the building more easily without penetrating the air barrier. The addition of a service wall also let trades run all building infrastructure freely without penetrating the air barrier and was incorporated into 62% of projects. Of all projects that used service walls, 50% had a SIP structural wall.

A common solution used by projects to lower the ACH (air changes per hour) post air-barrier installation was Pacific Aerobarrier; a liquid aerosolized sealant that is pushed through leaks, able to fill up to a ½” hole. Aerobarrier is also effective for sealing improperly adjusted windows and doors.

Windows

Cost

63% of projects found windows to be one of the most significantly more costly aspects of passive house building compared to a code-built home. All participants determined a Passive House Certified window (or equivalent) to be 3-4 times more expensive than a standard vinyl-based window, and 2-3 times more expensive than a higher efficiency window (not PH certified). As more products are becoming available, the price point for PH Certified windows has been decreasing, however general construction costs are continually rising and evening out the price.

Product Choice and Availability

European windows were used by 66% of projects, 75%of those being sourced through importer Vetta. The most common window package choice was the Elite-Alu92, which doesn’t have Passive House Certification however is verified by Passive House Institute as a compliant product. Compared to the other Vetta products such as Puro Passiv, which is Passive House certified, builders noted an approximate cost difference of 20%. Also, the Elite-Alu92s are a wood aluminum window, which was preferred for aesthetics reasons and were noted to be approximately the same price as local vinyl PHI certified windows and cheaper than the local fiberglass windows.

Passive house windows were commonly sourced from Europe due to the lack of supply within North America, however over time products have become more available and more local. More recently the European market is starting to phase out their products with Passive House certification. A Passive House Certified window package from Josko was used by one project but was discontinued by the manufacturer soon after because consumers were not willing to pay for the premium that came with product certification. Instead, European manufacturers are said to be focusing more on the production of low energy and high-performance windows in the future. Non-certified products have been used by some projects, which required adjustments to the PPHP model. Projects that used a European window package mostly made this decision based on the quality difference between European and North American products.

The availability of high-performance windows also becomes limited by size, with many projects expressing a difficulty in sourcing larger windows at an acceptable price point or that are Passive House certified. Another challenge that projects faced was due to the thicker wall assembly, which meant that standard doors or windows did not fit into the jamb, requiring custom-made jambs, alternative solutions, or only Passive House certified products that account for this.

Materiality

Across all projects, 9 used a wood/aluminum cladded frame, 4 used GFRP and 5 used vinyl. Materiality was determined for each project based on either the performance, availability, cost, durability, environmental impact, or aesthetic of the frame. From the 50% of projects that chose a wood/aluminum-cladded window, only one was Canadian sourced.

Mechanical systems

HRVs

High efficiency HRVs are a necessary product for passive houses to achieve energy targets and effectively upgrade a build from ESC3 to ESC4 or 5, however the market is limited to a few brands; namely Zehnder and Paul Novus, which have a higher price point. 66% of projects used a

Zehnder HRV, with almost half confirming it to be an aspect of a high-performance building that is significantly more costly in comparison to a code-built home, being approximately 2-3 times the price. From the 5 houses that were not targeting Passive House certification, two still used a Zehnder HRV. 35% of projects Installed more than one HRV (primarily for servicing a basement suite) that were smaller models, such as the Zehnder ComfoAir 200.

Projects that were just short of meeting PHPP requirements explored using an HRV with a higher efficiency to bump up the overall performance of the home, such as the Paul Novus which has the highest reported heat recovery efficiency of 93%.

DHW

There was an overwhelming choice for the Sanden CO2 Domestic hot water system, being used by 83% of projects. Those that opted out from using the Sanden brand were most commonly targeting ESC5as opposed to Passive House. Like the Zehnder HRV, there is a limited number of available products for high efficiency, heat pump domestic hot water heating.

Heating and Cooling

Consistently across all designs there was an emphasis on creating opportunities for passive cooling (35% of projects stating no active cooling systems being included at all), incorporating overhangs or exterior shading devices, as well as selective window placement for cross ventilation and strategic solar gains. Some took into consideration night cooling/summer bypass from the HRV system or mini-split and heat pump systems, which allow for additional mechanical cooling if needed. Only 4 out of 17 projects included night cooling as a part of the cooling strategies, despite the bypass feature being available across most models of HRV used.

A trend couldbe seen of a transition to include more active cooling when comparing older projects to those built after 2018, incorporating mostly mini-split systems or heat pumps (combined accounting for 41% of cooling systems used by projects). Furthermore, the systems used for heating are transitioning from radiant in-floor heating to mini-split heat pumps, primarily because of the delayed heat from radiant in-floor mats in conjunction with the highly insulated assemblies causing overheating toward the end of the day. 64% of projects used a heat pump or mini-split compared to 29% using in-floor radiant and 11% electric baseboard.

Placement of Mechanical Systems

Across all projects, the locations for placement of the HRV and other mechanical systems varied. Some locations included being in a laundry room on the second floor, centrally on the first floor or along an exterior wall or in a corner; in closets or mechanical rooms. The most common location, however, was found to be in the basement. How much space that is dedicated to these systems also varies between 35 and 51 sqft.

Although typically placed in the basement, relocating the HRV system centrally or at an exterior corner was proven helpful in shortening runs to intakes and supply air diffusers throughout the home, and the ability to have exhaust and intake located on different walls- therefore limiting the distance required between them and ultimately saving money. By removing the HRV from the basement, penetrations in foundation walls could also be avoided. The HRV and domestic hot water systems were most commonly situated together as well.

The mechanical room and where an HRV is located requires there to be enough space and the ability for the mechanical equipment to be serviceable. It’s common for HRVs to be installed in an attic or crawlspace, so the likelihood of the consumer knowing it’s there to service it is low. One of the better locations for a mechanical room expressed within the projects would be at the center of the house on the main floor, however, is an important area within the house for livable spaces, so is less applicable. Having the mechanical room next to the stairwell also allows a chase to run directly up for ductwork. City of Vancouver grants 100sqft of free FSR if the HRV is placed above-ground, which is considered to also be the ideal size for the mechanical room so to accommodate for higher efficiency HRV being four times larger than that of a standard model.

Appendix

Figure 1. Wall Assemblies

Project	Standard	Wall Structure	Wall Thickness	R-Value	Air Tightness Strategy	A.B. Location
E 37th House	PH	SIP Panel	430mm	R52	Tyvek A.B./M.B. to the exterior	Both
Khotso House	PH	TJI + Stud wall	406mm	R49	Self adhered membrane to sheathing	Exterior
563 E 13th	PH	2x8 Advanced	340mm	R43	Self adhered membrane to sheathing	Exterior
Turner St. PH1	PH	Stick Frame	430mm	R56	Taped fabric membrane in the SIGA Majvest as an interior air barrier to the 2x8	Interior
465 E 18th	PH	SIP Panel	394mm	R47	Naturaseal air barrier, taped along SIP joints	Exterior
Beaumont NZ	PH	Stick frame	330mm	R47	Siga Majvest breathable membrane	Exterior
Neultin House	PH	ICF	420mm	R46	Internal Vapour Barrier paint	Interior
Cambridge House	PH	TJI + Stud wall	424mm	R48	Taped A.B. + V.B. to plywood sheathing	Exterior
Lilac House	PH	2x6 Advanced	430mm	R43	A.B. on sheathing + spray foam	Exterior
E. 8th 3-plex	PH	Stick Frame	476mm	R50	Propriety A.B./M.B. at plywood sheathing + interior Intello Smart V.B.	Exterior
Knight Residence	ESC 5	Stick Frame	393mm	R30	A.B. Siga Majvest + A.B. Sig Majrex	Both
Georgia St. Home	ESC 5	SIP Panel	280mm	R28	Tyvek weather and air barrier + Siga taped along seams	Exterior
Point Gray Home	ESC 5	Stick frame	330mm	R22	Self adhered membrane to sheathing	Exterior
Anju Niwas	ESC 5	Stick Frame	343mm	R28	Self adhered membrane to sheathing	Exterior
Poetta House	PH	Stick Frame	425mm	R55	Taped OSB sheathing on the inside of 2x8	Interior
Blindheim House	PH	SIP Panel	345-447mm	R65-83	Continuous Fluid applied membrane to exterior of SIP panels	Exterior
Jacob-zu Residence	ESC 5	SIP Panel	425mm	R52	Taped seams	Interior

Figure 2. Window Specifications

Project	Standard	Windows	Doors	Uw [iv]	Ug [v]	Material	Location
E 37th House	PH	Puro Passiv	CAL	0.66W/m2K	0.53W/m2K	Wood/Alu clad	Poland
Khotso House	PH	Heckel	Oeko	<0.99W/m2K*	0.6W/m2K	Wood/Alu clad	Germany
563 E 13th	PH	Euroline	Euroline	0.79W/m2K	0.7W/m2K	Vinyl	Canada
Turner St. PH1	PH	Puro Passiv	CAL	0.66W/m2K	0.53W/m2K	Wood/Alu clad	Poland
465 E 18th	PH	Elite-Alu92	Vetta	0.72W/m2K	0.56W/m2K	Wood/Alu clad	Poland
Beaumont NZ	PH	Josko	Josko	0.76W/m2K	0.6W/m2K	GFRP	Austria
Neultin House	PH	Puro Passiv	Vetta	0.66W/m2K	0.53W/m2K	Wood/Alu clad	Poland
Cambridge House	PH	Cascadia	Cascadia	0.8W/m2K	0.68W/m2K	GFRP	Canada
Lilac House	PH	Euroline/Puro Passiv	Euroline	0.79W/m2K	0.53W/m2K	Vinyl	Canada
E. 8th 3-plex	PH	Euroline	Euroline	0.79W/m2K	0.7W/m2K	Vinyl	Canada
Knight Residence	ESC 5	Sigg	Sigg	0.8W/m2K	0.5W/m2K	Wood/Alu clad	Austria
Georgia St. Home	ESC 5	Westeck	Westeck	0.8W/m2K	0.7W/m2K	Vinyl	Canada
Point Gray Home	ESC 5	Cascadia	Cascadia	0.8W/m2K	0.68 W/m2K	GFRP	Canada
Anju Niwas	ESC 5	Vinyltek	TBD	0.86W/m2K	Unknown	Vinyl	Canada
Poetta House	PH	Puro Passiv	CAL/Ecoslider	0.66W/m2K	0.53 W/m2K	Wood/Alu clad	Poland
Blindheim	PH	Fenstur	Fenstur	0.67W/m2K	0.57 W/m2K	Wood/Alu clad	Canada
Jacob-zu Residence	ESC 5	Elite-Alu92	CAL	0.72W/m2K	0.56W/m2K	Wood/Alu clad	Poland

[iv] The U-Value or Uw is a measure of conductivity of the whole window (glass and frame included).

[v] The Ug value is the thermal transmittance through glazing.

Figure 3. Mechanical Systems

Project	Standard	HRV	SRE %[vi]	DHW	Heating	Cooling
E 37th House	PH	Zehnder CA550	95%	Sanden CO2 HW	In floor Radiant	None
Khotso House	PH	Zehnder CA550	84%	GeoSpring Heat Pump Water Heater	Heat pump	None
563 E 13th	PH	(2) Zehnder CA350	84%	Sanden CO2 HW	Electric Baseboard	None
Turner St. PH1	PH	Paul Novus 300	93%	Sanden CO2 HW	In floor Radiant	None
465 E 18th	PH	Zehnder/Paul Novus 300	93%	Sanden CO2 HW	In floor Radiant	None
Beaumont NZ	PH	Zehnder CA550	84%	Sanden CO2 HW	Heat pump	Minisplit
Neultin House	PH	Zehnder CA350 + Q200	90/95%	Sanden CO2 HW	VRF air source Heat pump	VRF air source Heat pump
Cambridge House	PH	Zehnder CA550+350	84%	Sanden CO2 HW	Minisplit	Minisplit
Lilac House	PH	Zehnder CA200 per unit	94%	Sanden CO2 HW	HRV Minisplit	HRV Minisplit
E. 8th 3-plex	PH	Zehnder CA350 + Q200	90/95%	Sanden CO2 HW	HRV	HRV Night cooling
Knight Residence	ESC 5	Drexel & Weiss	83-89%	Sanden CO2 HW	Combi Unit	Combi Unit
Georgia St. Home	ESC 5	HERO Fantech	65%	Nordic Desupeheater	Heat pump + Baseboard minisplit	Heat pump + minisplit
Point Gray Home	ESC 5	Zehnder CA350	90%	Rheem Hybrid	Heat pump	None
Anju Niwas	ESC 5	Minotair	87-116%	Sanden CO2 HW	Heat pump + Fireplaces	Heat pump bypass
Poetta House	PH	Paul Novus 300	93%	Sanden CO2 HW	In floor Radiant + minisplit	Minisplit
Blindheim	PH	Zehnder 550+200	84/93%	Sanden CO2 HW	Minisplit + heating mats	HRV Bypass
Jacob-zu Residence	ESC 5	Minotair Pentacare + Zehnder CA200	87-116 /95%	Sanden CO2 HW	VRF Heat pump, HRV	Heat pump

[vi] The Sensible Heat-Recovery Efficiency of the HRV.