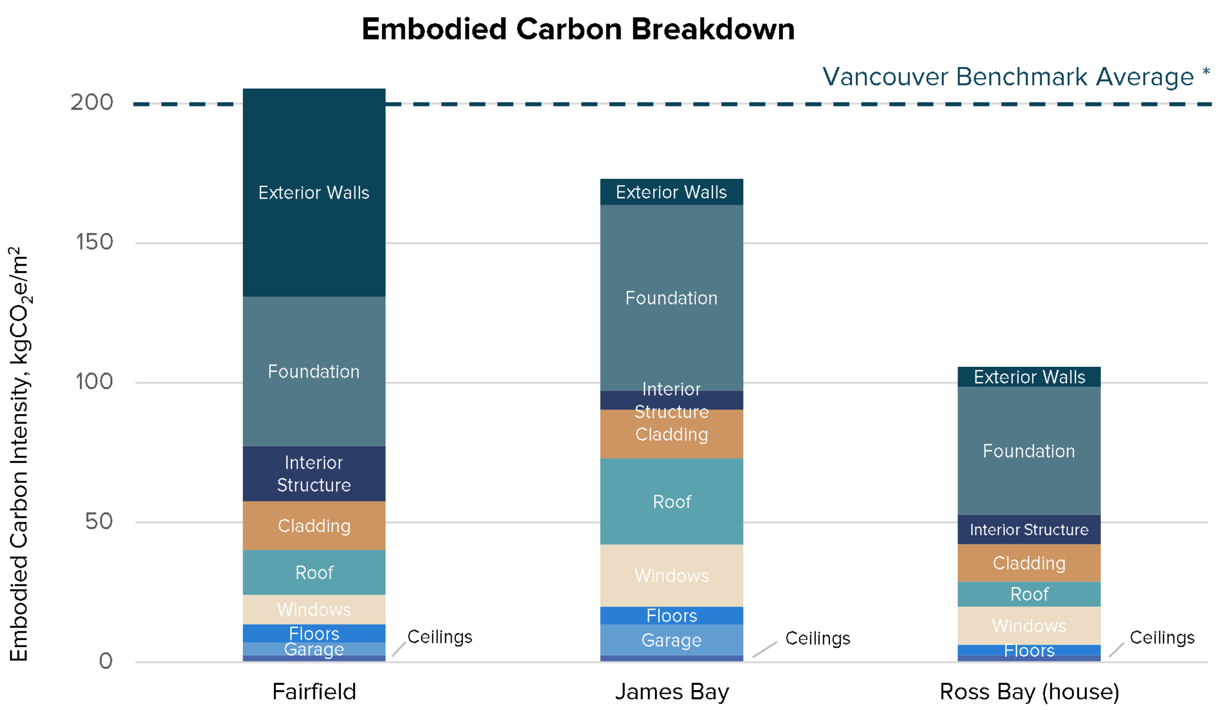
carbon wise
sustainable innovation

Building All-Electric Homes in Victoria

Climate Friendly Homes Case Studies

Common Strategies for Success

- Heat pumps! All homes, with the exception of some garden suites, used heat pumps as a highly efficient and cost saving way to provide heating.
- Early planning of energy systems, equipment locations, duct and pipe routing, and an airtightness strategy.
- Simplifying the building design improves energy efficiency, makes airtightness easier, and saves time and cost.
- A 200 amp electrical panel sufficed for all the case study homes.



* The benchmark of 200 $kgCO_2e/m^2$ is an average value for newly built homes in the Vancouver area, provided here for comparison

Methodology

- Overall trends and statistics were based on the compiled data of Energy Step Code compliance forms submitted to the City of Victoria between Feb 19 – Nov 2023, removing any obvious outliers from the data.
- Data collection and analysis for the case study homes included the following:

- Interviews with the homeowner and/or builder provided quotes and general details about the experience of building and living in the homes.

- Operational emissions were quantified using Hot2000 (software produced by Natural Resources Canada), using the existing Step Code compliance energy models updated as necessary by data collected from take-offs of the building plans. The gas comparison case used a copy of the same model but with natural gas heating systems.

- Embodied emissions were quantified by a stage A1 to A3 (extraction to manufacturing) lifecycle analysis using Natural Resources Canada's MCE2 Material Carbon Emissions Estimator. This process was also informed by data collected from take-offs of the building plans.

- The $200kgCO_2e/m^2$ average value is retrieved from the City of Vancouver Material Emissions Benchmark Study for Part 9 Homes (2022)

- Utility Cost estimations for the case study homes were developed as follows:

- Utility rates were those advertised on BC Hydro and FortisBC websites in fall 2023.

- Two-tier pricing for electricity was included.

- Base rates, daily rates and flat fees paid each month were included as well as the cost per GJ or kWh. All electric homes were assumed to not pay any gas-associated flat fees.

- For a clearer comparison, the electrical load related to lighting and appliances, also called baseload, was removed before calculating the utility cost as this would be equivalent in both comparison cases.

- For homes with cooling, AC for cooling has been used for the natural gas model to make it equivalent to the all-electric model (i.e. it has a gas furnace and AC unit)

Case Studies Comparison Table

	Fairfield	James Bay	Ross Bay	
			House	Suite
Heated floor area	4,031 sq ft	2,433 sq ft	2,560 sq ft	600 sq ft
Zero Carbon Step Code	Zero Carbon	Zero Carbon	Zero Carbon	Zero Carbon
Energy Step Code Level	4	4	4	5
Annual Energy Use GJ	58.5	45	45.4	40.8
GHG $kgCO_2e/yr$	179	138	139	125
GHGi $kgCO_2e/m^2/yr$	0.48	0.6	0.6	2.2
Airtightness ACH	1.85	0.98	1.25	1.51
Embodied Carbon				
Emb. Carbon $kgCO_2e$	76,900	39,100	25,200	9,900
Intensity $kgCO_2e/m^2$	205	171	106	178
Building Assembly and Insulation				
Foundation Type	Basement and crawlspace	Slab on grade	Unheated Crawl-space	Slab on grade
Foundation Insulation	R21 ICF	R12 under slab	R12 spray foam	R12 under slab
Exterior Walls	R24 ICF	2x6@16"o/c; R20 batt; 1" ext. insul.	2x6@16"o/c; R22 batt	R22 Pacific SmartWall
Windows	Double glazed, vinyl, argon gas fill			
Air Barrier	Interior polyethylene	Interior poly. and Aerobarrier	Interior polyethylene	
Exposed Floor	2 x 11 7/8" TJI @ 16" o/c, R-31 batt	2 x 11 7/8" TJI @ 16" o/c, R-31 batt	n/a	n/a
Roof	Attic R-40	Attic R-40	Attic R-40	n/a
HVAC System				
Heating & Cooling	2x heat pump to central ducted air handlers	Air-to-water heat pump for in-floor radiant and hot water; no cooling	Central Split ASHP	Mini Split Ductless ASHP
Heat Pump Model	Daikin RXL24UMVJU	Sanden G53-45HPC	American Standard Quest 4TXD2060	
Hot Water Heating	Electric resistance water tank	Sanden electric storage tank SAN-83SSAQA	Electric resistance water tank	
Ventilation	2x Daikin air handlers, Venmar HRV	Zehnder ComfoAir Q 450 HRV	Central recirculating ventilation	Utility fan
Back-up or supplementary heating	Electric baseboards; electric fireplace	Electric baseboards; Woodstove in main house	Electric resistance backup	
Electric panel size	200 amp	200 amp	200 amp	100 amp

Fairfield

Setting the New Industry Standard

Zero Carbon Step Code Case Study #1 Fairfield

Impact

By choosing an all-electric approach, this home will prevent 192 tonnes of CO_2e from entering the atmosphere over its lifespan, which is roughly equivalent to driving a gas vehicle 790,000 km.

Year Built	2023
Heated Floor Area	4,031 square feet
Foundation	Basement and unheated crawlspace
Space Heating	Central air-source heat pump
Hot Water Heating	Electric resistance tank heater
Energy Step Code	Step 4

Description

Justin Reynolds, the owner of Collaboration Homes, wanted to build his own all-electric home as a showcase to sustainable home construction for his clients. Avoiding any gas use in the home for sustainability, air quality, and safety reasons, two Daikin heat pumps and air handlers provide home heating with efficient zone control. A Venmar heat recovery ventilator provides fresh air, and hot water is supplied by an electric resistance tank heater.

By incorporating 29 solar PV panels on his own home Justin hopes to inspire clients to embrace climate-friendly solutions. The panels generated 12,200 kWh annually, significantly reducing Justin's summer electricity bills, even with daily electric vehicle use and air conditioning. (Solar panels were excluded from the calculations as they did not yet have a full year of operating data available).

Key Takeaways

1. A high-performance envelope reduces electrical capacity concerns.
2. Distributed heating and cooling enhance efficiency, save space and improve comfort—plan for ducting routes during installation.
3. All-electric home design offered a more straightforward construction process by avoiding running and connecting gas lines.

Background

Timeline		
2021	May	Early Design
	Oct	Permits
2022	Jan	Demolition
	Feb	Foundation Framing
	Mar	Slab Pour Windows & Doors
	May	Insulation
	June	Drywall
	Oct	Mechanical & Electrical Complete
2023	Jan	Final Inspection & Occupancy

Justin Reynolds, the owner of Collaboration Homes, wanted to take a proactive approach to home construction, focusing on sustainability and the potential of renewable energy. With the goal of using his own home as a showcase for clients, Justin wanted to set himself apart in the industry and inspire his clients to explore innovative and environmentally friendly solutions in their own projects.

He also considered the safety implications of having the house powered only by renewables, after a personal experience a decade ago when a relative's home experienced a gas leak explosion.

One surprise for Justin during his project was the cost of an electric hot water tank compared to a gas heater, but the benefit of all-electric systems outweighed the additional upfront cost. Justin also installed 29 solar panels on his roof, which yielded impressive results when his summer electricity bills reached single-digit costs.

Justin's one regret was opting for a natural gas connection for his BBQ instead of a propane tank. This change would have avoided the need for a gas line, which Justin stated "for the amount it's being used, it's not worth the expense".

Building Assemblies		HVAC Systems	
Exterior Walls	R-24 ICF	**Heating**	2 x Daikin heat pumps
Roofs	R-40 attic	**Cooling**	
Below Grade Walls	R-21 ICF	**Hot Water**	Electric resistance tank heater
Foundation	R-12 under slab	**Ventilation**	2 x Daikin ducted air handlers, Venmar heat recovery ventilator
Exposed Floor	2 x 11 7/8" TJI @ 16" o/c, R-31 batt	**Back-up Heating**	Electric Baseboards Electric Fireplace
Windows	Double glazed, vinyl, argon gas filled	**Solar PV**	29-panel Rooftop System
Air Barrier	Interior polyethylene vapour barrier		

Strategies for Success and Project Takeaways

Electrical capacity is less of a concern with a high-performance envelope.

The electrical panel for this home is 200 amps, with capacity to spare even with an EV charger. This surplus capacity is attributed in part to the home's low heating demand, resulting in a low electrical demand for the already very energy-efficient heat pump.

Distributed heating and cooling saves space, improves efficiency, and provides better comfort – but plan ahead!

To optimize the heating and cooling distribution within the home, two fan coils were strategically located—one in the basement and another on the upper floor. This distributed placement minimizes the need for drop ceilings, maintaining an open and spacious aesthetic. Secondly, it reduces the distance heated air needs to travel to the room, minimizing heat losand ensuring more effective temperature control. It also allows finer temperature control in each zone, enhancing overall comfort and contributing to energy savings as the heating and cooling system operates with increased efficiency and precision. Living in the house, Justin noticed that his heating system is very responsive, feeling like it warms up in no time! He did find that dealing with complex ducting can be quite cumbersome during installation and recommends pre-planning or pre-design for ducting to help avoid some of these issues.

All-electric homes are more straightforward to build.

By removing work related to a gas system, this project required less coordination and was more straightforward to build. Not having to navigate the complexity of natural gas lines and the venting and combustion systems common in gas-powered water heaters, made it easy for the plumbers to make connections to the electrical tank during installation.

"Comparing building an all-electric home to one powered by fossil fuels, building electric doesn't take much more time at all." - *Justin (builder and homeowner)*

Use an HRV damper or filter for smoke events.

Installing a Heat Recovery Ventilator (HRV) is necessary for ensuring efficient air circulation, providing fresh air, maintaining optimal humidity levels and reducing the buildup of indoor pollutants. Justin recommends having a shut off damper or carbon filter for the HRV to prevent unwanted outdoor scents, for example smoke during forest fires.

Solar panels drop summer electricity bills significantly.

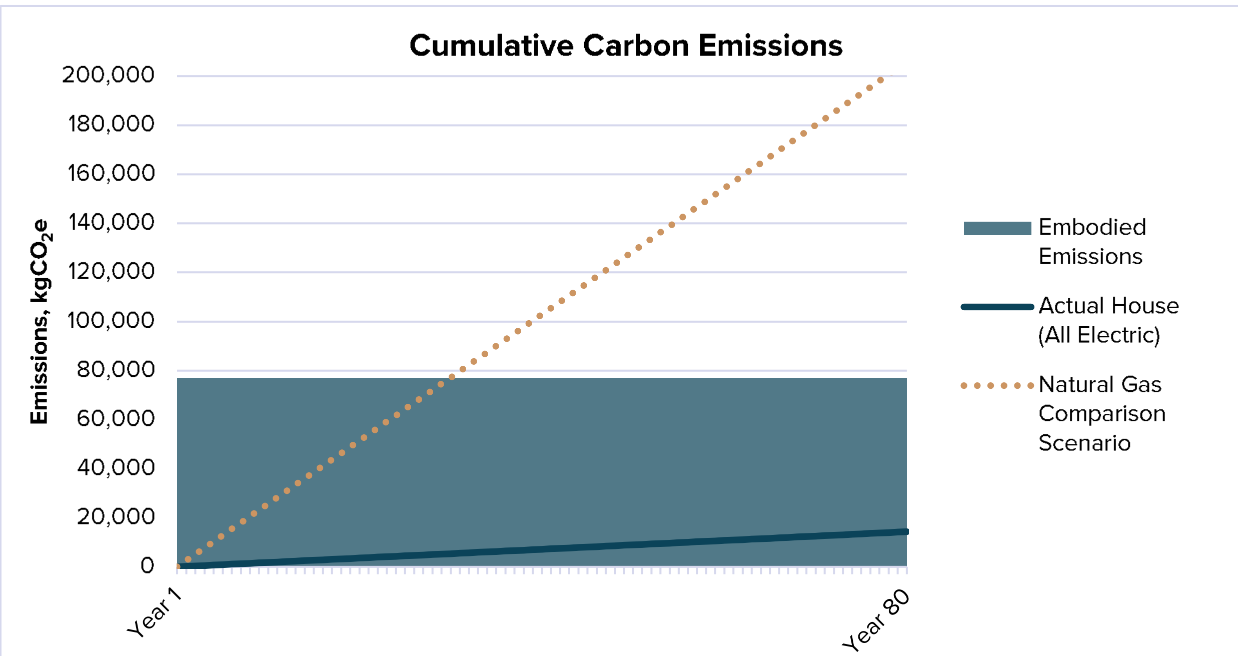
Justin's 29 solar PV panels are projected to generate 12,200 kWh annually. This summer, he saw his electricity bills drop surprisingly low, despite driving his electric vehicle daily and using AC.

Energy and Emissions Analysis

GHG Emissions

This graph shows the emissions performance of this all-electric home compared to the same home if it had been equipped with a high-efficiency natural gas boiler and hot water tank. With BC's hydroelectricity having an exceptionally low emissions factor, all-electric homes in the province release minimal operational emissions over time, underscoring the long-term benefits of choosing low-emission electricity sources.

Annual Energy Consumption (GJ)	59
GHG Emissions (kgCO_2e/year)	179
GHGi (kgCO_2e/m^2/year)	0.5
Embodied Carbon (kgCO_2e)	76,900
Embodied Carbon Intensity (kgCO_2e/m^2)	205
Airtightness (ACH)	1.9



By choosing an all-electric approach, Justin will prevent 190 tonnes of CO_2e from entering the atmosphere, which is roughly equivalent to driving a gas vehicle 790,000 kilometers!

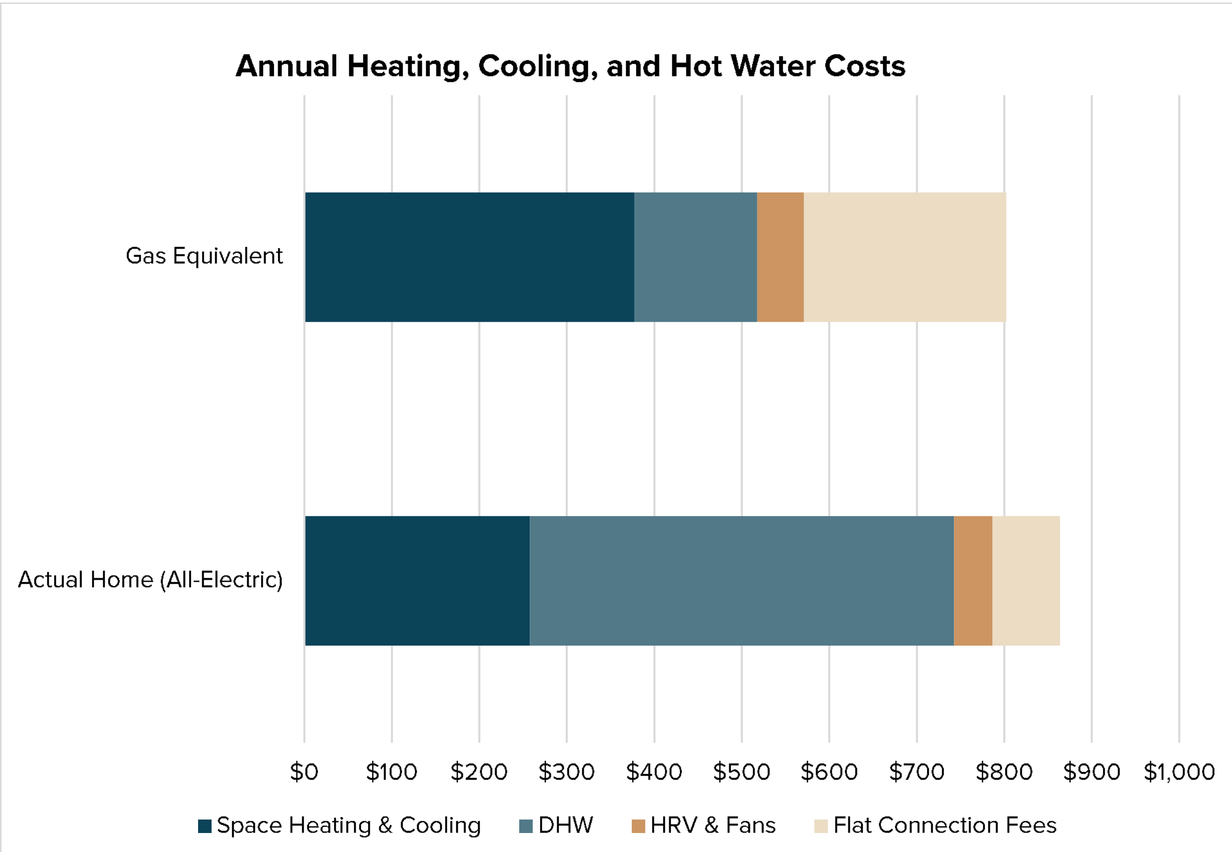
Assuming an 80-year lifespan for the home, it will emit around 14 tonnes of CO_2e. This is a 90% reduction in emissions compared to the same home with natural gas heating and hot water, which would emit over 200 tonnes of CO_2e emissions. Real-life emissions would be further reduced by the newly installed rooftop solar panels.

The shaded area indicates the estimated embodied emissions required to produce the building materials for the home. These embodied emissions surpass the lifetime operational emissions of the home and are equivalent to the operational emissions of a gas-powered home over 30 years.

While it's essential to focus our efforts to reduce operational emissions, it's equally important not to overlook embodied emissions when building a climate-friendly home.

Utility Costs

This case study used the home's energy model to estimate the heating and cooling expenses of the all-electric systems compared to a hypothetical home that uses natural gas. Considering that the energy model is an estimate, **the overall costs for heating, cooling, and hot water are basically on par**. The calculation estimated that the annual expenses for an all-electric home are slightly greater than those for a gas-powered home (roughly $860 versus $800, or 7%).



The graph highlights the cost savings from a heat pump used for space heating and cooling, but the additional costs for an electric resistance hot water tank. As shown in the James Bay case study, using a heat pump for water heating as well can help drop these costs significantly. This estimation does not consider the recently installed rooftop solar PV system that would reduce monthly electricity costs even further! For Justin, any slight additional cost for the assurance of living in a safe, climate friendly and healthy home is worth it.

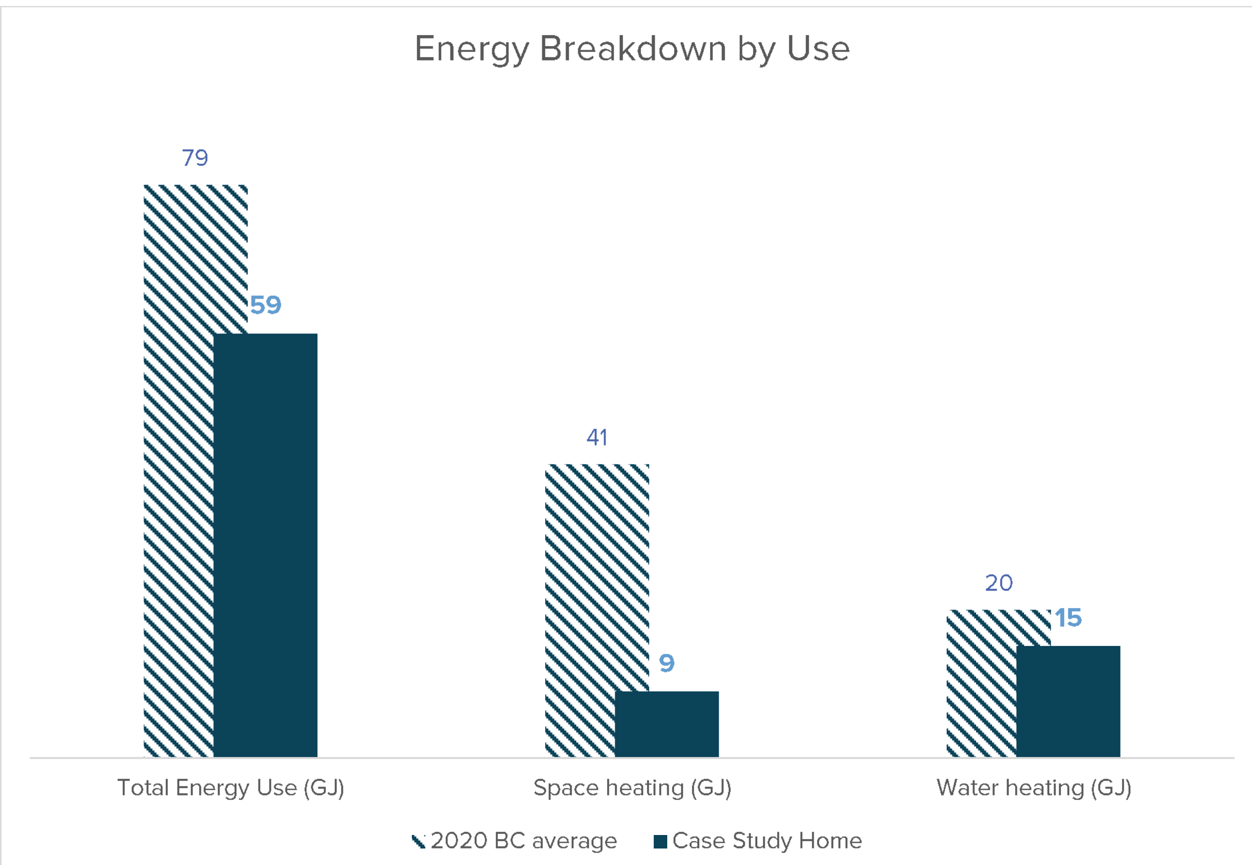
Note 1: Energy Costs in the Future

These cost comparisons may change to benefit all-electric homes in the future. Natural gas prices will be affected by the increasing federal carbon tax until 2030, and natural gas costs are historically more volatile than electrical costs, due to exposure to the dynamics of international markets. As homeowners consider long-term sustainability and cost-efficiency, the reliability of electricity's stable pricing may become an increasingly attractive option.

Energy Use

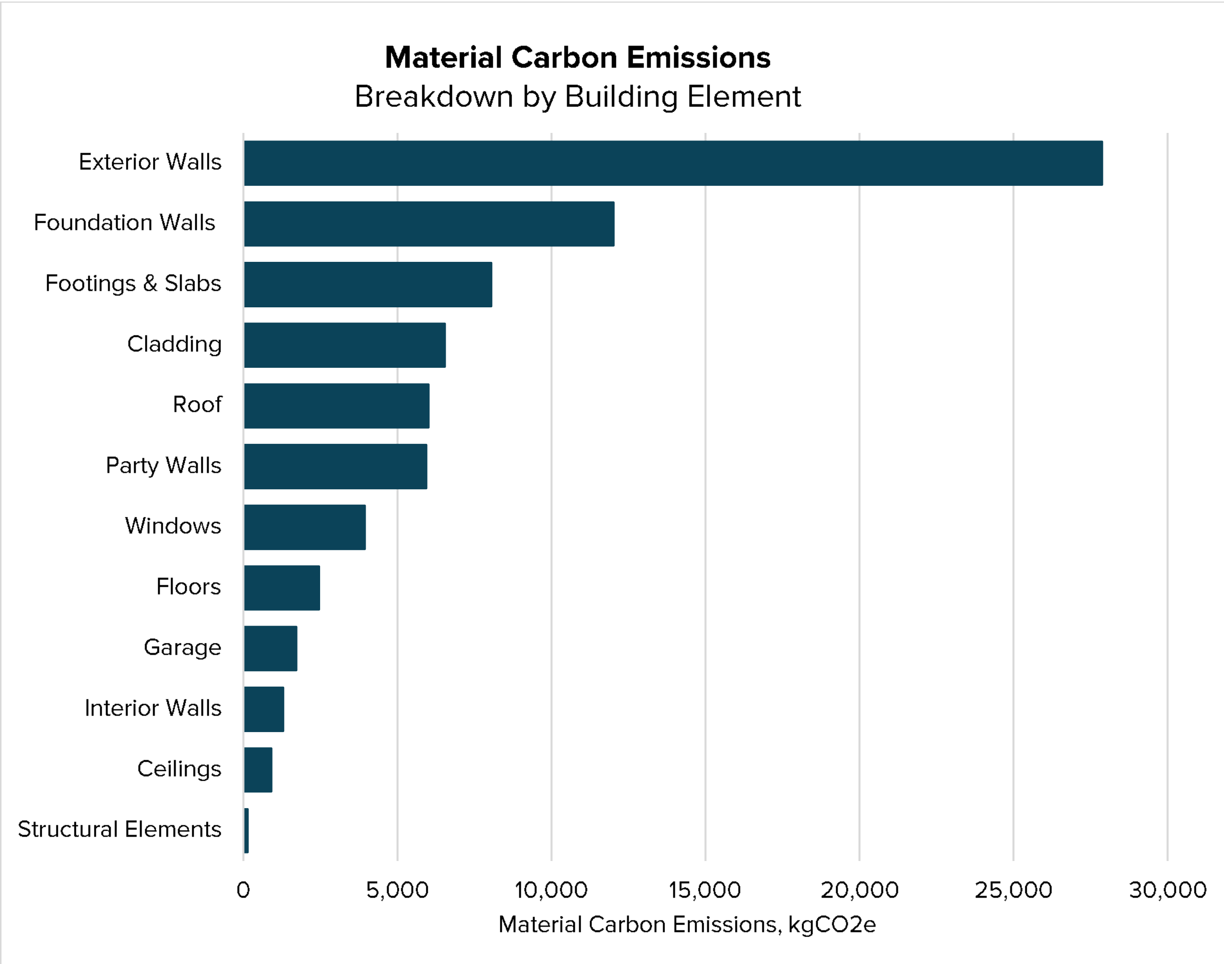
Space heating has historically been the highest element of energy usage in homes. With the shift toward high-performance design in buildings, energy-efficient homes frequently showcase a remarkable decrease in energy consumption especially related to heating. When we compare Justin's house to the average home in BC, it uses 26% less energy overall, 77% less for space heating and 24% less for water heating.

This significant 77 drop in energy usage for space heating is primarily attributed to the efficiency of the home's heat pump. Heat pumps use energy to transfer heat instead of generating it, achieving more than 300% efficiency.



Embodied Carbon

This house has an estimated embodied carbon intensity of 205kgCO_2e/m^2, close but slightly above the 200kgCO_2e/m^2 benchmark recently released by the City of Vancouver. This benchmark value is a rough average of newly built homes in the Vancouver area based on a 2022 study.



The primary contributors to embodied emissions are the external wall systems and foundation walls, primarily due to the utilization of insulated concrete forms (ICF) as a wall structure. ICF construction involves more concrete than traditional wood-frame construction. This highlights that projects using ICF should explore lower-carbon concrete mixes to offset the impact of the increased concrete used in construction.

Some key design choices helped keep the home closer to the Vancouver baseline:

- Reasonably sized windows resulted in less glass use than average.
- The garage is smaller than average.
- Part of the basement is an unheated crawlspace, reducing total concrete and insulation use.

David
BUILDER + HOMEOWNER

"It's neither expensive nor difficult."

James Bay

David's Low Carbon Dream Home

Zero Carbon Step Code Case Study #2 James Bay

Climate Impact

By opting for the all-electric approach, David is preventing 123 tonnes of CO_2e from entering the atmosphere over the lifespan of the home, roughly equal to driving a gas vehicle 500,000 km.

Year Built	2022
Heated Floor Area	2,433 square feet
Foundation	Slab on grade
Space Heating	Central air-source heat pump Single air-to-water heat pump for both in-floor radiant heating and hot water tank
Hot Water Heating	
Energy Step Code	Step 4

Description

After living in old drafty homes, David Thomas set out to build a dream home with comfort and the environment as a focus. He undertook much of the work himself, learning and researching high-performance and low carbon building methods throughout the project.

The home was constructed within budget, beyond minimum code and exceeding the strictest requirements of the Zero Carbon Step Code. David later added solar panels, achieving a nearly carbon-neutral home! He believes that with prior knowledge and pre-planning, the effort wouldn't have been significantly more than building any other new home.

The home uses a CO_2-based air-to-water heat pump for in-floor radiant heating and domestic hot water. Installing the self-contained system is as easy as connecting two water lines, simplifying the process and needing just a plumber to install.

Key Takeaways

1. Evaluate the necessity of natural gas amenities. David opted for an efficient induction stove to enhance efficiency and indoor air quality, deciding against a gas fireplace that would likely overheat his energy-efficient home.

2. Establish an airtightness strategy from the project's inception.

3. An air-to-water heat pump is a straightforward, high-performance system (but may need air conditioning in the future due to rising summer temperatures).

Background

Timeline		
2021	Feb	Early Design
	May	Permits
	June	Demolition
	July	Grading & Foundation
	Oct	Framing
	Aug	Slab Pour
2022	Jan	Windows & Doors
	Mar	Insulation
	Apr	Drywall
	Jun	Mechanical & Electrical Complete
	July	Final Inspection & Occupancy

This high-performance, low-emission home stands as a testament to the values of homeowner and builder, David Thomas, who embarked on this project with determination and a commitment to sustainability. With a small house framing stint in his youth, David had only a little experience building high performance homes. Throughout the design and build process, he researched key methods such as airtightness and good HVAC design. He managed the overall project, from design to planning to coordination. Most of the work for this project including the exterior insulation, HRV installation, kitchens, bathrooms, and interior finishes, was completed by David himself. He is adamant that had he been more knowledgeable about high performance building in advance, it wouldn't have been much extra effort at all.

The home was built both under budget and beyond the minimum step code requirements. Using a single heat pump for both underfloor radiant heating and hot water heating, it exceeded the strictest level of the Zero Carbon Step Code before the standard was even required!

If building his own low emissions home wasn't enough, six months after completion, David added 12kW of solar panels to the roof. This upgrade provides renewable generation to cover almost all of his electricity usage, bringing the house very close to net zero and securing a future free from costly utility bills. Looking back, the only thing David wishes he'd done differently was choose different windows, so the house could have met Step 5 of the Energy Step Code!

Building Assemblies		HVAC Systems	
Exterior Walls	2 x 6 @ 16" o.c. R-20 batt with 1" exterior insulation	**Heating**	Air-to-water heat pump for in-floor radiant Sanden G53-45HPC
Roof	Attic R40	**Cooling**	None
Foundation	R-12 under slab	**Hot Water**	Air-to-water heat pump with storage tank Sanden SAN-83SSAQA
Exposed Floor	2 x 11 7/8" TJI @ 16" o.c. R-31 batt	**Ventilation**	Zehnder ComfoAir Q 450 heat recovery ventilator
Windows	Double glazed, vinyl, argon gas fill, USI 1.3, SHGC 0.3	**Back Up Heating**	Electric baseboards in bedrooms, wood stove
Air Barrier	Interior polyethylene supplemented by Aerobarrier	**Solar PV**	Rooftop PV (12kW)

Low Carbon Strategies for Success

Early planning simplifies the process and prevents delays.

None of the assemblies in this home are particularly groundbreaking compared to a typical build. The big takeaway for David is that early planning goes a long way in simplifying the build process, ultimately preventing costly delays.

The heat recovery ventilator and hot water storage tank being installed in a crawl space under the stairs.

"All it takes is a little attention to detail, a little bit of caring, understanding and selecting the right products."
- David (Builder & Homeowner)

Consider if natural gas "luxuries" are worth it.

Originally, the home was planned to have a gas fireplace, stove and barbeque; however, throughout the design process, having learned about the inefficiencies and air quality issues of burning natural gas, David decided on an induction stove. Further, the heating load of the home (4.5kW or 15,400 btu) is so low that a gas fireplace would have likely overheated the house and was thus deemed unnecessary. As a result, David decided not to connect to the gas line at all.

Determine an airtightness strategy from the beginning.

To improve his home's airtightness, David used Aerobarrier, an aerosol sealant injected into a pressurized home once the envelope is complete and seals any gaps up to ½" in diameter. In this case, the product managed to improve the airtightness from 2.41 air changes per hour (ACH) to an impressive final 0.98 ACH. The home's simple geometry, use of interior wall cavities to minimize exterior wall penetrations and lack of below-grade structure also aided in optimizing the home's energy performance. David acted as the "air boss" during the project, making sure trades were on board with his air tightness strategy.

An air-to-water heat pump is a simple high performance system but consider future cooling.

This one heat pump outdoor unit provides enough energy for both space heating and hot water.

This project uses one CO_2-based air-to-water heat pump technology to provide in-floor radiant heating as well as heating for domestic hot water. These self-contained heat pump systems only need water lines to enter the house, requiring just a plumber for a relatively simple install. Finding a plumber knowledgeable about the installation procedures is important.

David sourced the equipment from Small Planet Supply, a company dedicated to energy efficient building materials and practices, who offered a lot of support on the installation requirements. The maintenance has been very straightforward so far, and it doesn't take up too much space as the water tank and distribution equipment were able to be installed underneath the stairs.

One challenge of the radiant heating system is that it doesn't provide cooling in the summer. David says this hasn't been an issue so far thanks to good passive cooling design, but there is room on the cement pad to install another air-to-air heat pump for cooling if that is needed in the future.

Energy and Emissions Analysis

This home achieved Step 4 of the BC Energy Step Code and, by using no fossil fuels, meets the strictest level of emissions performance in the BC Zero Carbon Step Code.

Annual Energy Consumption (GJ)	37
GHG Emissions (kgCO_2e/year)	113
GHGi (kgCO_2e/m^2/year)	0.5
Embodied Carbon (kgCO_2e)	39,100
Embodied Carbon Intensity (kgCO_2e/m^2)	171
Airtightness (ACH)	0.98
Annual Energy Consumption (GJ)	37
GHG Emissions (kgCO_2e/year)	113

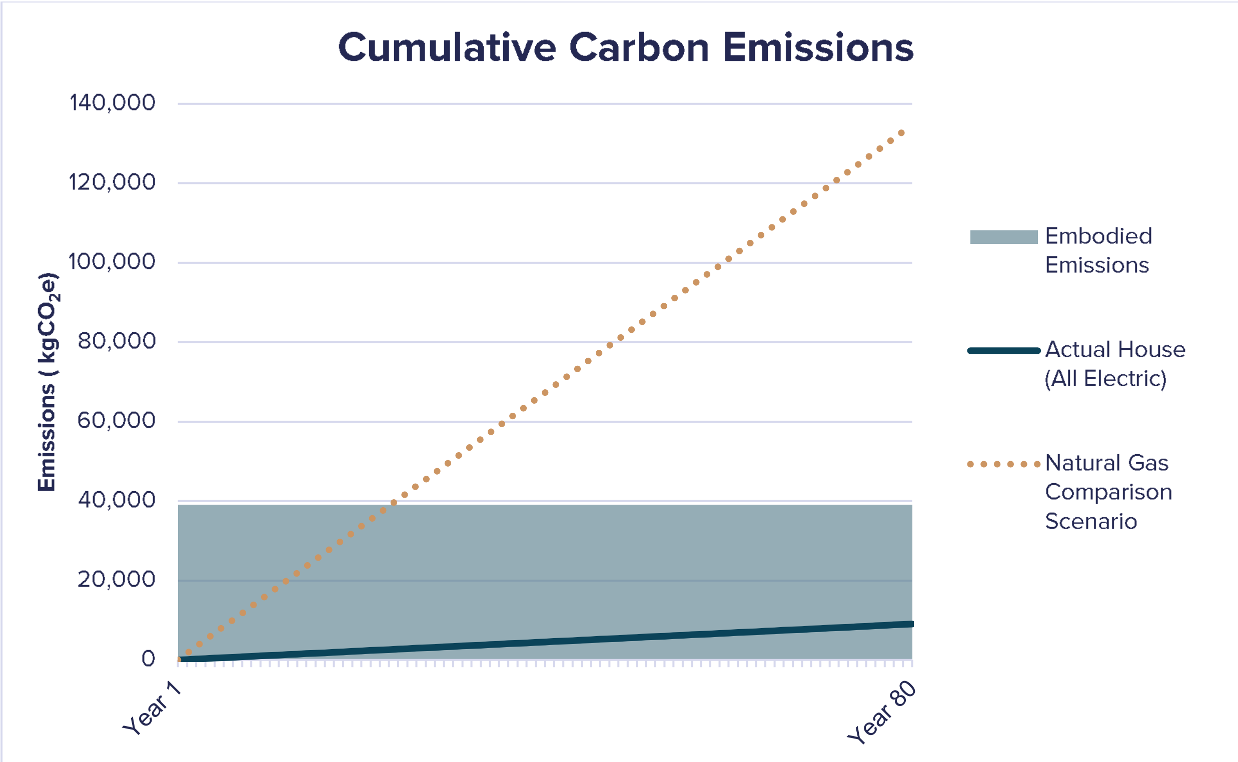
GHG Emissions

The graph below shows this home's cumulative GHG emissions over time and compares it to the same home if it had been equipped with a high-efficiency natural gas boiler and gas hot water tank.

Over the 80-year expected lifespan of this all-electric home, it will emit just 9 tonnes of CO_2e. This is a 93 reduction in emissions compared to the same home with natural gas heating and hot water. By opting for the all-electric approach, David is preventing 125 tonnes of CO_2e from entering our atmosphere, roughly equal to driving a gas vehicle 500,000 km!

The graph also indicates the estimated embodied emissions associated with the building materials of the home. It's significantly more than the lifetime operational emissions of the home (and equivalent to 23 years of operational emissions of a similar gas home). This highlights that for all-electric homes in BC, because operational emissions are minimal, it's important to consider the embodied emissions and try and choose lower impact building materials and concrete mixes.

Note on Methodology: Due to limitations of Hot2000, the hot water system connected to the common heat pump was modeled as a separate electric system with a C.O.P. of 3 (i.e. 300 efficiency).



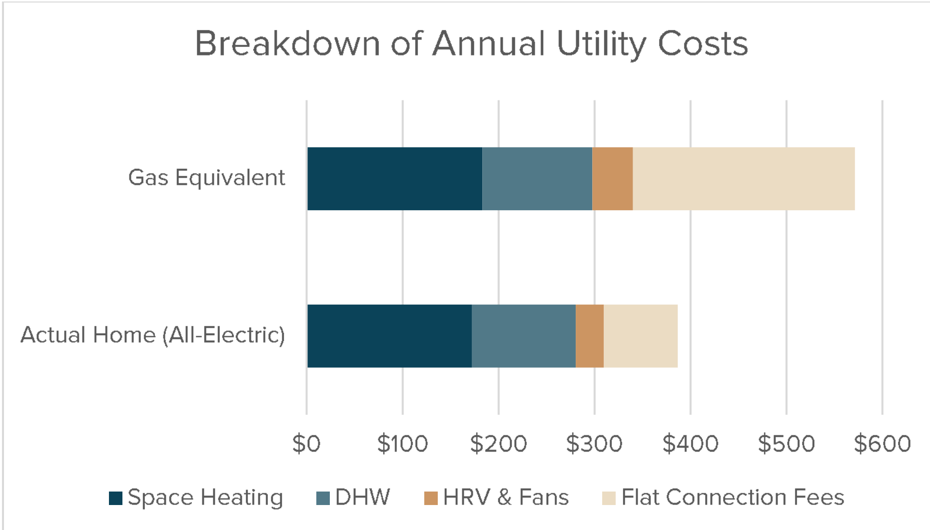
Utility Costs

This case study used the home's energy model to estimate the all-electric home's utility expenses compared to those of a hypothetical all-gas home.

The analysis indicates that the **annual heating and hot water expenses for this all-electric home are 30% less than those for an equivalent natural gas-powered home** (approx. $390 versus $570). David's home is particularly cost effective because his heat pump is used for both space heating and his hot water tank, allowing the high efficiency of a heat pump to be applied to both systems. This estimation does not consider the recently installed rooftop solar PV system that would reduce monthly electricity costs even further!

To allow for a better comparison, the monthly utility connection fees for electricity and gas systems are included, as an all-electric home saves by not having to connect to the gas grid. Also, the electricity for lighting, electronics, and appliances has been excluded from the analysis as it would be equivalent in both an all-electric and a gas home.

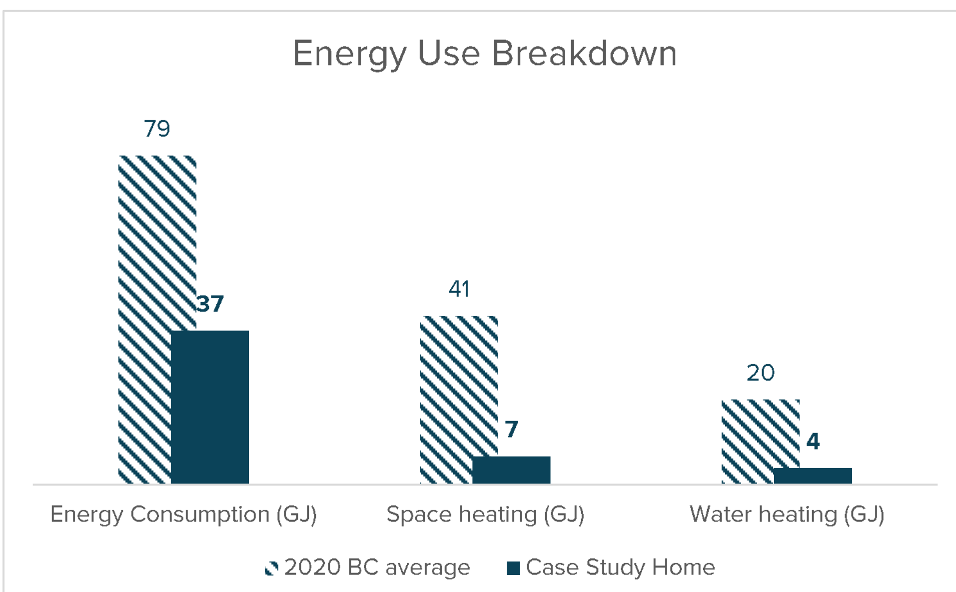
The graph illustrates the estimated annual energy bills for this all-electric home compared to the case if it had been equipped with a high-efficiency natural gas boiler and natural gas hot water tank.



These cost comparisons may change to benefit all-electric homes in the future (see Note 1 on Page 13).

Energy Use

Historically, space heating has been the highest element of energy usage in homes. However, as buildings transition towards high performance design, energy efficient homes often exhibit a significant reduction in heating-related energy consumption. When compared to the average home in BC, David's house uses roughly 55% less energy (GJ), approximately 80% less for space heating and 80% less for water heating.



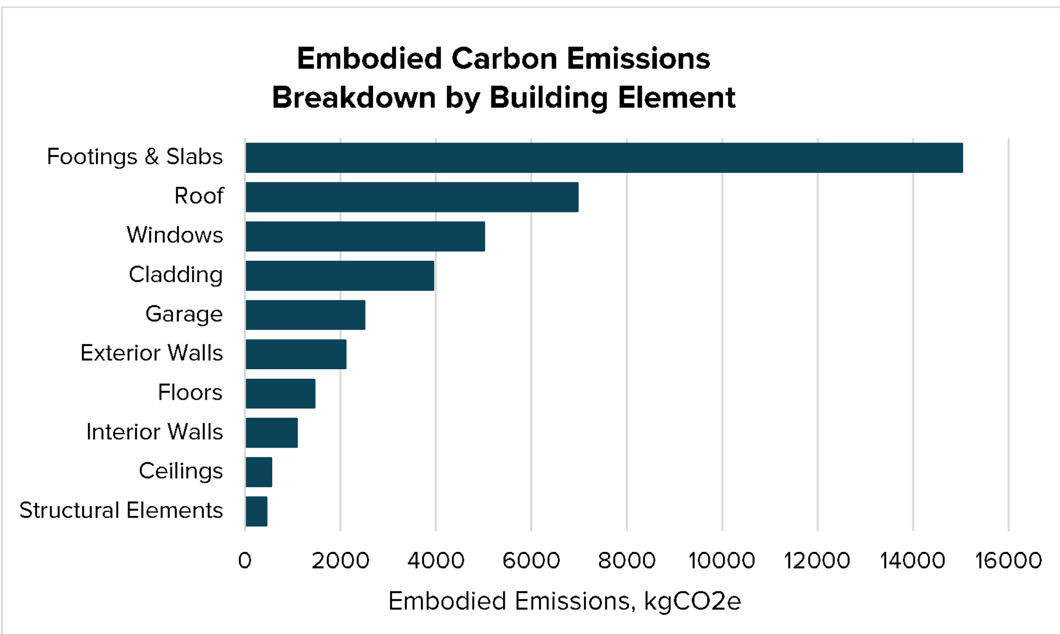
Embodied Carbon

While reducing embodied carbon was not a primary focus for this project, David's design choices resulted in an embodied carbon intensity of 171 $kgCO_2e/m^2$, coming in below the 200 $kgCO_2e/m^2$ average value for newly built homes in the City of Vancouver. The biggest reason for this above-average performance was the choice to use a slab-on-grade foundation instead of a basement. The reduction in concrete (the highest embodied carbon culprit in a new home) saved around 10 tonnes of carbon.


White siding being installed over the green layer of exterior insulation.

The old house was deconstructed and salvaged as best as possible. Old windows and doors were sold locally while hardwood floors were reclaimed to be reused in the new build. Even the new kitchen island is made from reclaimed siding to honor the sentimental value of the original home. These small details were not able to be included in the embodied carbon calculation but have helped reduce the home's true impact.

In the chart below, we can see that the footing and slab, roof, windows and cladding make up almost 80% of the embodied emissions. Of these, footing and slabs are the highest, consisting of 38% of the total.



Drew
SITE SUPERVISOR

"Building all-electric wasn't all that different."

Ross Bay

A High-Performance Home and Garden Suite

Zero Carbon Step Code Case Study #3 Ross Bay

<table>
<tr><th></th><th>Main House</th><th>Garden Suite</th></tr>
<tr><td>Year Built</td><td>2022</td><td>2023</td></tr>
<tr><td>Floor Area</td><td>2,560 square feet</td><td>600 sq ft</td></tr>
<tr><td>Foundation Type</td><td>Unheated crawlspace</td><td>Slab on grade</td></tr>
<tr><td>Space Heating</td><td rowspan="2">Single air-to-water heat pump for both in-floor radiant heating and hot water tank</td><td>Minisplit Air-source Heat Pump: American Standard</td></tr>
<tr><td>Hot Water Heating</td><td>Electric resistance tank heater</td></tr>
<tr><td>Energy Step Code</td><td>Step 4</td><td>Step 5</td></tr>
</table>

Climate Impact

This fully electric home and garden suite will produce 89 percent fewer emissions than an equivalent home powered by natural gas.

Description

This 2,560 sq ft detached home with a 600 sq ft garden suite of the lot met Zero Carbon Performance and reached higher levels of the Energy Step Code before the Zero Carbon Step Code requirements were in place. This was only the second all-electric home project for Villamar Construction, but they found the experience positive and without any particularly unique challenges.

Both structures are entirely electric, using heat pumps and electric water heaters for heating and cooling. The main house employs an American Standard Quest Cold Climate Heat Pump linked to a central air system, while the suite uses a minisplit system.

Key Takeaways

1. Simple architectural design helps hit performance targets.
2. Effective team coordination is crucial.
3. Pre-designing mechanical systems streamlines the process.

Background

Timeline		
2022	May – June	Architecture/Engineering Design
	June – Aug	Permits
	Oct – Dec	Demolition/Excavation/Foundation
2023	Jan – Feb	Framing/Roofing/Lockup
	Mar	Surface Rough-ins
	April	Siding/Insulation/Drywall
	May – June	Interior Finishes/Decking

This 2,560 sq ft home in the Ross Bay neighbourhood also features a separate 600 sq ft garden suite at the rear of the lot. Though completed before any Zero Carbon Step Code requirements, both the home and suite met Zero Carbon Performance and reached high levels of the Energy Step Code.

Meeting these high levels of performance didn't require anything outside-of-the-box. The home itself has a straightforward and efficient design, is well insulated, and has good airtightness. Meeting carbon emission performance came down to choosing electric heating and hot water systems over conventional natural gas alternatives.

The home was built by Villamar Construction with a high degree of input and involvement from the homeowner. For this build, the homeowner went in knowing they wanted an all-electric home. For the team at Villamar, this was just their second all-electric home project, but the experience has been a positive one and they don't feel that the project presented any particularly unique challenges.

The site supervisor on this project, Drew Mackie from Villamar Construction, first ventured into building high-performance homes several years ago after taking a locally run high-performance building course. Since then, he has been educating himself and his team on the latest advancements in building science. He is driven by the desire not just to meet minimum code compliance but to be at the leading edge of the industry, saying "I'd rather be in the driver's seat than the backseat!"

Window Installation

The same concepts can be applied to many other homes and Drew feels they are positioned to deal with future code changes. For those looking to get on board with the latest advancements in building science, Drew's advice is to visit other job sites that are doing the same thing, at various stages of construction, to learn from what others are doing. They also emphasize that a unified and collaborative team is essential to achieving successful results.

Building Assemblies		**HVAC Systems**	
Exterior Walls	*House*: 2 x 6 @ 16" oc, R-22 batt *Suite*: R-22 Pacific SmartWall	**Heating**	*House*: Central ASHP *Suite*: Mini Split Ductless ASHP
Roofs	Attic or Scissor Vault, R-40	**Cooling**	From ASHPs
Below Grade Walls	*House*: R-12 spray foam *Suite*: N/A	**Hot Water**	Electric resistance tank heater
Foundation Slab	*House*: R-12 spray form for crawlspace walls, no insulation under slab *Suite*: R-12 under slab	**Ventilation**	*House*: Central recirculating ventilation *Suite*: Utility fan
Windows	Double-glazed, argon fill	**Backup Heating**	Electric resistance backup
Air Barrier	Interior polyethylene vapour barrier	**Fireplace**	Wood-burning fireplace in the main house

Low Carbon Strategies for Success

This project exemplifies how a well-well-thought-out, straightforward design and a strong builder-homeowner partnership can result in an exceptional home. Drew and the Villamar team wanted to differentiate themselves by proactively building an all-electric high-performance home, positioning the business as a leader in the field before it became a mandatory requirement in Victoria.

Simple design helps hit performance targets.

The simple but charming architecture of the home improved envelope energy performance and allowed for less under-slab insulation required to meet the Step Code target.

To optimize air distribution throughout the home, the air handler was centrally located. Additionally, the choice of more durable and energy-efficient materials, such as mineral wool insulation over fiberglass batt, further enhanced the home's overall performance.

Drew and his crew implemented a pre-planned air barrier strategy, incorporating rubber gaskets for exterior wall penetrations, showcasing a thoughtful and proactive approach to ensuring airtightness in the construction process.

Team coordination is essential.

This project involved thorough planning and execution. Ensuring that subtrades are in alignment with the chosen project management approach fosters effective communication, collaboration, and overall project efficiency. Thoughtful coordination minimizes the potential for misunderstandings, delays, and conflicts that can arise when different parties have divergent expectations or working methods.

“Coordination is important: bringing the right players into a meeting and discussing how we are going to do it ensures everyone is on the same page.” - *Drew (Site Supervisor)*

Drew attested that a well-coordinated team of subtrades ensures that each understands their roles, responsibilities, and timelines, resulting in a smoother and more harmonious construction process while reducing the likelihood of rework and costly errors. In this case, the homeowner also had a high degree of input, remaining looped in through daily or weekly discussions with the project team.

Pre-designing mechanical systems makes things easier.

Strategically planning and designing the all-electric mechanical systems in advance offered advantages by minimizing the need for penetrations through the building envelope. This approach not only ensured an efficient and optimized ducting layout but also reduced air leaks and thermal bridges.

If anything, it’s less effort.

This project’s sustainability goals were mainly driven by the builder and homeowner. Subtrades were also on board, but there was no need to hire additional trades or specialists to meet the energy and emissions goals beyond the usual, including the energy advisor for mid-construction and final blower door tests.

Drew recognized it takes effort, focus and an understanding of the air and vapour barrier. In terms of equipment, it took a bit of effort to make sure everything was functioning correctly. Still, when asked about the challenges switching from building homes with natural gas to all-electric, Drew said: “It's just picking different appliances, different heating systems and, if anything, it's less effort because you don’t need to worry about running gas.”

Energy and Emissions Analysis

	House	*Garden Suite*
Annual Energy Consumption (GJ)	45	41
GHG Emissions (kgCO_2e/year)	139	125
GHGi (kgCO_2e/m^2/year)	0.6	2.2
Embodied Carbon (kgCO_2e)	25,200	9,900
Embodied Carbon Intensity (kgCO_2e/m^2)	106	178
Airtightness (ACH)	1.3	1.5

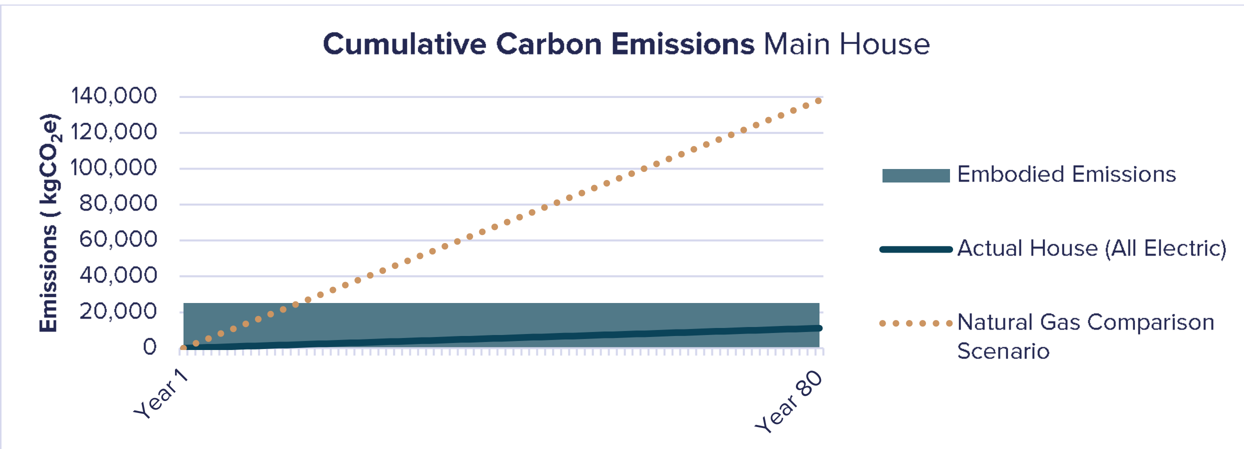
This home achieved Energy Step Code Step 4 in the main house and Step 5 for the garden suite, surpassing all requirements. Using no fossil fuels, this home and suite meet the strictest level of emissions performance in the BC Zero Carbon Step Code.

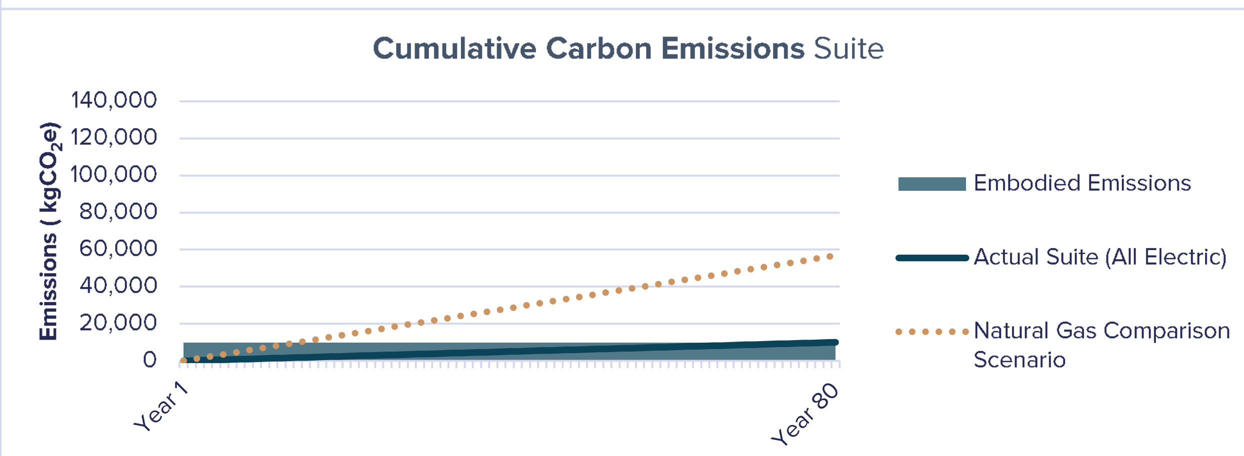
GHG Emissions

The graphs below show this home and suite's cumulative GHG emissions over time and compare it to the same home if it had been equipped with a high-efficiency natural gas boiler and gas hot water tank. Considering an 80-year lifespan, this all-electric home and garden suite will emit just 21 tonnes of CO_2e, an 89% reduction in emissions compared to the same home using natural gas instead.

By building an all-electric home, the homeowner, Jeff, is preventing 195 tonnes of CO_2e from entering the atmosphere, roughly equal to driving a gas vehicle 800,000 km!

The graphs also show the estimated embodied emissions associated with creating the building materials for the home. It's significantly more than the lifetime operational emissions of the home (and equivalent to 15 years of operational emissions of an equivalent gas home). This highlights that reducing the true carbon impact of a building involves not only using low-carbon all-electric systems but also considering the embodied emissions by choosing lower-impact building materials and concrete mixes.





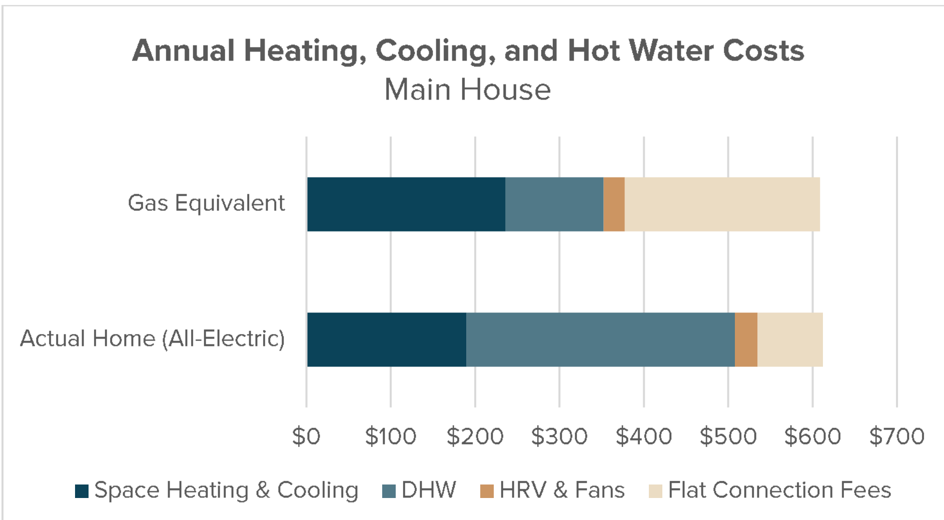
Utility Costs

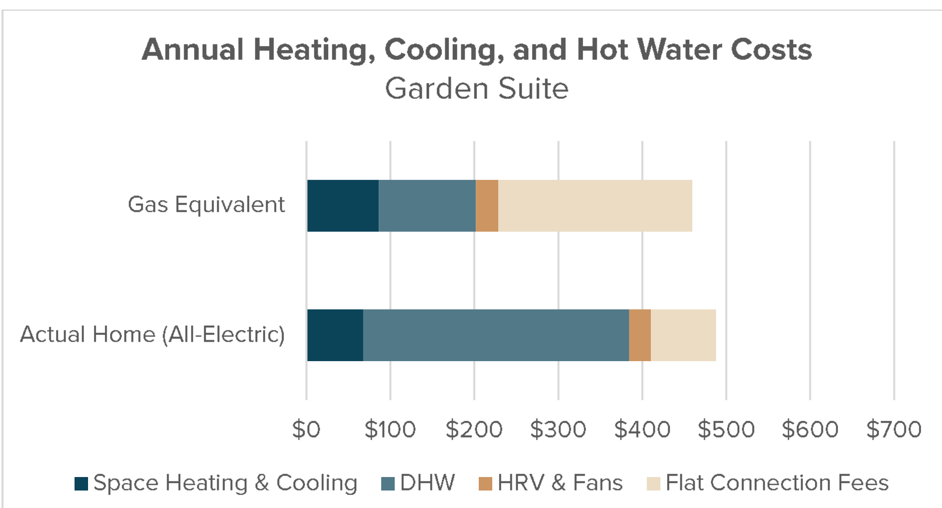
This case study used the home's energy model to estimate the utility expenses of the all-electric system compared to a hypothetical all-gas system. Considering that the energy model is an estimate and doesn't consider variations in occupant behaviour, utility costs can be considered nearly on par.

The energy model indicated that utility expenses for this all-electric home and garden suite are roughly comparable with a natural gas equivalent home (combined total of approx. $1,100 versus $1,070).

The graphs below illustrate the estimated annual energy costs for heating cooling and hot water for this all-electric home and garden suite compared to an equivalent home with a high-efficiency natural gas boiler and hot water tank and separate AC unit, at the current utility rates.

To illustrate a better comparison, the monthly utility connection charges for electricity and gas systems are included, as an all-electric home saves by not having to connect to the gas grid. As well, the electricity for lighting, electronics, and appliances has been excluded from the analysis as it would be equivalent in both an all-electric and a gas home.



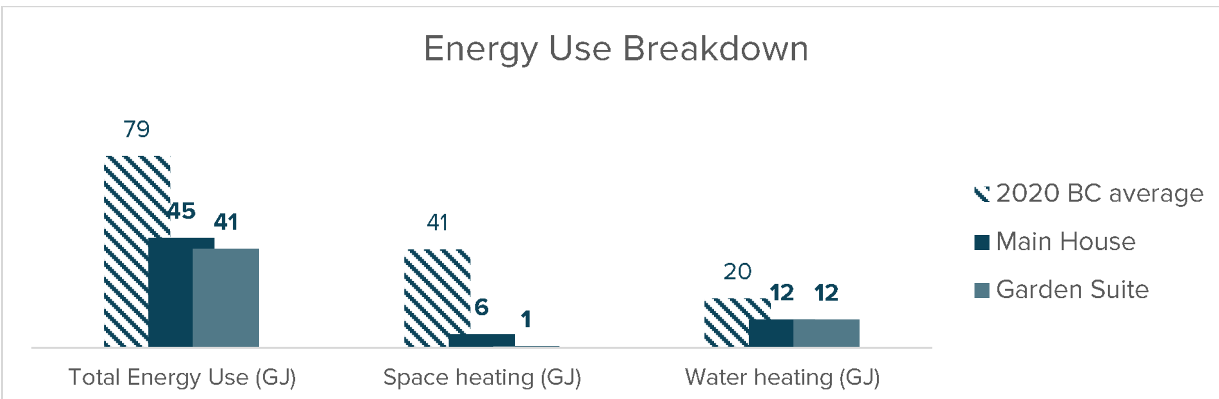


As we experience warmer summer seasons, the importance of effective passive or active cooling solutions becomes increasingly necessary. Heat pumps emerge as versatile solutions, efficiently handling both heating and cooling needs for homes. Cooling has transitioned from a luxury to a necessity in some households, especially those with individual health risks associated with high temperatures. Incorporating passive or active cooling considerations into the early design stage is a must. As seen in the graph, cooling equipment has a noticeable effect on utility bills, so prioritizing passive cooling measures can help keep costs lower in the summer. These cost comparisons may change to benefit all-electric homes in the future (see note on page 13).

Energy Use

While space heating often accounts for the largest share of energy usage in existing homes, high-performance design can result in significant reductions in heating-related energy consumption in new, energy-efficient homes. Jeff's house uses roughly 40% less energy than the average BC home (and a significant 85% less for space heating and 40% less for water heating).

The garden suite uses much less energy for space heating than the main house due to its reduced size. However, as a result of the assumptions built into the modeling software, the garden suite is estimated to use a similar amount of hot water and electricity for appliances, electronics, and lighting, so the overall energy consumption is closer to the main home than one might expect. This highlights the energy efficiency of the envelope and HVAC, which reduces heating energy requirements below what is needed for lighting and appliances.



Embodied Carbon

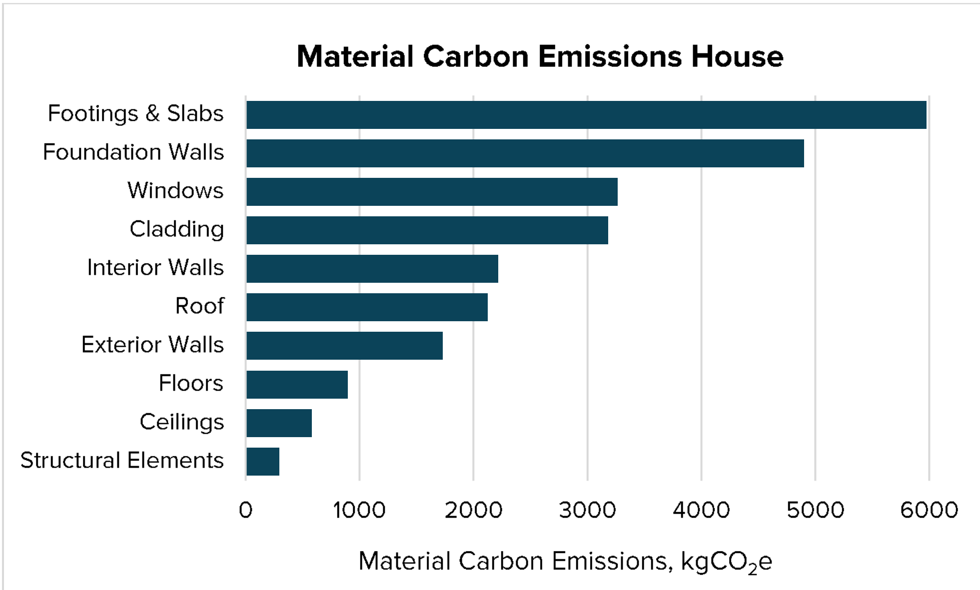
Although minimizing embodied carbon wasn't a defined goal for this project, the estimated GHG impacts of its materials are significantly lower than the recent average benchmark release by the City of Vancouver. This better-than-average performance came from several design decisions, including:

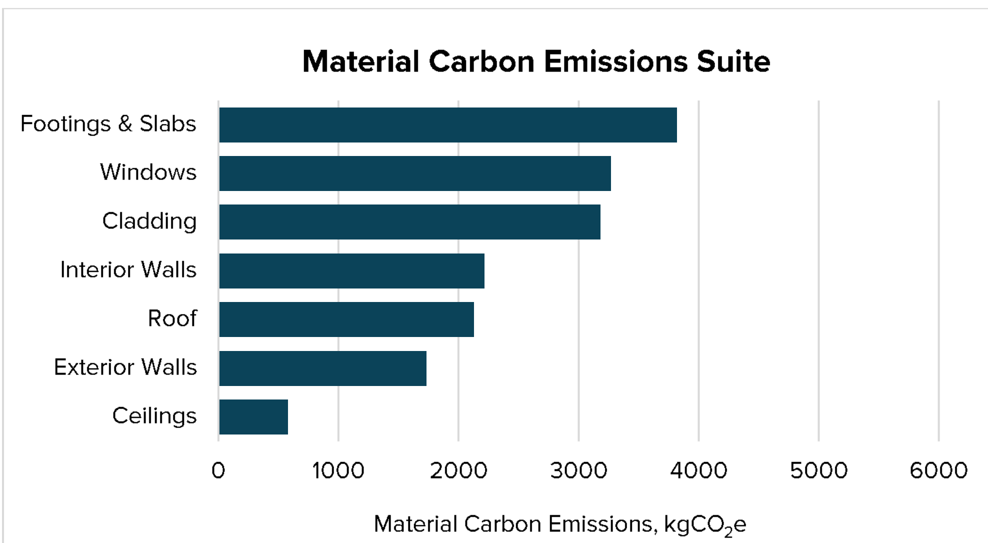
- Wood-frame construction
- Choosing a crawlspace instead of a full basement and reducing concrete use
- Not including a garage
- The uncomplicated form required less insulation to achieve energy efficiency targets.

Using the MCE2 Material Carbon Emissions Estimator tool, this project's embodied carbon intensity was calculated as 106 $kgCO_2e/m^2$ for the main house and 178 $kgCO_2e/m^2$ for the garden suite. Both showed excellent performance compared to the new 200 $kgCO_2e/m^2$ average value for newly built homes in the City of Vancouver.

As the home that was demolished to build the new one had been in the family since 1970, the owner was eager to reclaim and reuse its material. They were able to build a whole fireplace out of reclaimed fir from the original house. Cedar tongue and groove ceiling boards were also saved and re-used as some aesthetic features in the new home. While these smaller features were not included in the calculations, they certainly helped further reduce the actual carbon impact of the home.

As shown in the following charts, the primary sources of embodied emissions are the footing and slab, foundation walls, cladding, and windows, collectively comprising two-thirds of the overall emissions. Notably, footings and slabs stand out as the most substantial contributors, emphasizing the impact of concrete on embodied emissions.





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