The 2032 Home

carbon wise

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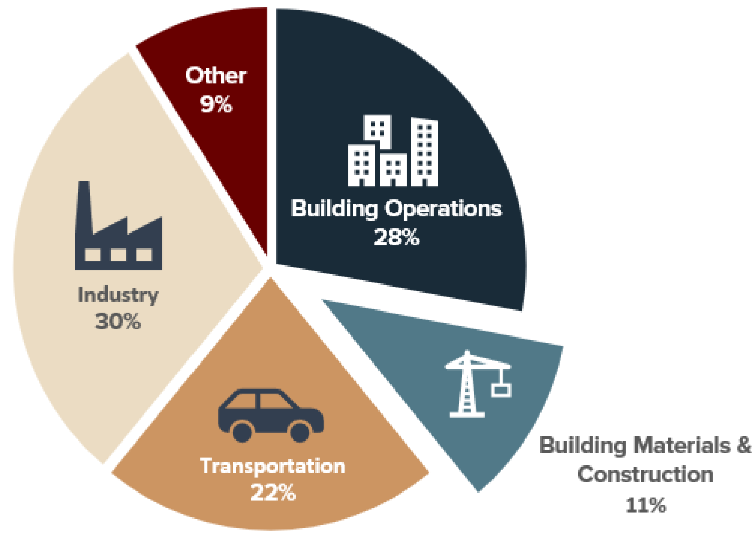
Introduction

Together, building operations and construction are responsible for a total of 39% of global CO_2 emissions. While 28% comes from the energy used to heat, cool, light, and ventilate buildings, the remaining 11% comes from the embodied emissions associated with extraction, manufacturing, transportation, installation, and the decommissioning of building materials.

Over the past few decades huge progress has been made toward addressing building operational emissions however, this only represents two-thirds of the total problem. As buildings continue to become more and more energy efficient, embodied emissions will represent an ever-increasing portion of the total emissions. Recent building code developments such as Vancouver Building By Law's embodied carbon limits have brought embodied emissions into the spotlight when it comes to part 3 buildings however, addressing embodied emissions in part 9 homes will also play a crucial part in meeting municipal, provincial, and national climate goals.

This study explores how one home on the Sunshine Coast managed to meet Step 5 of the BC Energy Step Code while also keeping embodied emission intensity to an impressive 118 kg CO_2 e/m². This is significantly below the City of Vancouver's first benchmark of 200 kg CO_2 e/m².

Global CO_2 Emissions by Sector



Source: Global CO_2 emissions by sector, adapted from the World Green Building Council, Global Status Report, 2019

BC Energy Step Code:	Step 5
GHG:	108.4 $kgCO_2e$/year
GHGi:	1.24 $kgCO_2e/m^2$/year
Embodied Carbon:	13,866 $kgCO_2e$
Embodied Carbon Intensity:	118 $kgCO_2e/m^2$
Airtightness:	0.9 ACH

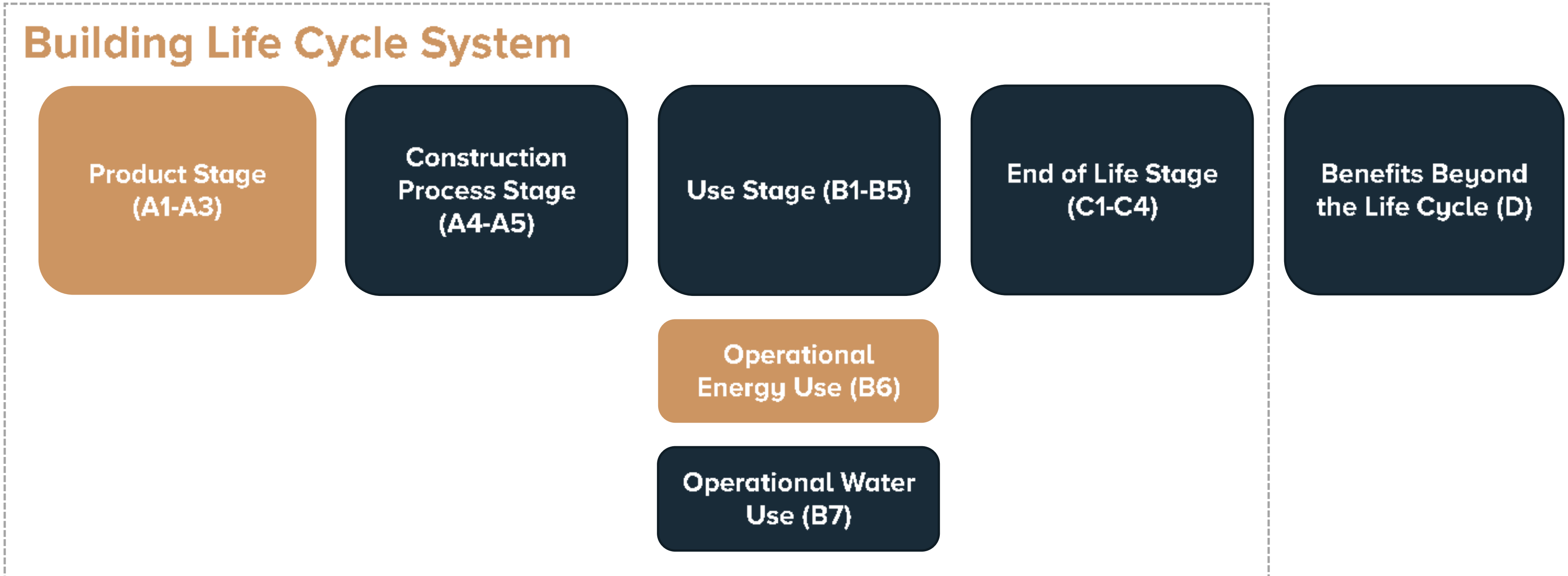
Background

The homeowner began with a vision to build a home that focused on both operational and embodied emissions reductions. Upon purchasing an undeveloped plot of land in the District of Sechelt, the homeowner initially engaged Lincoln Construction as the builder, seeking out their advice and experience with designing sustainable homes. Lincoln recommended GNAR Sustainable Design as the building designer and Carbon Wise was brought on as energy advisor and LCA consultant for the project.

Throughout entire the design and build process the homeowner, GNAR, Lincoln Construction, and Carbon Wise maintained close communication, ensuring everyone was aligned with the goals of reducing embodied emissions and ensuring the project remained on track to meet Step 5 of BC Energy Step Code.

A Life Cycle Assessment (LCA) is a systematic methodology for assessing the energy use and environmental impacts of a building throughout its entire life cycle.

Calculating Emissions



Building lifecycle system illustrating the stages (highlighted in orange) included in the scope of this study.

As per Natural Resources Canada's national guidelines for whole-building life cycle assessment, the building's structure and enclosure are both included in the life cycle analysis. Building components such as mechanical, electrical, and plumbing materials, fixtures, appliances, fasteners, surface finishes, stairs, decks, and exterior yard work were not part of the scope.

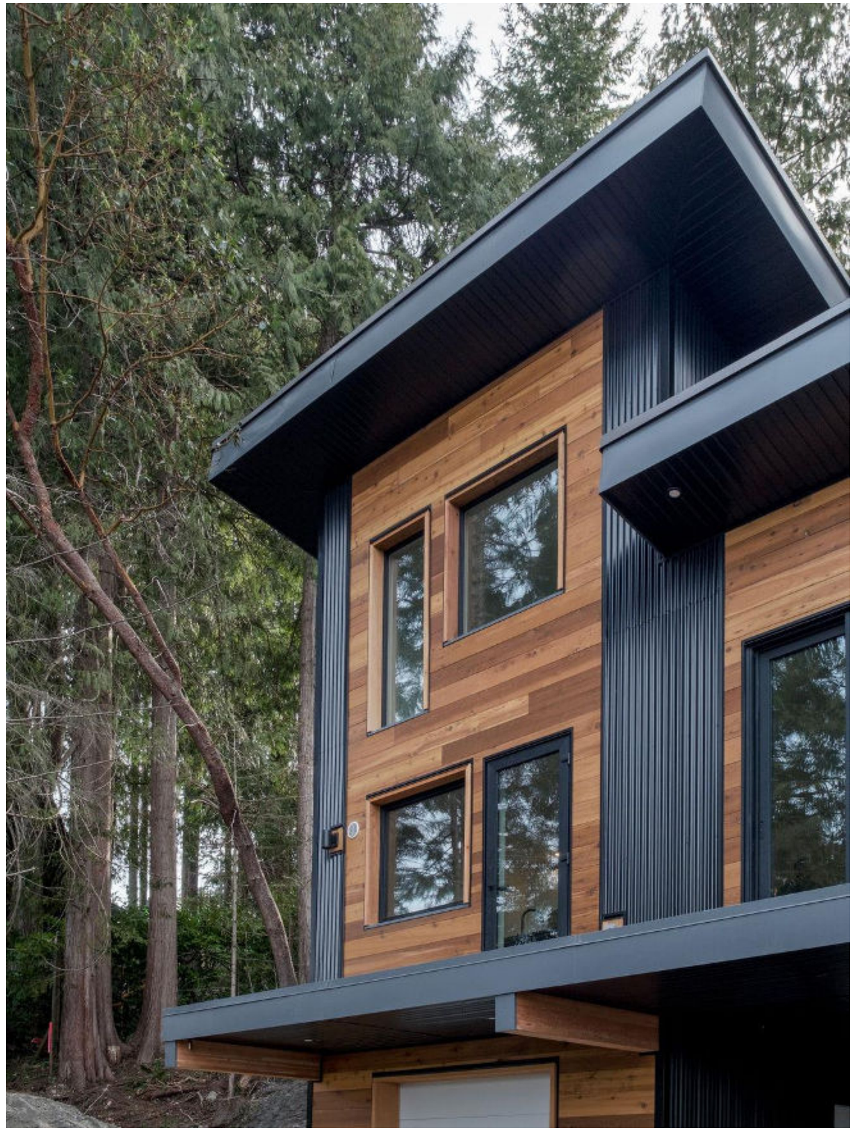
Carbon storage is also considered in the scope of this study. Materials that have been reclaimed and reused on the project have been factored in at 25% of the emissions of the new product, as per the Builders for Climate Action guidelines.

Low-carbon design strategies

Modest size, simple design

The homeowner made a conscious sustainability decision to build a home that was modest in size but could easily be expanded upon in the future to meet the needs of a growing family. This phased approach to construction focuses on only building what is absolutely necessary, significantly reducing material usage and the associated emissions. Phase 1, which is the current build, is approximately 1,100 square feet in size (plus approximately 400 square feet for a garage and mechanical room). Phase 2 is designed to incorporate 600 square feet of additional floor space and is projected to be completed, only if needed, in 10-15 years. This phased approach also takes embodied carbon into consideration. By only requiring one additional concrete footing, the amount of concrete required for this second phase of the build is minimized.

Overall, the size of the initial build has been reduced by 35.3%, which translates to embodied carbon savings of approximately 7,565 kg CO_2e. Although more difficult to directly quantify, the simple geometry of the home is another factor that helps to both reduce material use and keep operational emissions down.



Low-carbon design strategies

BC Passive House prefabricated panels

The use of BC Passive House prefabricated panels was a suggestion made by GNAR, the building designer, to help lower embodied emissions on the project. These panels are filled with dense-packed blown-in cellulose insulation, made from recycled paper products. Carbon is initially sequestered by trees during their growth and recycling of the paper products prevents this carbon from subsequently being re-released back into the atmosphere. As such, blown cellulose insulation is considered to be a form of carbon storage. The prefabricated panels used for the exterior walls, roofs, and exposed floors are responsible for total emissions savings of 3,699 $kgCO_2e$.

Although excluded from the scope of this study, it is worth mentioning that the decision was also made to run conduit through the wall panels, eliminating the need for an interior service cavity and further reducing material usage on the project.

Low-carbon design strategies

Minimize concrete

One of the ways the designers and owner sought to minimize embodied carbon was to design for the site conditions and minimize the amount of concrete required. This meant, limiting any below-grade portions of the home and reducing the concrete needed for a foundation slab. The garage comprises the majority of the foundation for the home, while a significant portion of the main floor is an exposed floor, eliminating the need for a full-size concrete slab and instead opting for smaller concrete footings and wooden posts. Despite this, concrete still remains the largest source of carbon emissions for the entire home.

Reclaimed siding

The home uses a combination of metal and reclaimed cedar siding, each piece of which was painstakingly stained and sanded by the homeowner. This material decision led to emissions savings of 1,966 $kgCO_2e$ versus a typical alternative such as Hardie board siding.

Small wins

The homeowner was also able to reclaim enough engineered hardwood from a renovation project via Facebook Marketplace for the entire home (excluding the bathrooms) in addition to recycled bathroom tiles. These small embodied carbon savings via reclaimed materials are not directly quantifiable under the scope of this study but they are a conscious sustainable decision nonetheless and noteworthy in the quest to further reduce emissions.

Challenges

Upon excavation, it was determined that the house needed to be moved back nine feet, which resulted in a larger amount of concrete being required for bank retention and stability. The owner and builder spent significant effort trying to execute the design in a way that minimized the amount of concrete; however, ultimately, the site conditions dictated additional concrete, and a lower embodied carbon concrete mix was not accessible due to budgetary constraints.

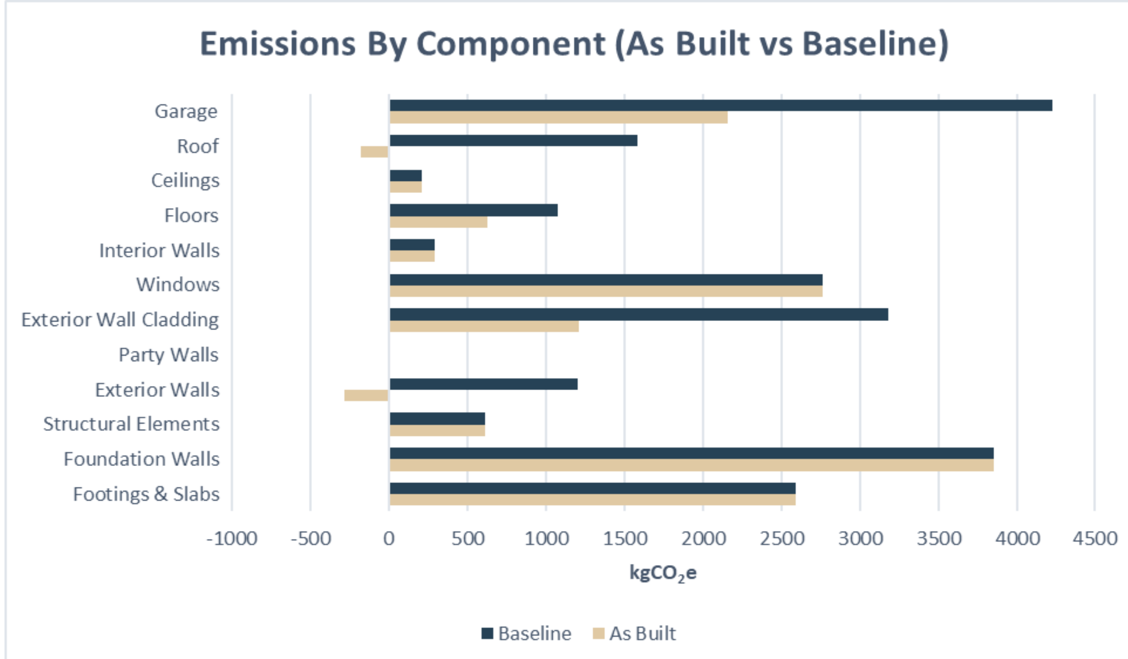
The homeowner also attempted to use reclaimed lumber from Unbuilders to further lower the embodied carbon of the build; however, the requirement from the structural engineer that every piece of lumber was individually graded led to logistical and cost barriers that could not be overcome. The house was even originally engineered with the reclaimed lumber specifications from Unbuilders in mind. Unfortunately, when the use of reclaimed lumber failed to be viable, the owner incurred significant additional engineering costs to have the home re-engineered.

Despite meeting with the builder, designer, BC Passive House, Unbuilders, and the engineers together as a group, and the homeowner's continued advocacy for using reclaimed materials in the build, certain logistical and cost constraints could not be overcome. It is their hope that the conversations that were had in the attempt to use reclaimed lumber in the build will help pave the way to future adoption of these more sustainable practices.

Embodied Emissions baseline comparison

In order to assess and quantify the impact material choices have made on the overall embodied emissions of the design, the model has been compared to a 'baseline home'. This 'baseline home' is the exact same house built using materials and assemblies which are more in line with conventional local construction practices.

In this case, traditional framing and fiberglass batt insulation was replaced by dense-packed cellulose pre-fabricated wall, roof, and floor panels. A typical Hardie board siding was replaced by reclaimed cedar and metal siding.



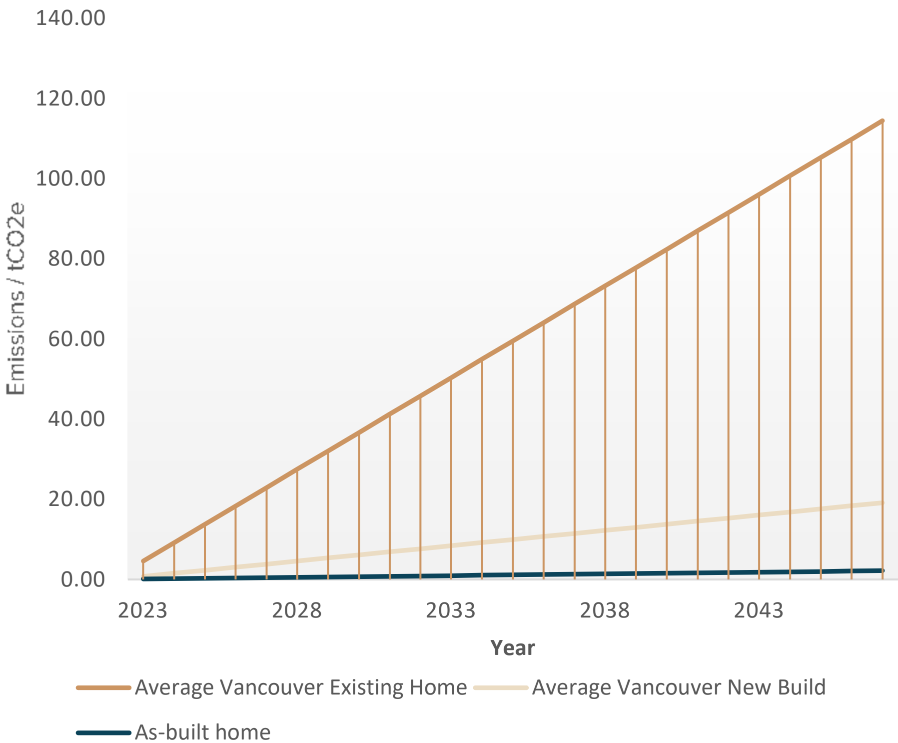
Graph illustrating the emissions by building component of the home (as-built) and the same home built using conventional practices (Baseline).

Original Material	Embodied Emissions $KgCO_2e$	Material Substitution	Embodied Emissions $kgCO_2e$	Reduction
Fiberglass batt - Wall insulation	436	Blown Cellulose	-1,513	447%
Fiberglass batt - Roof insulation	279	Blown Cellulose	-1,146	510%
Fiberglass batt - Exposed floor insulation	153	Blown Cellulose	-631	512%
Hardie Sliding	2,882	Mix steel and reclaimed cedar	890 + 26	68%

Table outlining the emissions reductions from the top 4 material substitutions in the as-built home.

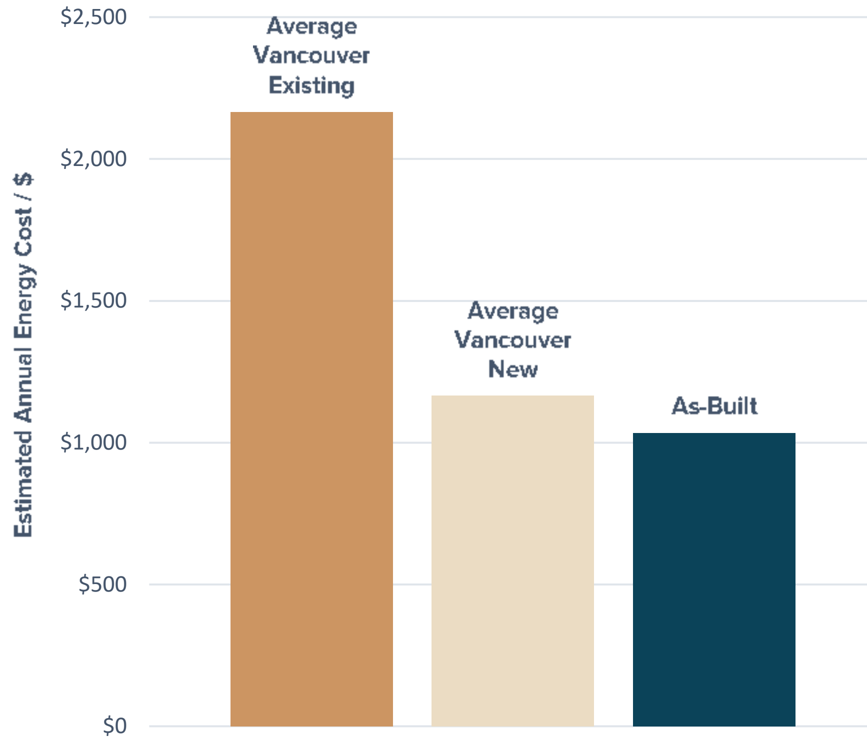
Operational Emissions & Costs

Cumulative Emissions Over 25 Years



Graph showing the cumulative operational emissions of the as-built home, a new build in the City of Vancouver, and an existing home in the City of Vancouver.

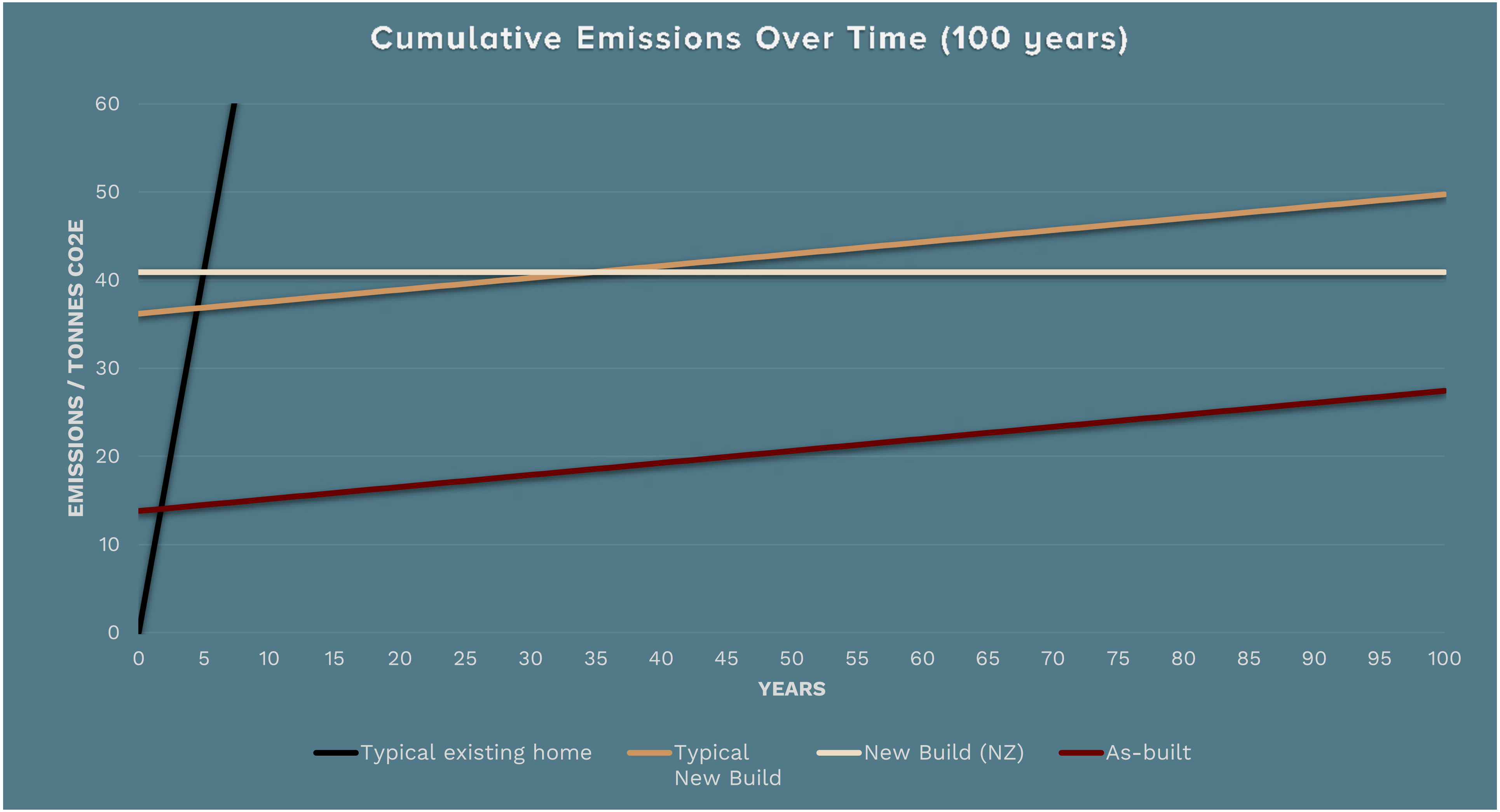
Estimated Annual Energy Cost



Graph showing the estimated annual energy bills for the as-built home compared to the average new build and average existing home in the City of Vancouver.

The graphs above demonstrate how this home saves on both operational emissions and costs when compared to the average existing home and the average new home built in the City of Vancouver. Moreover, this home is currently heated by electric baseboards and the future installation of a high-efficiency heat pump provides further opportunity to drive operational costs down in the future. One could make the argument that the average single-family home is considerably larger than this modest new build and as such, this does not satisfy an adequate like-for-like comparison. Nonetheless, the size of this home was a conscious design choice and only serves to illustrate how moving away from the traditional 2,500 sq ft single-family home concept can have a significant impact on both embodied and operational emissions.

Embodied and Operational Emissions over Time



Conclusions

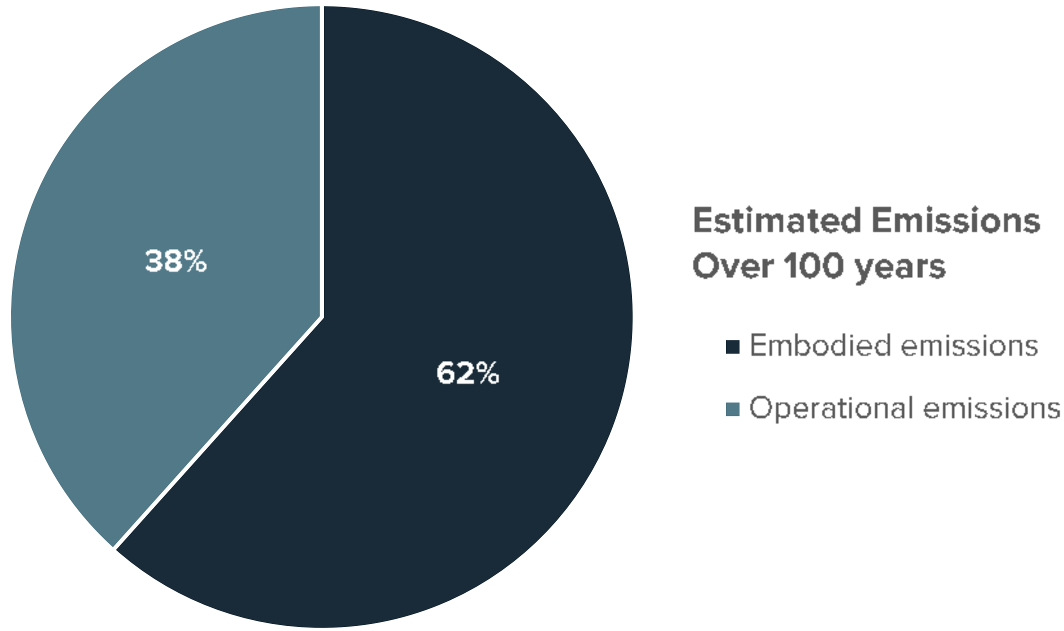
- Concrete, whether part of footings and slabs, garage, or foundation walls represents the largest portion (51.5%) of embodied emissions throughout the entire building. After all concrete portions are accounted for, the biggest emitters are then windows (19.9%) and metal cladding (6.4%) respectively.

- The exterior walls, exposed floors, and roof demonstrate net carbon storage due to large volumes of dense-packed cellulose insulation used in the pre-fabricated panels. This helps to offset some of the emissions associated with other materials in the building.

The home is all-electric, operating off BC's largely clean electricity grid, with low operational emissions. What this means is that the embodied emissions of the building materials represent the majority of all emissions associated with this building.

- This home has an embodied emissions intensity of 118 $kgCO_2e$/m2. This is a **41% savings** compared to the City of Vancouver benchmark of 200 $kgCO_2e/m^2$.

- Material substitutions alone have resulted in emissions savings of 7,732 $kgCO_2e$ or 65 $kgCO_2e/m^2$ (36%) from the baseline home using conventional construction practices. **That is the equivalent of taking 2.37 cars off the road.**



Pie chart showing the breakdown of estimated emissions associated with the as-built home over the course of 100 years.

This home is the type of new home that will be built in the future, already meeting the operational and embodied emissions standards which will be required in 2032.

By making a few conscious yet simple design changes and material selections which deviate from conventional construction practices, it is possible to make a significant impact on both embodied and operational emissions. This is a true success story of how the integrated design process and collaboration between the homeowner, builder, designer, and life cycle consultants can help pave the way toward low-carbon, high-performance homes.

References

[1] City of Vancouver Embodied Carbon Limits On Part 3 Buildings

[2] City of Vancouver Embodied Carbon Benchmark of 200 $kgCO_2e/m^2$

[3] NRCan National Guidelines For Whole Building Lifecycle Assessment

[4] World Green Building Council Global Status Report 2019

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Questions?

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