Researching the embodied carbon reduction potential of low-rise construction and development of a low-carbon building supply inventory

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Executive Summary

In order to reduce Canada’s carbon footprint, the reduction of carbon emissions from buildings is crucial. In Canada, buildings contribute to 13 percent of emissions. The carbon emissions from building can be categorized as embodied carbon (EC) and operational carbon (OC) emissions. EC emissions refer to the emissions generated when building materials are produced, transported and assembled for building construction or renovation. Fifty percent of carbon emissions of new construction projects until 2050 are expected to come from EC. According to the Paris Agreement, the EC of all new buildings, infrastructure and renovations must be reduced by at least 40% by 2030, and to achieve net-zero EC by 2050. Hence, as part of the City's declaration of a climate emergency, Vancouver City Council has set a target of reducing EC emissions by 40% by 2030.

This project looks at the products and materials available to the Vancouver market that can be used in low rise residential buildings. The goal of this research is to assess the potential to reduce the embodied carbon of low-rise residential construction using materials and products available to builders in Vancouver.

This report consists of two parts; first, an inventory of materials that are locally available for low rise residential buildings and their suppliers contact information. Second, the potential reduction in EC emissions of low-rise residential buildings using locally available materials.

Introduction

Approximately 40% of global energy-related carbon emissions are derived from buildings. These carbon emissions consist of embodied carbon (EC) and operational carbon (OC) emissions. EC emissions refer to the emissions generated when building materials are produced, transported and assembled for building construction or renovation[1]. Fifty percent of carbon emissions of new construction projects until 2050 are expected to come from EC. According to the Paris Agreement, the EC of all new buildings, infrastructure and renovations must be reduced by at least 40% by 2030, and to achieve net-zero EC by 2050[2]. Hence, as part of the City's declaration of a climate emergency, Vancouver City Council has set a target of reducing EC emissions by 40% by 2030.

The EC emissions of typical low-rise residential buildings are calculated to be between 90-420 kg CO_2 per m^2 of building area. Availability and affordability of construction materials with low EC emissions allow builders and designers to choose carbon-smart materials such as plant-based building materials. This opportunity allows building sectors leaders to reduce or even eliminate the EC emissions of buildings and move towards making buildings with zero up-front emissions 3.

In order to achieve the target of reducing EC emissions, the goal of this research project is to assess the potential to reduce the EC of low-rise residential construction using materials and products available to the Vancouver market. The first objective of this project is

[1]World Green Building Council, Advancing Net Zero, Ramboll, C40, 2019. Bringing embodied carbon upfront.

[2] UNFCC, 2015. Adoption of the Paris agreement. United Nations framework convention on climate change report, Conference of the Parties on its twenty-first session.

[3] A breakdown of emissions from insulation. Courtesy of builders for Climate Action 2019 White Paper, Low-Rise Buildings as Climate Change Solution.

to provide a list of low-carbon building supply inventory that can be used by local builders, developers, architects and designers to specify low carbon products.

This project supports an incentive program based on work by Builders for Climate Change Action (https://www.buildersforclimateaction.org/) known as BEAM (Building Emissions Accounting for Materials). BEAM is a user-friendly tool to evaluate the carbon footprint of a building through all the material options. It also helps users to understand the best approaches to reduce the EC of a building. The second objective of this project is working with construction thought leaders to draft a new house that sequesters carbon would look like using locally approved and available materials.

Research Approach

The steps of research work include:

1. Reaching out (calling, emailing) to Vancouver builders to find suppliers' information.
2. Reaching out to suppliers such as concrete supply, lumber supply, insulation manufacturers and distributors, window suppliers, etc. to understand what products (from an existing list which outlines common materials and some lower and higher carbon options- BEAM tool) are available for low rise residential construction projects.
    a. This stage is conducted through sending emails or phone call and requesting for collaboration; if agreed, a Zoom meeting is scheduled to go over the BEAM calculator and explaining the requirements information and the ways in which the information should be provided.
3. Developing contact sheets in the BEAM tool Excel file with tabs by material (concrete, wood, insulation, etc.) and by local suppliers along with minimum volume for product delivery if applicable.
4. Evaluating locally available materials to indicate if they have a high, medium, or low potential to reduce carbon though using BEAM tool. The contact and information sheets are populated in a manner that assist local builders, developers, architects and designers with procuring materials that have reduced embodied carbon emissions in low rise residential buildings.
5. Working with construction thought leaders to draft houses that have low EC emissions or even have the potential to sequester carbon.

Key findings

Vancouver Building Supply Inventory

The inventory of building supply which can be applied in low rise residential buildings is derived from BEAM Calculator. BEAM (Building Emissions Accounting for Materials) includes all major structure, enclosure and finishes information that can be used for residential buildings. Current BEAM calculator tool, which is used in this project, consists of 12 sheets for categorizing materials that include 1. Footings and slabs, 2. Foundation walls, 3. Structural elements, 4. External walls, 5. External wall systems, 6. Cladding, 7. Windows, 8. Internal walls, 9. Floors, 10. Ceilings, 11. Roof, and 12. User-defined [4]. In each sheet, the information of suppliers is provided in front of the materials, which they can provide to the city of Vancouver builders. A sample of the inventory with suppliers' information is provided in Figure 1.

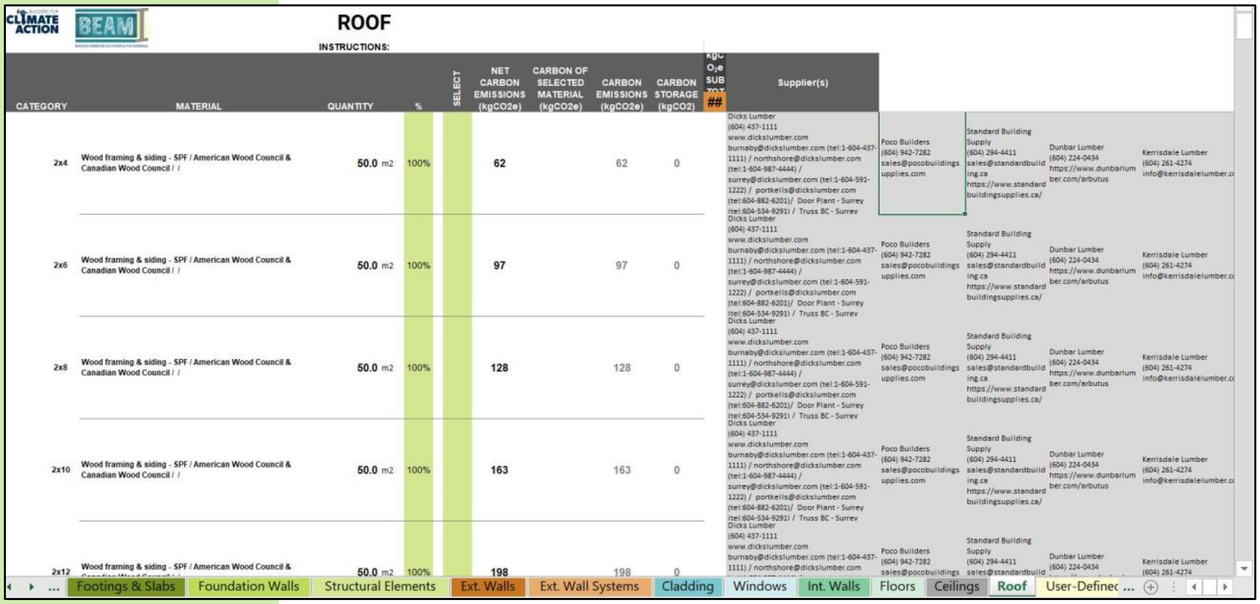


Figure 1 A sample of Vancouver building supply inventory with supplier's information

[4] Introducing the BEAM estimator: https://www.buildersforclimateaction.org/beam-calculator.html

Through analyzing the availability of materials and suppliers in Vancouver, it is found that 93% of materials mentioned in BEAM have local suppliers in Vancouver. Figure 2, shows the number of materials provided in BEAM and those that are available for Vancouver builders. Vancouver suppliers are also providing 36 materials which are not already available in BEAM; Hence, they are mentioned in the use-defined sheet of the tool.

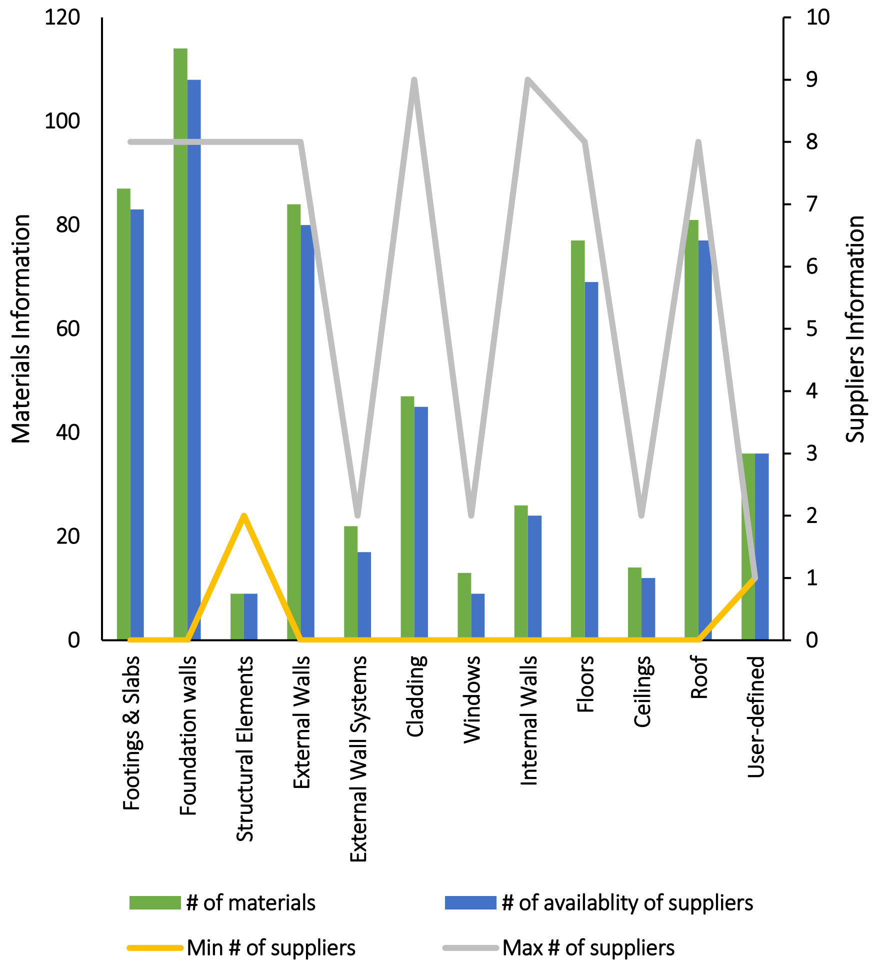
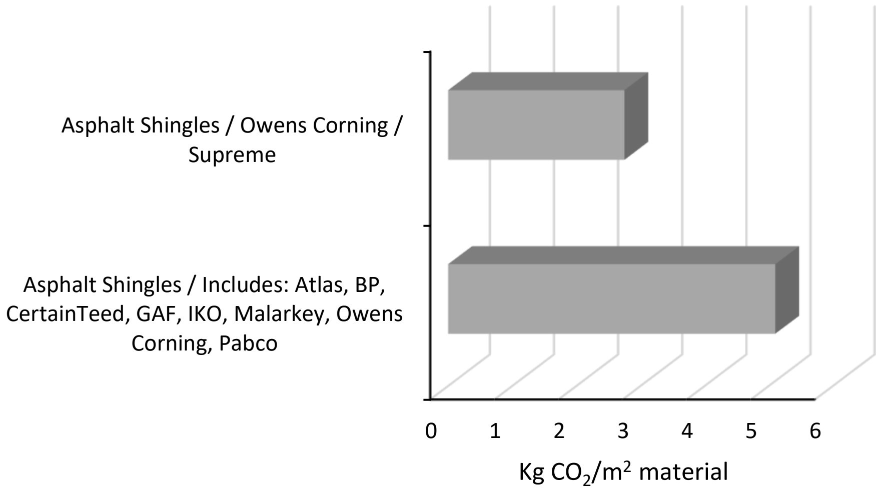


Figure 2 Availability of materials and suppliers in Vancouver

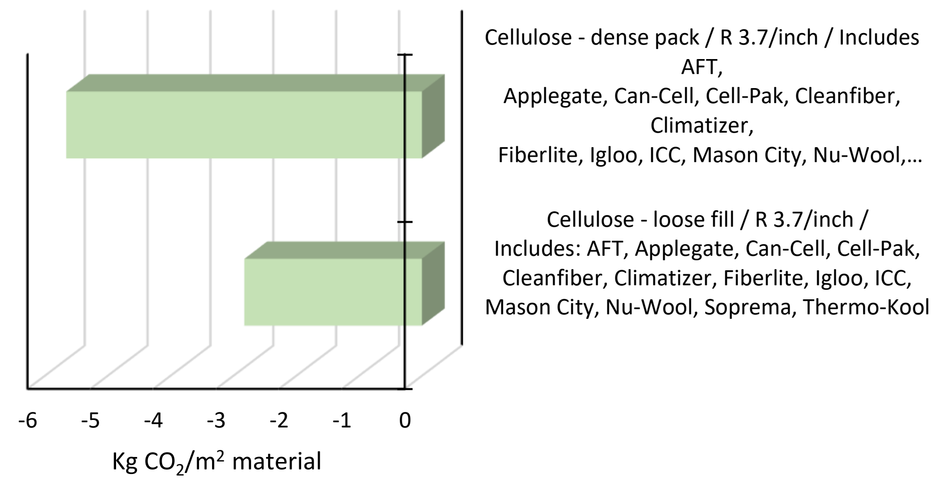
Low versus high EC materials

This section provides examples of materials with same functionality but different EC emissions. Please visit BEAM for more information.

Shingle Roof



Roof Insulation Cellulose



Through interactions with builders and suppliers to collect required data, we have received the following comments on our current materials inventory – BEAM calculator:

"The option for EPS foam is missing from the roofing tab as it is often used for flat roof applications, roof top patios, etc." This product is available in flat and sloped options for builders in Vancouver.

"There is no option for an EIFS (Exterior Insulation and Finish System) application that some single and multi-family dwellings will use as part of a continuous outsulation application."

"The specifications for thermal insulation are from ASTM C578, an American standard, when the City should be reviewing the Canadian standard of CAN/ULC-S701, which also has the LTTR requirement for certain rigid foams."

"When dealing with passive homes, typically the full slab and footings of the structure will be sitting on geofoam material to act as thermal break between the ground and the structure. This option is missing from your tables."

Reduction in Embodied Carbon Emissions of Low-Rise Residential Buildings

Reducing the embodied carbon emissions of low-rise residential buildings can be undertaken through three different pathways; **1) builder substitutions, 2) designer substitutions, and 3) zoning changes**. In this project, the impacts of builder substitutions and designer substitutions on reducing the EC emissions of residential buildings and the effects of zoning changes on designer substitutions were discussed.

Builder Substitutions

Builder substitutions refer to the choice of materials that do not affect the look and design of a building. However, a builder can play a critical role by choosing a material which has a low or zero EC emissions while fulfills the required functionality. An example of building substitutions can be the choice of exterior insulation. According to the courtesy of builders for Climate Action 2019 White Paper [5], selecting mineral wool board is a better solution compared to XPS foam, and even selecting the wood fiber board is a better solution than mineral wool board.

Figure 3 shows a list of different types of insulation and their associated EC emissions represents R-20 at 234 m^2. Extruded polystyrene (XPS) shows the highest EC emissions (6,735 kg CO_2); in contrast straw bale with (-7,437 kg CO_2) shows the ability of sequestering and storing carbon.

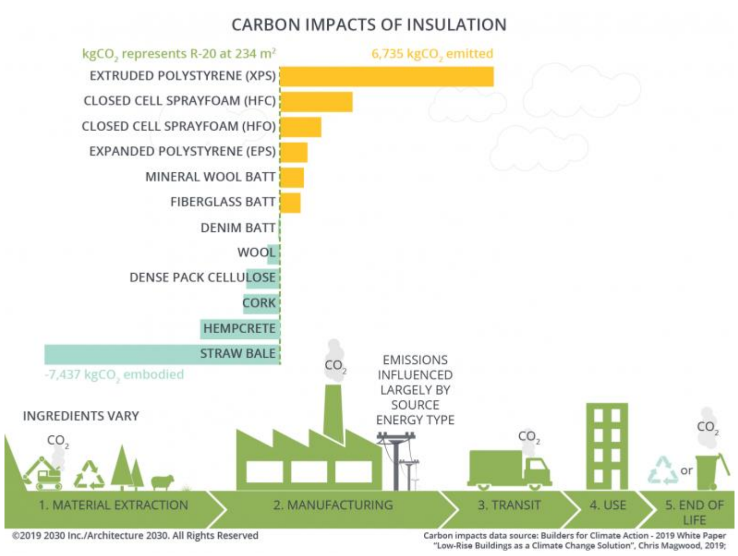


Figure 3 Carbon emissions (kg CO2) of different types of insulation (3)

[5] A breakdown of emissions from insulation. Courtesy of builders for Climate Action 2019 White Paper, Low-Rise Buildings as Climate Change Solution.

Designer Substitutions

Designer substitutions refer to the choices related to the structure and features of a building. For instance, selective use of concrete and steel in the structure and features (e.g. materials used in stairs) is a better choice in terms of reducing EC emissions in low-rise residential buildings compared to the aesthetic concrete and steel. However, designing all wood or wood fiber structure is the best choice. Examples of designer substitutions to choose among various materials for structure and features are shown in Figure 4 and 5.

Designer Substitution: Structure

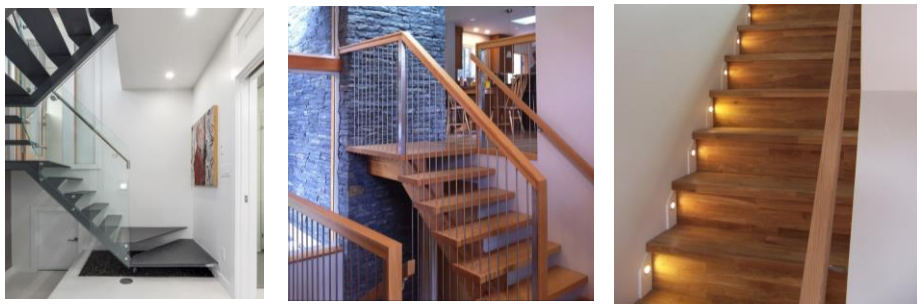
WORST	BETTER	BEST

Aesthetic Concrete and Steel	Selective use of concrete and steel	All wood / wood fiber

Figure 4 An example of designer substitutions to choose among the best, better, and worst materials in structure

Designer Substitution- Features

WORST | BETTER | BEST



Aesthetic Concrete, Glass and Steel | Selective use of steel, concrete with wood | All wood / wood fiber

Figure 5 An example of designer substitutions to choose among the best, better, and worst materials in features

Zoning Changes

Zoning changes refer to removing barriers which result in constructing low EC buildings easier. Examples of zoning changes are provided by Vancouver builders and include allowing “At Grade” homes with sufficient height and no above grade FSR (floor space ratio) rules, which is the ratio of a building's floor area to the size of the property on which is built; “Attached Homes” which require less insulation and cladding; and “Zero parking” requirement or at-grade parking. Case studies are provided to evaluate the impacts of builder substitutions, designer substitutions, and zoning changes.

Case studies to evaluate the effects of designers and builders' substitutions and zoning changes

Low-Rise Residential Buildings with basement vs. without basement

The difference among the EC emissions of residential buildings with basement and residential buildings without basement, are evaluated and compared. Table 1 and 2 list the information about the materials used in the roofing & ceilings, structure of above grade walls and below grade foundation. Tables 1 and 2 also show the alternative EC materials for low-rise residential buildings with basement vs. without basement, respectively. Information about the type and quantity of materials are provided by Vancouver builders, Lanefab and AA ROBINS architect. Information about the EC emissions (kg CO_2) are evaluated based on BEAM. The exact amount of EC emissions (Kg CO_2 per quantity) is provided when the material with specific properties was available in BEAM; however, low and high amounts of EC are provided when similar materials with the same applicability were available or the exact material was missing in BEAM. It should be noted that, when the EC emissions of a material is not available, EC emissions of an identical material is provided. However, in case of unavailability of the category of materials in BEAM entirely, the material is excluded from EC emissions calculation and it is mentioned as N.A. (not available).

Table 1 List of materials applied in low-rise residential buildings with basement

Roofing & Ceilings				
	Quantity	Unit	Kg CO_2 emissions (low, high, average[#])	
Shingle Roof	227	m^2	624	1,158
			Ave. 837	
Roof Insulation Cellulose	102	m^2	-577	-288
			Ave.-474	
Roof Insulation EPS	23	m^2	1,851	7,254
			Ave. 4231	
Roof Decks	16	m^2	56	98
			Ave. 70	
Ceilings (insulated)	124	m^2	- 306	3,057
			Ave. 729	
TOTAL CO_2 emissions from roofing & ceilings			1,648	11,279
			Ave. 5,395	
Above Grade Walls				
SIP Wall with Stucco	Quantity	Unit	Kg CO_2 emissions (low, high, average[#])	
¾" Rock Dash Stucco	306.8	m^2	2,937	
¾" ventilated rainscreen cavity	306.8	m^2	N.A.	
Tyvek	27	Kg	N.A.	
7/16" OSB	566	m^2	2,264	
7.25" EPS Foam	283	m^2	6,205	
3.5" fiberglass Batt	283	m^2	266	539
			Ave. 385	
3.5" fiberglass Batt with 2x4 Framing	283	m^2	349	
½" Drywall	707	m^2	2100	6,865
			Ave. 2,303	

TOTAL CO_2 emissions from above grade walls			14,121	19,159
			Ave. 14,443	
Below grade foundation				
Concrete with internal insulation	Quantity	Unit	Kg CO_2 emissions (low, high, average[#])	
4" Cast in place concrete wall with rebar	28	m^3	6,799	10,250
			Ave. 8,419	
15 M Rebar	1881	m	2,891	
8" 2lb foam* continuous	121	m^2	4,255	13,461
			Ave. 8858	
Waterproof Membrane	130	m^2	554	871
			Ave. 717	
TOTAL CO_2 emissions from below grade foundation			14,499	27,473
			Ave. 20,885	
Above Grade Walls Alternative Low Carbon				
Double stud w batt and wood cladding	Quantity	Unit	Kg CO_2 emissions (low, high, average[#])	
¾" Cedar	306.8	m^2	529	
¾" ventilated rainscreen cavity	306.8	m^2	N.A.	
Tyvek or Peel and Stick	27	Kg	N.A.	
Structural Wall				
½" Plywood	283	m^2	788	6978
			Ave. 3883	
7.25" fiberglass batt w 2x8 Framing	283	m^2	1,834	2,973
			Ave. 2,330	
Majrex Vapour Retarder / Air barrier	283	m^2	N.A.	
3.5" fiberglass Batt	283	m^2	266	539
			Ave. 385	

3.5" fiberglass Batt with 2x4 Framing	283	m^2	349	
½" Drywall	707	m^2	2100	6865
			Ave. 2303	
TOTAL CO_2 emissions from above grade walls alternative low carbon			5,866	18,233
			Ave. 9,779	
Below grade foundation Alternative Low Carbon using a 'Slabless Slab'				
Concrete with internal insulation	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
4" Cast in Place concrete wall with rebar	17.2	m^3	4,176	6,296
			Ave. 5,172	
15 M Rebar	1,155	m	1,775	
12" EPS	121	m^2	4,391	
1 1/8" OSB	242	m^2	1,678	
Flooring	107	m^2	- 293	2,900
			Ave. 846	
Waterproof Membrane	130	m^2	554	871
			Ave. 717	
TOTAL CO_2 emissions from below grade foundation alternative low carbon			12,281	17,911
			Ave. 14,579	

*The foam selecting can be either high GWP HFC foam or low GWP HFO foam (Insulthane Extreme or similar)

average refers to the average amount of CO_2 emissions from all materials in the category; not only the two materials with low and high CO_2 emissions

N.A. means kg CO_2 emissions is not available in BEAM

Table 2 List of materials applied in low-rise residential buildings without basement

Roofing & Ceilings				
	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
Shingle Roof	227	m^2	624	1,158
			Ave. 837	
Roof Insulation Cellulose	102	m^2	-577	-288
			Ave.-474	
Roof Insulation EPS	23	m^2	1,851	7,254
			Ave. 4231	
Roof Decks	16	m^2	56	98
			Ave. 70	
Ceilings (insulated)	124	m^2	- 306	3,057
			Ave. 729	
TOTAL CO_2 emissions from roofing & ceilings			1,648	11,279
			Ave. 5,395	
Above Grade Walls				
SIP Wall with Stucco	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
¾" Rock Dash Stucco	306.8	m^2	2,937	
¾" ventilated rainscreen cavity	306.8	m^2	N.A.	
Tyvek	27	Kg	N.A.	
7/16" OSB	566	m^2	2,264	
7.25" EPS Foam	283	m^2	6,205	
3.5" fiberglass Batt	283	m^2	266	539
			Ave. 385	
3.5" fiberglass Batt with 2x4 Framing	283	m^2	349	
½" Drywall	707	m^2	2100	6,865
			Ave. 2,303	
TOTAL CO_2 emissions from above grade walls			14,121	19,159
			Ave. 14,443	

Below grade foundation				
Concrete with internal insulation	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
4" Cast in place concrete wall with rebar	28	m^3	6,799	10,250
			Ave. 8,419	
15 M Rebar	1,881	m	2,891	
Above Grade Walls Alternative Low Carbon				
Double stud w batt and wood cladding	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
¾" Cedar	306.8	m^2	529	
¾" ventilated rainscreen cavity	306.8	m^2	N.A.	
Tyvek or Peel and Stick	27	Kg	N.A.	
Structural Wall				
½" Plywood	283	m^2	788	6978
			Ave. 3883	
7.25" fiberglass batt w 2x8 Framing	283	m^2	1,834	2,973
			Ave. 2,330	
Majrex Vapour Retarder / Air barrier	283	m^2	N.A.	
3.5" fiberglass Batt	283	m^2	266	539
			Ave. 385	
3.5" fiberglass Batt with 2x4 Framing	283	m^2	349	
½" Drywall	707	m^2	2100	6865
			Ave. 2303	
TOTAL CO_2 emissions from above grade walls alternative low carbon			5,866	18,233
			Ave. 9,779	
Below grade foundation Alternative Low Carbon using a 'Slabless Slab'				

Concrete with internal insulation	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
4” Cast in Place concrete wall with rebar	17.2	m^3	4,176	6,296
			Ave. 5,172	
15 M Rebar	1,155	m	**1,775**	

The results of analyzing the EC of low-rise residential buildings with basement showed that builders can play a significant role in reducing EC of construction by choosing low EC materials. According to the results demonstrated in Table 1, the application of low EC materials compared to high EC materials reduced the EC emissions of "roofing & ceilings" by 85%, above grade walls by 28%, and below grade foundation by 47%. Figure 6 shows the differences between EC emissions of each part of low-rise residential buildings with basement choosing low or high EC materials.

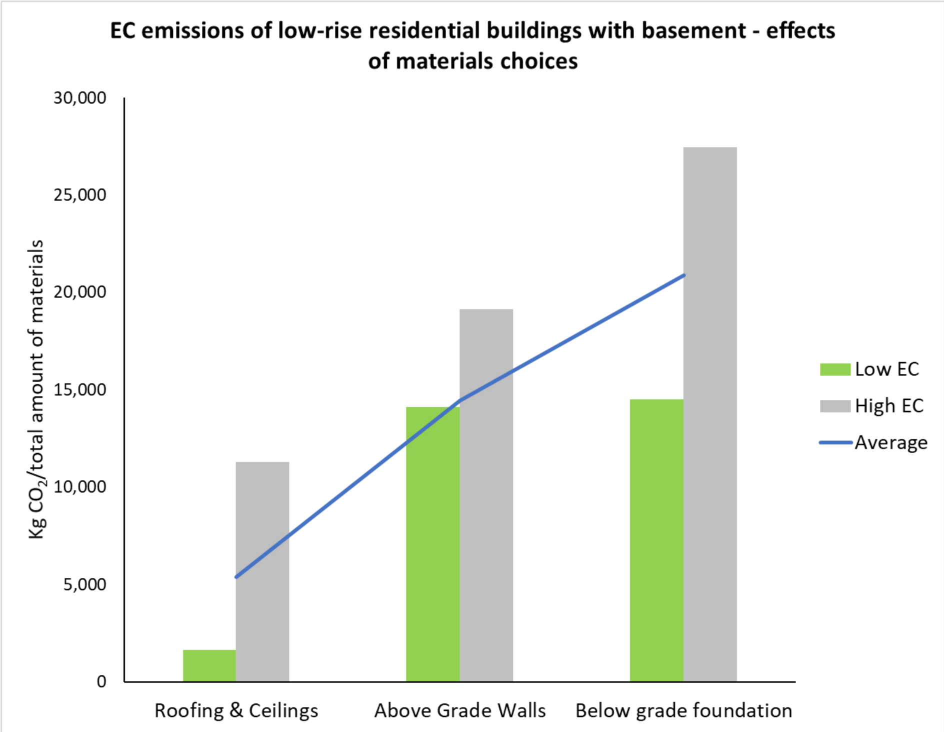


Figure 6 Effects of materials choices on the EC emissions of low-rise residential buildings with basement

The results of considering low carbon alternatives at the designer substitutions phase showed that, the EC emissions of low-rise residential buildings with basement can be reduced up to 26% and 37% for “above grade wall” and “below grade foundation” parts of a building, respectively. Figure 7 shows the effects of designer substitutions on the EC emissions reduction in low-rise residential buildings with basement.

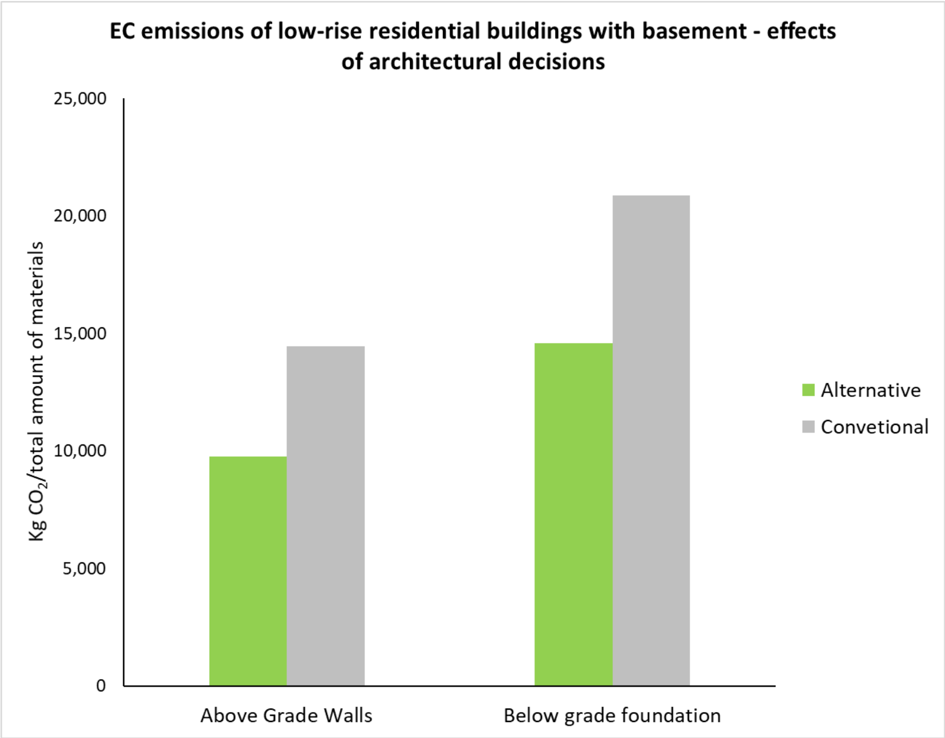


Figure 7 Effects of architectural decisions on the EC emissions of low-rise residential buildings with basement

The results of analyzing the EC of low-rise residential buildings without basement, showed that the EC emissions of below grade walls and foundation can be reduced on average by 60% compared to low-rise residential buildings with basement. The EC emissions reduction can be further decreased by 75% when considering the alternative low carbon materials at the architectural level. Figure 8 shows the differences among EC emissions of “below grade walls and foundation” in low-rise residential buildings with basement, and in low-rise residential buildings without basement. It also shows the effects of alternative low EC materials at the designer substitutions phase in low-rise residential buildings without basement.

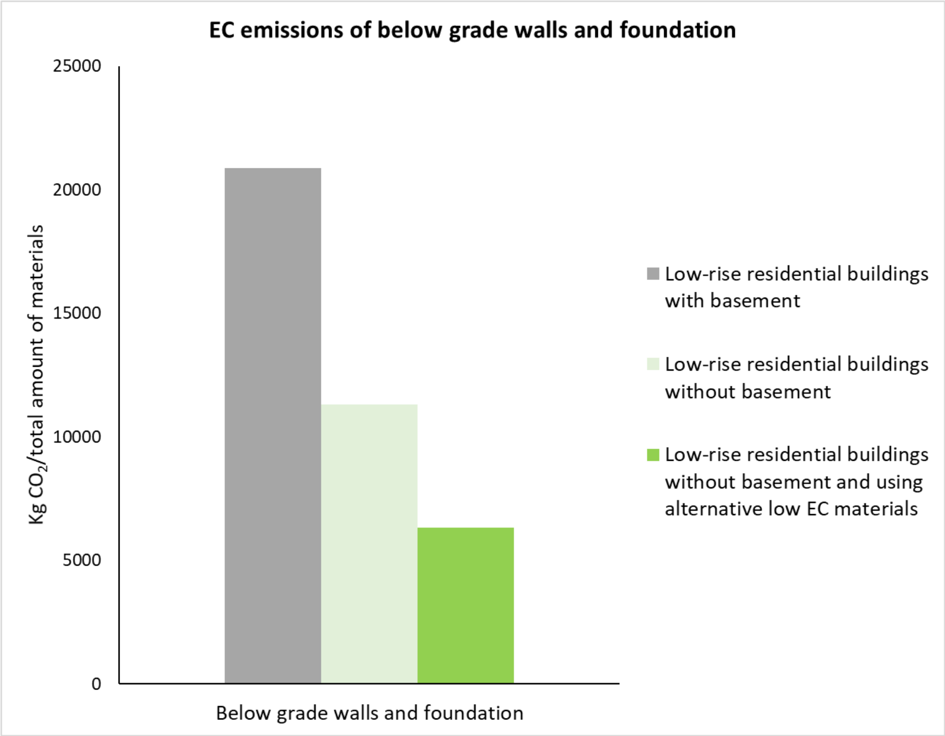


Figure 8 Effects of basement removal and application on alternative low EC materials on the EC emissions of below grade walls and foundation

Passive House with Basement Requirement vs At Grade – Example 1

An example of additional materials required for a building with basement is provided by Lanefab and the quantity of materials are provided by AA ROBINS architect (Figure 9). A rough calculation of EC emissions is provided in Table 3.

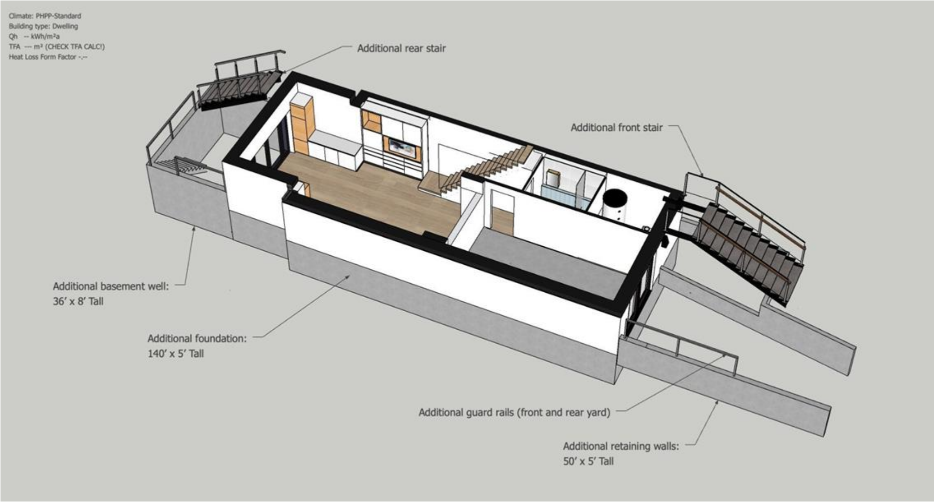


Figure 9 additional materials required for fulfilling basement requirements – credit: Lanefab

Table 3 List of materials applied in a passive house with basement – Example 1

	Quantity	Unit	Kg CO_2 emissions (low, high, average[#])	
Roof	87	m^2	239	3,271
			Ave. 963	
Roof Insulation Knauf Ecobatt	65	m^2	209	
Roof Decks	25	m^2	87	153
			Ave. 108	
Ceilings	91	m^2	-223	2,244
			Ave. 380	
Cladding	243	m^2	292	11,541
			Ave. 4,184	
Flooring	127	m^2	-348	3442
			Ave. 1,089	

Interior Drywall on the envelope alone	403	m^2	599	1,956
			Ave. 994	
Interior Walls 2x4 with drywall				
45' @ 9'	38	m^2	56	184
			Ave. 93	
23' @ 9.5'	20	m^2	30	146
			Ave. 49	
57' @ 9'	48	m^2	71	233
			Ave. 118	
Concrete	38	m^3	16,633	25,077
			Ave. 19,973	
TOTAL CO_2 emissions			17,645	48,456
			Ave. 28,160	

The following assumptions were considered to see the impacts of designers' substitution in a passive house.

1. *Application of 'slabless slab' which replaces the 4" thick polished concrete floor with a double-layer subfloor:*

The impact of a 'Slabless Slab' application is the reduction of (8.32m^3) of concrete, but add 82m^2 of double layered 1 1/8" OSB (so 156m^{2}total) and 74 m^{2}of alternative flooring instead of the polished concrete.

Concrete (eliminated)	8.32	m^3	3,680	4,997
			Ave. 4,419	
1 1/8" OSB (added)	156	m^2	481	1,030
			Ave. 156	
Flooring (added)	74	m^2	-203	2,005
			Ave. 635	
Total CO_2 emissions (Reduced)			3,402	1,962
			Ave. 3,628	

In overall the application of 'slabless slab' showed the EC emissions reduction.

2. *Application of a 'Permanent Wood Foundation' which would be very similar to a Magnesium Oxide (MGO) SIP Foundation Panel.*

The impact of changing basement walls to MGO SIP or Permanent Wood Foundation is the reduction of 21m^3 of concrete; however, it adds a 2x10 stud wall and adds 107m^2 of MGO board on each side of the wall (214m^2 in total).

Concrete (eliminated)	21	m^3	5,698	7,687
			Ave. 6,026	
15 M Rebar (eliminated)	1,337	m	2,056	
2x10 stud wall (added)	107	m^2	313	512
			Ave. 385	
(MGO) SIP Foundation Panel (added)	214	m^2	1,584	
Total CO_2 emissions (Reduced)			**5,857**	**7,647**
			Ave. 6,113	

The results of changing basement walls to MGO SIP showed an increase in EC emissions reduction. EC emissions reduction with application of the MGP SIP panel is only possible if low EC materials are used.

3. *Combining the 1st and 2nd assumptions.*

4. *The option of not requiring a foundation at all.*

The impact of eliminating the basement altogether would be similar to either 2nd or 3rd assumption mentioned above; in addition to eliminating digging 228m^3 basement and trucking it away.

Eliminating the basement altogether compared to having a concrete basement results in a huge difference in EC emissions.

Passive House with Basement Requirement – example 2

An example of materials required for a passive house with basement and the quantity of materials are provided by AA ROBINS architect (Table 4). EC emissions were calculated using BEAM.

Table 4 List of materials applied in a passive house with basement – Example 2

Roof				
	Quantity	Unit	Kg CO_2 emissions (low, high, average#)	
Thermoplastic Polyolefin (TPO) Roof membrane	86.7	m^2	383	
6" EPS insulation	13.2	m^3	1,145	1,597
			Ave. 1,371	
fluid applied air/water barrier	86.7	m^2	N.A.	
11.25" NEOPOR GPS insulation	24.8	m^3	5,074	
7/16" OSB	173	m^2	629	
2x4 studs @ 16"	86.7	m^2	1,346	2,203
			Ave. 1,658	
5/8" drywall	86.7	m^2	180	259
			Ave. 219	
Roof Decks				
2" concrete pavers	0.6	m^3	3,278	5,018
			Ave. 4088	
Thermoplastic Polyolefin (TPO) Roof membrane	12.5	m^2	55	
4" tapered (average 2") High Density EPS insulation	0.63	m^3	55	76
			Ave. 66	
1/8" protection board	12.5	m^2	N.A.	

Vacuum insulation	24.9	m^2	814
7/16" OSB	24.9	m^2	99
6" Neopor GPS	1.91	m^3	729
Mineral Wool Batt Insulation	1.1	m^3	32 99 Ave. 54
2x4 stud cavity	12.4	m^2	N.A.
5/8" drywall	12.4	m^2	26 37 Ave. 31
SIP Panel Walls			
1/4"cementitious stucco	327	m^2	11,445
4" EPS insulation	327	m^2	2,840 3,961 Ave. 3,401
fluid applied water/air barrier	327	m^2	N.A.
7/16" OSB	654	m^2	2,616
2x12 stud wall at 4' on center	327	m^2	5,075 8,308 Ave. 6,252
11.25" Neopor GPS insulation	93.4	m^3	19,112
2x4 stud cavity	327	m^2	N.A.
5/8" drywall	191	m^2	397 570 Ave. 483
Foundation + basement floor			
12" thick Concrete	35.2	m^3	27,603 37,005 Ave. 31,555
15 M Rebar	2,363	m	3,632
Waterproof Membrane Bituminous	133.7	m^2	570 896 Ave. 737
14" thick EPS insulation	115.6	m^2	3,517 4,901 Ave. 4,208
vinyl flooring tiles	64	m^2	317 909 Ave. 560

Basement Walls MGO SIP				
11.25" (2x12's) NEOPOR GPS Insulation	35.4	m^3	7,243	
1/2" MGO Board	182.4	m^2	Ave. 1,350	
2x12 Stud Wall	91.3	m^2	1,417	2,320
			Ave. 1,746	
Waterproof Membrane	111	m^2	471	744
			Ave. 612	
4" EPS Insulation	111	m^2	936	1,305
			Ave. 1,121	
L1 Floor				
SPF (spruce-pine-fir) timber	8.55	m^3	44	68
			Ave. 56	
4" Plywood	3.28	m^3	Exact. 91	
1/2" Drywall	57.7	m^2	86	280
			Ave. 141	
4" concrete topping	6.5	m^3	15,534	20,825
			Ave. 17.758	
vinyl flooring tiles	64	m^2	317	909
			Ave. 560	
L2 Floor				
3" concrete topping	6.33	m^2	19,836	26,592
			Ave. 22,676	
2x8 DLT (Dowel Laminated Timber)	15.4	m^3	1,870	
Carpet + underlay	83.6	m^2	-21	1,112
			Ave. 1,104	
Millwork				
wood veneer on 5/8" plywood	94.3	m^2	329	
Interior partition walls				

5/8" drywall	674	m^2	1,400	2,010
			Ave. 1,704	
4" Plywood	1.21	m^3	34	
Lightwells/retaining walls + Concrete steps to basement				
Concrete	13.4	m^3	32,024	42,932
			Ave. 36,610	
Windows				
8mm 8mm 8mm Triple Glazed IGU (Low-E coated Glass)	0.45	m^3	3,560	7,144
			Ave. 5,252	
6mm 6mm 6mm Triple Glazed IGU (Low-E coated Glass)	1	m^3	10,551	21,171
			Ave. 15,565	
Hemlock	1.92	m^3	N.A.	
Wood Beams				
SPF Structural Select Gluelam Timber	6	m^3	31	48
			Ave. 39	
Wood Shear Panels				
Laminated Veneer Lumber (OSB)	2.54	m^3	918	
Total				
concrete	62.1	m^3	148,410	198,962
			Ave. 169,662	
15 M Rebar	3,953	m	6,076	
SPF (Spruce/Pine/Fir Select Structural)	24	m^3	123	190
			Ave. 157	
Plywood	4.5	m^3	125	
SPF Structural Select Glulam Timber	6	m^3	31	48
			Ave. 39	
Laminated Veneer Lumber (OSB)	2.54	m^3	918	

11.25" Neopor GPS insulation	194.6	m^3	39,821	
EPS Insulation	13.2	m^3	1,113	1,552
			Ave. 1,333	
Mineral Wool Batt Insulation	1.1	m^3	32	99
			Ave. 54	

Alternative options:

1) If the house didn't have to be below grade, it could be taller and would have avoided 333m^3 of excavation, 13.4m^3 concrete lightwells and retaining walls, while adding 600sf of stucco cladding.

2) If the house had used a normal concrete foundation, it would have added 22.5m^3 of concrete for the basement walls, while eliminating the MGO panels and 2x12 framing.

Limitations, Recommendations and Next Steps

To fulfill the first objective of this project which is identifying the Vancouver building materials suppliers and the materials provided by them for low-rise residential buildings in Vancouver, a few limitations have been observed.

Limitations

Among 70 suppliers which their contact information is provided by local builders, only 10 suppliers **(14%)** responded to our inquiries and provided us with a complete list of their materials which can be locally available for low-rise residential buildings.

The suppliers contact list is not 100% completed as we mainly have access to suppliers whose contact information is provided to us by Vancouver builders.

Low response, engagement and motivation, observed from suppliers regarding contributing in building supply inventory creation and understanding the availability of low-embodied carbon materials for Vancouver builders.

Hence the following recommendations are provided to improve the reliability of the building supply inventory in order to have a complete list of Vancouver's construction materials suppliers.

Recommendations

City of Vancouver should take a solid approach to collect information of suppliers and materials to complete the inventory. One approach would be developing a platform in which suppliers can enter their contact information, availability of materials, the minimum amount for delivery, uploading EPDs if available, and any other information as needed.

Spreading the word about this platform, making sure all Vancouver suppliers are aware of this platform and would participate in this initiative.

Developing incentivize program for suppliers who contribute in the inventory creation and making efforts in reducing the embodied-carbon emissions of their materials.

The EC emissions calculators (e.g. BEAM) need to be further simplified in order to be used by builders. It also should provide more options for calculations e.g. providing a way to calculate the amount of rebar used in a concrete structure.

Considering the time, energy, expert knowledge requiring to calculate the EC emissions of a building, support should be provided to builders, e.g. LCA advisor.

Link to the low embodied carbon residential building supply inventory