



BUILDING BETTER WORKSHOP SERIES

Intro to Embodied Carbon w/ Chris Magwood

October 4, 2022

October 24, 2022

City of
NELSON
BUILDERS FOR
**CLIMATE
ACTION**

 **FORTIS BC**
Energy at work

Today, we're going to talk about...

what are embodied carbon emissions,

how they are calculated, and

why are they important to address?



We understand operational emissions:

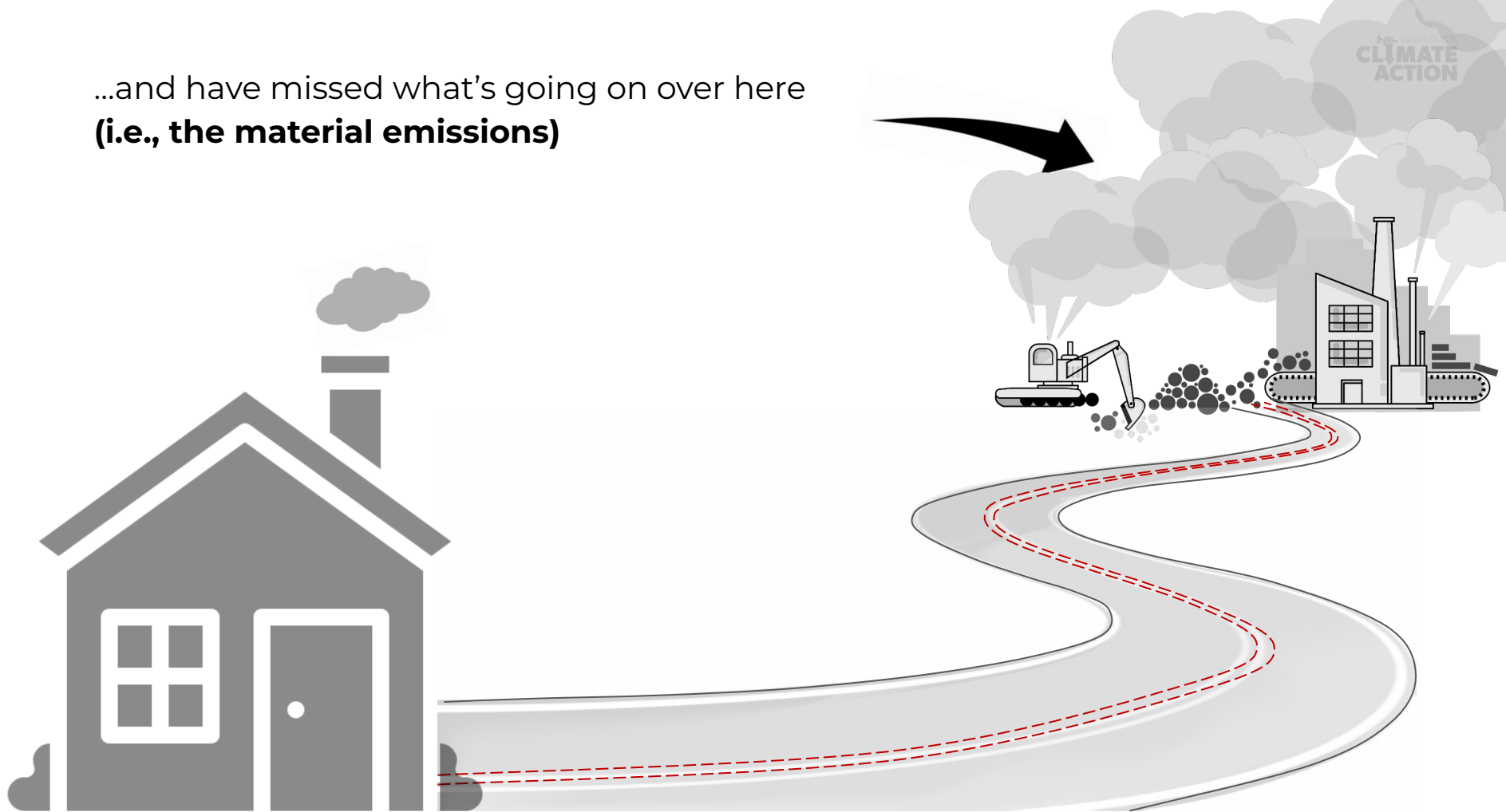
$$\text{ENERGY USE} \\ \times \\ \text{ENERGY SOURCE EMISSIONS}$$

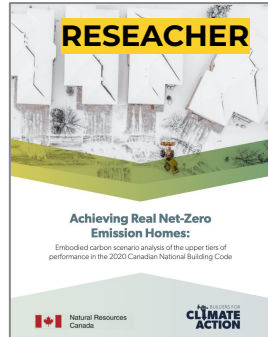


**We've been focusing our
attention here...**



...and have missed what's going on over here
(i.e., the material emissions)

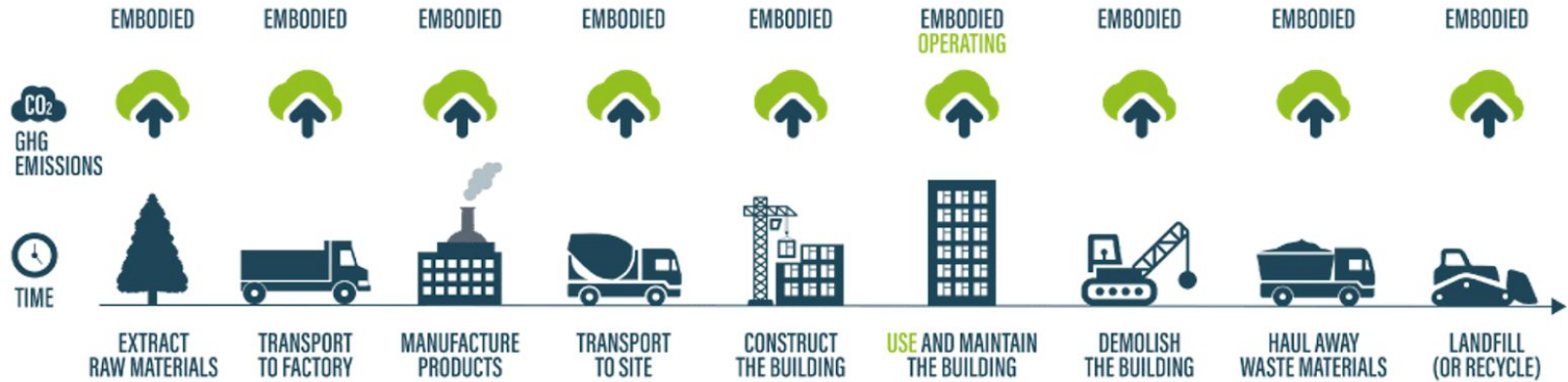




2012:

**What is the
carbon
footprint of
this house?**

Material emissions over the life cycle – “embodied carbon”

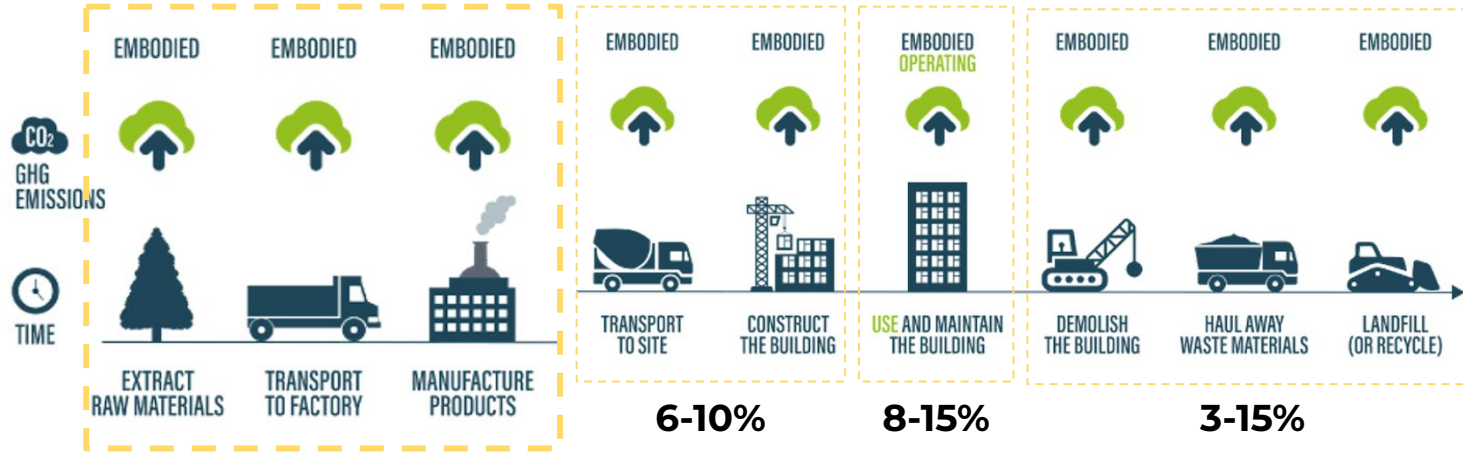


Cradle to gate - - - - - ➔

Up-front embodied carbon - - - - - ➔

Whole life cycle - - - - - ➔

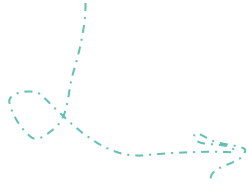
Product emissions are the largest contributor



65-80%
of lifecycle emissions

Estimating Material Carbon Emissions (MCE)

EPD



An **Environmental Product Declaration (EPD)** *"quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function."*

This methodology follows international standards (ISO series 14040 requirements)



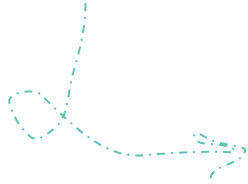
CO₂e

Carbon Dioxide Equivalent

- allows a group of greenhouse gases (GHGs) to be expressed as a single number by converting amounts of other greenhouse gases, like methane, to the equivalent amount of CO₂
- this metric is used to compare emissions on the basis of their global warming potential (GWP)
- metric of choice for EPDs etc.

Estimating Material Carbon Emissions (MCE)

EPD



Timber:

42.56 kg CO₂e/m³

Concrete:

304.53 kg CO₂e/m³

Steel:

1.16 t CO₂e/ton

NOW WHAT?

Estimating Material Carbon Emissions (MCE)

A1-A3 GWP
factors from
EPDs



A1-A3 biogenic
carbon storage



Material quantity
(based on
dimensions)



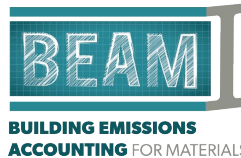
Net emissions
kg CO₂e



FOUNDATION WALL AREA	74.3	m ²
FOUNDATION SLAB AREA	55.7	m ²
EXTERIOR WALL AREA	100.0	m ²
WINDOW AREA	18.7	m ²

8,292

**NET EMISSIONS
(kg CO₂e)**



Estimating Material Carbon Emissions (MCE)

TIMBER

42.56 kg CO₂e/m³

6x6 post =

4 kg CO₂e

CONCRETE

304.53 kg CO₂e/m³

6" dia. post =

12 kg CO₂e

STEEL

1.16 t CO₂e/ton

3.5" dia. post =

73 kg CO₂e

Now we can start to make
informed decisions!

The BEAM tool can help you compare materials

CAVITY INSULATION		R-VALUE	20.0		
HIGH R-VALUE CAVITY INSULATION					
Aerogel blanket / Aspen Aerogels / R9.6/inch		100.0 m ²	100%	<input type="checkbox"/>	6,499
SPRAY POLYURETHANE FOAM – HIGH DENSITY					
Spray polyurethane foam - High Density (HFC gas) / R 6.3/inch / SPFA [Industry Avg US & CA]		100.0 m ²	100%	<input type="checkbox"/>	5,995
Spray polyurethane foam - High Density (HFO gas) / R 6.5/inch / SPFA [Industry Avg US & CA]		100.0 m ²	100%	<input type="checkbox"/>	1,744
SPRAY POLYURETHANE FOAM – CLOSED CELL					
Spray polyurethane foam - Closed Cell (HFC gas) / R 6.6/inch / SPFA [Industry Avg US & CA]		100.0 m ²	100%	<input type="checkbox"/>	4,635
Spray polyurethane foam - Closed Cell (HFO gas) / R 6.6/inch / SPFA [Industry Avg US & CA]		100.0 m ²	100%	<input type="checkbox"/>	1,465
Spray polyurethane foam - Closed Cell (HFO gas) / Huntsman / Heatlok Soya HFO & Heatlok HFO / R 6.5/inch		100.0 m ²	100%	<input type="checkbox"/>	882
SPRAY POLYURETHANE FOAM – OPEN CELL					
Spray polyurethane foam - Open Cell / R 4.1/inch / SPFA [Industry Avg US & CA]		100.0 m ²	100%	<input type="checkbox"/>	500
SHEEP WOOL INSULATION					
Wool / Havelock Wool / Loose-fill / R 4.4/inch		100.0 m ²	100%	<input type="checkbox"/>	271
Wool / Havelock Wool / Batts / R 3.6/inch		100.0 m ²	100%	<input type="checkbox"/>	354
MINERAL WOOL BATT INSULATION					
Mineral wool batt / Owens Corning / Thermafiber UltraBatt / R 4.3/inch		100.0 m ²	100%	<input type="checkbox"/>	1,409
Mineral wool batt / Rockwool / ComfortBatt R24 (5.5") / R 4.4/inch		100.0 m ²	100%	<input type="checkbox"/>	600
Mineral wool batt / [BEAM Avg]		100.0 m ²	100%	<input type="checkbox"/>	597
Mineral wool batt / Rockwool / ComfortBatt R15 (3.5") / R 4.3/inch		100.0 m ²	100%	<input type="checkbox"/>	461
Mineral wool batt / Rockwool / Safe'n'Sound, ComfortBatt / R 3.8/inch		100.0 m ²	100%	<input type="checkbox"/>	461
Mineral wool batt / Rockwool / ComfortBatt R14 (3.5") / R 4.0/inch		100.0 m ²	100%	<input type="checkbox"/>	415
Mineral wool batt / Rockwool / ComfortBatt R22 (5.5") / R 4.0/inch		100.0 m ²	100%	<input type="checkbox"/>	415



**BUILDING EMISSIONS
ACCOUNTING** FOR MATERIALS

...help you compare assemblies

ASSEMBLY 1

			1,564	1,564	0
SECTION	CATEGORY	MATERIAL	NET EMISSIONS (kg CO ₂ e)	CARBON EMISSIONS (kg CO ₂ e)	CARBON STORAGE (kg CO ₂ e)
Exterior Walls	LIGHT WOOD FRAME WALLS	Wood / SPF / 2x6 Lumber / AWC & CWC [Industry Avg US & CA]	220	220	0
Exterior Walls	STRUCTURAL SHEATHING	OSB sheathing / 5/8" / AWC & CWC [Industry Avg US & CA]	385	385	0
Exterior Walls	CAVITY INSULATION	Mineral wool batt / [BEAM Avg]	627	627	0
Exterior Walls	CONTINUOUS INSULATION	EPS foam board / R 4.0/inch, Type II, 15 psi (100 kPa) / EPS Industry Alliance [Industry Avg US & CA]	332	332	0

ASSEMBLY 2

			6,533	6,533	0
SECTION	CATEGORY	MATERIAL	NET EMISSIONS (kg CO ₂ e)	CARBON EMISSIONS (kg CO ₂ e)	CARBON STORAGE (kg CO ₂ e)
Exterior Walls	EPS FOAM ICF WALLS	EPS FOAM ICF R-23, 2 Sheets of 2.75"@R4/in., webbing, 15M rebar (not incl. 6" concrete core)	2,480	2,480	0
Exterior Walls	EPS FOAM ICF WALLS	Concrete – 0-25 MPa, 30-40% Fly Ash, GU / CRMCA [Industry Avg CA]	4,053	4,053	0

ASSEMBLY 3

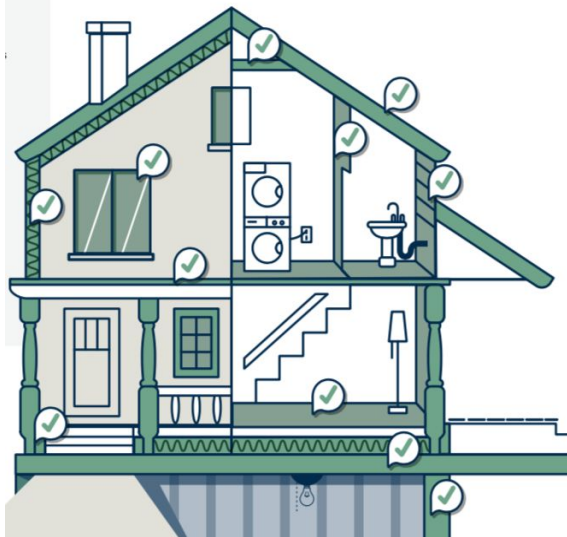
			2,542	2,542	0
SECTION	CATEGORY	MATERIAL	NET EMISSIONS (kg CO ₂ e)	CARBON EMISSIONS (kg CO ₂ e)	CARBON STORAGE (kg CO ₂ e)
Exterior Walls	STRUCTURAL INSULATED PANELS	SIP panel - R30 8.25" - EPS 7.25" @ R4/in. core, 2 sheets 1/2" OSB	2,542	2,542	0

...and help you compare whole houses

REVIEW OF SELECTED MATERIALS			81,510	83,421	1,911
SECTION	CATEGORY	MATERIAL	NET CARBON FOOTPRINT [kg CO2e]	CARBON EMISSIONS [kg CO2e]	CARBON STORAGE [kg CO2e]
Footings & Slabs	CRUSHED STONE BASE	Aggregate / / Avg construction aggregate (gravel & sand)	4	4	0
Footings & Slabs	FOOTINGS & PADS	Concrete - 0.25 MPa, Canadian Benchmark Average / CRMA / Can. /	3,049	3,049	0
Footings & Slabs	REBAR FOR FOOTINGS & PADS	Rebar / Concrete Reinforcing Steel Institute / / 15M	322	322	0
Footings & Slabs	REINFORCING MESH FOR SLAB	Welded wire mesh / Serfas / 1/8" x 6" x 6/6g / Norway	160	160	0
Footings & Slabs	CONCRETE SLAB FLOOR(S)	Concrete - 0.25 MPa, Canadian Benchmark Average / CRMA / Can. /	2,258	2,258	0
Foundation Walls	CONCRETE WALLS	Concrete - 0.25 MPa, Canadian Benchmark Average / CRMA / Can. /	9,572	9,572	0
Foundation Walls	REBAR FOR FOUNDATION WALLS	Rebar / Concrete Reinforcing Steel Institute / / 15M	1,420	1,420	0
Foundation Walls	CONTINUOUS INSULATION	XPS foam board - AVERAGE (excludes new NGX 250)	25,813	25,813	0
Structural Elements	HEAVY TIMBER FRAMING	Wood framing & siding - SPF / American Wood Council & Canadian /	94	94	0
Structural Elements	HEAVY TIMBER FRAMING	Laminated strand lumber / American Wood Council & Canadian Woo	14	14	0
Structural Elements	HEAVY TIMBER FRAMING	Laminated veneer lumber / American Wood Council & Canadian Woc	85	85	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W200x27 (W8x18) / American Institute of Steel Construc	276	276	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W310x39 (W12x26) / American Institute of Steel Construc	252	252	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W250x33 (W10x22) / American Institute of Steel Construc	219	219	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel post / Generic / / 3.5 x 0.216" (89 x 5.5 mm), Sched 40 STD	408	408	0
Ext. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	501	501	0
Ext. Walls	STRUCTURAL SHEATHING	OSB sheathing / American Wood Council & Canadian Wood Council	37	37	0
Ext. Walls	STRUCTURAL SHEATHING	Plywood / American Wood Council & Canadian Wood Council / / 1/2"	595	595	0
Ext. Walls	CAVITY INSULATION	Fiberglass batt / Owens Corning / EcoTouch Pink batt and roll / R 3.6	278	278	0
Ext. Walls	CAVITY INSULATION	Mineral wool batt / Owens Corning / Thermafiber UltraBatt / R 4.3inci	800	800	0
Ext. Walls	CONTINUOUS INSULATION (EXT. or INT.)	XPS foam board / Owens Corning / Foamular 250 / R 5/inch	10,098	10,098	0
Ext. Walls	GARAGE ATTACHMENT WALL INSULATION	Fiberglass batt / Owens Corning / EcoTouch Pink batt and roll / R 3.6	81	81	0
Ext. Walls	GARAGE ATTACHMENT WALLS	Wood framing & siding - SPF / American Wood Council & Canadian /	91	91	0
Cladding	EXTERIOR CLADDING	Brick, Clay, Generic Modular / Brick Industry Association / US-Canad	10,053	10,053	0
Cladding	EXTERIOR CLADDING	Brick, Stone / Amiscraft / Natural Limestone Masonry / Weighted ave	108	108	0
Cladding	EXTERIOR CLADDING	Vinyl Siding / Vinyl Siding Institute / 0.040" Double 4.5"	67	67	0
Cladding	INTERIOR CLADDING for EXTERIOR WALL	Drywall 1/2" Typical - CertainTeed - AVERAGE	328	328	0
Cladding	INTERIOR CLADDING for EXTERIOR WALL	Drywall 5/8" / / Includes American Gypsum, CertainTeed, Continta	200	200	0
Windows	DOUBLE PANE WINDOWS - GENERIC	Window - double pane / Vinyl frame / / USA & CAN	2,325	2,325	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	16	16	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	40	40	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	153	153	0

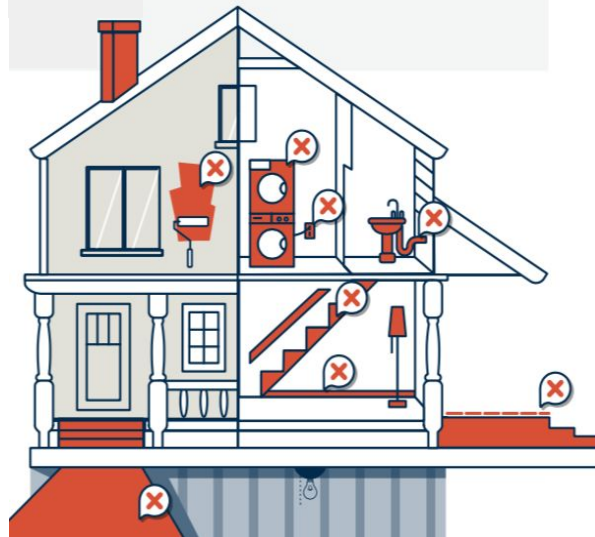
REVIEW OF SELECTED MATERIALS			20,380	31,008	10,628
SECTION	CATEGORY	MATERIAL	NET CARBON FOOTPRINT [kg CO2e]	CARBON EMISSIONS [kg CO2e]	CARBON STORAGE [kg CO2e]
Footings & Slabs	CRUSHED STONE BASE	Aggregate / Martin Marietta / / Avg construction aggregate (gravel &	1	1	0
Footings & Slabs	FOOTINGS & PADS	Concrete - 0.25 MPa, 35-50% Slag, GU / CRMA / Can. Avg. /	2,393	2,393	0
Footings & Slabs	REBAR FOR FOOTINGS & PADS	Rebar / Concrete Reinforcing Steel Institute / / 15M	322	322	0
Footings & Slabs	REINFORCING MESH FOR SLAB	Welded wire mesh / Serfas / 1/8" x 6" x 6/6g / Norway	160	160	0
Footings & Slabs	CONCRETE SLAB FLOOR(S)	Concrete - 0.25 MPa, 35-50% Slag, GU / CRMA / Can. Avg. /	1,772	1,772	0
Foundation Walls	CONCRETE WALLS	Concrete - 0.25 MPa, 35-50% Slag, GU / CRMA / Can. Avg. /	7,512	7,512	0
Foundation Walls	REBAR FOR FOUNDATION WALLS	Rebar / Concrete Reinforcing Steel Institute / / 15M	1,420	1,420	0
Foundation Walls	INTERIOR FRAMING - WOOD	Wood framing & siding - SPF / American Wood Council & Canadian /	191	191	0
Foundation Walls	CAVITY INSULATION	Cellulose - batt / CMS / R 3.6/inch / EcoCell	-1,331	318	1,649
Foundation Walls	INTERIOR WALL CLADDING	Drywall 1/2" / CertainTeed / Eco-Lite / 1/2" (12.7 mm)	14	14	0
Structural Elements	HEAVY TIMBER FRAMING	Wood framing & siding - SPF / American Wood Council & Canadian /	94	94	0
Structural Elements	HEAVY TIMBER FRAMING	Laminated strand lumber / American Wood Council & Canadian Woo	14	14	0
Structural Elements	HEAVY TIMBER FRAMING	Laminated veneer lumber / American Wood Council & Canadian Woc	85	85	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W200x27 (W8x18) / American Institute of Steel Construc	276	276	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W310x39 (W12x26) / American Institute of Steel Construc	252	252	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W250x33 (W10x22) / American Institute of Steel Construc	219	219	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel post / Generic / / 3.5 x 0.216" (89 x 5.5 mm), Sched 40 STD	408	408	0
Ext. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	501	501	0
Ext. Walls	STRUCTURAL SHEATHING	OSB sheathing / American Wood Council & Canadian Wood Council	37	37	0
Ext. Walls	STRUCTURAL SHEATHING	Plywood / American Wood Council & Canadian Wood Council / / 1/2"	595	595	0
Ext. Walls	CAVITY INSULATION	Cellulose - batt / CMS / R 3.6/inch / EcoCell	-1,628	390	2,018
Ext. Walls	CONTINUOUS INSULATION (EXT. or INT.)	Wood fiber board - AVERAGE	-1,595	1,323	2,927
Ext. Walls	GARAGE ATTACHMENT WALL INSULATION	Cellulose - batt / CMS / R 3.6/inch / EcoCell	-355	85	440
Ext. Walls	GARAGE ATTACHMENT WALLS	Wood framing & siding - SPF / American Wood Council & Canadian /	91	91	0
Cladding	EXTERIOR CLADDING	Vinyl Siding / Vinyl Siding Institute / 0.040" Double 4.5"	67	67	0
Cladding	EXTERIOR CLADDING	Engineered Wood Siding & Trim / LP / SmartSide / 5/16" (8 mm)	599	599	0
Cladding	INTERIOR CLADDING for EXTERIOR WALL	Drywall 1/2" / CertainTeed / AirRenew / 1/2" (12.7 mm)	299	299	0
Cladding	INTERIOR CLADDING for EXTERIOR WALL	Drywall 5/8" / USG / EcoSmart Firecoat / 5/8"	139	139	0
Windows	DOUBLE PANE WINDOWS - GENERIC	Window - double pane / Vinyl frame / / USA & CAN	2,325	2,325	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	16	16	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	40	40	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	153	153	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian /	16	16	0
Int. Walls	INTERIOR WALL CLADDING	Drywall 1/2" / CertainTeed / AirRenew / 1/2" (12.7 mm)	434	434	0
Floors	WOOD FLOOR FRAMING	Wood joist / American Wood Council & Canadian Wood Council / /	463	463	0
Floors	SUB FLOORING	OSB sheathing / American Wood Council & Canadian Wood Council	1,105	1,105	0

What's accounted for? BEAM methodology for benchmark studies



Structure, enclosure & partitions

- Largest data set
- Long life span for materials
- Most actionable analysis for users



MEP, appliances, finishes, millwork, yardwork

- Lack of data
- Less actionable analysis for users

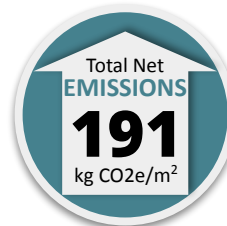
BfCA Study Results*

EMBARC Study
Greater Toronto Area, ON
503 As-built homes

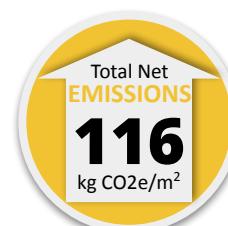
Highest
result



Average
result



Lowest
result

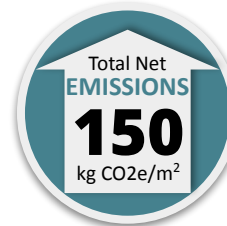


Low Carbon Homes Pilot
Nelson & Castlegar, BC
34 As-built homes

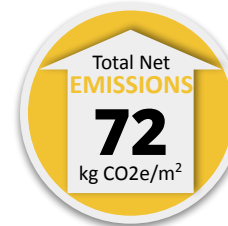
Total Net
EMISSIONS



Total Net
EMISSIONS



Total Net
EMISSIONS

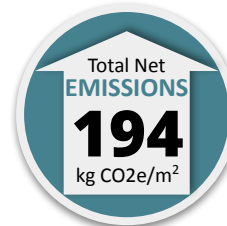


City of Vancouver Study
Vancouver, BC
13 As-built homes

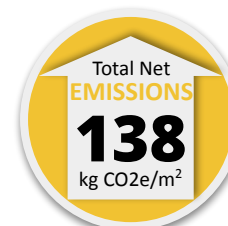
Total Net
EMISSIONS



Total Net
EMISSIONS



Total Net
EMISSIONS



*All results based on A1-A3 analysis of structure, enclosure and partitions.
Area based on heated floor area.

How much do Material Carbon Emissions matter?








57 million m²
new low-rise residential
in Canada



~12 million tonnes
annual emissions

Average of
800 new
homes
across Canada

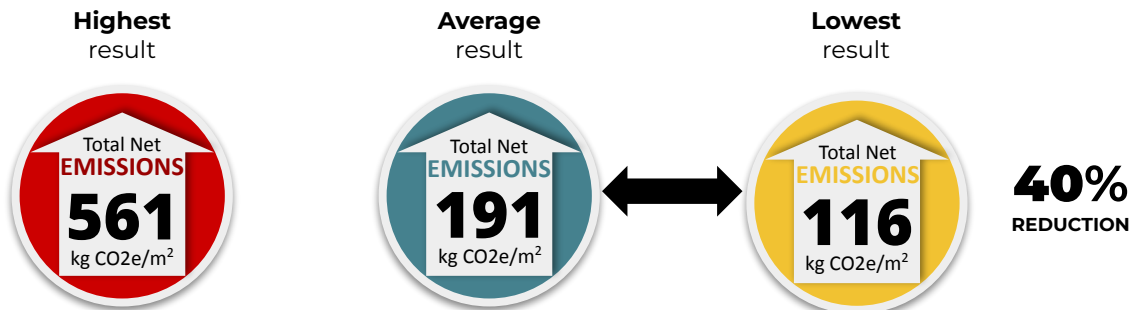
which is equivalent to...

	El Salvador	13
	Jamaica	10
	Luxembourg	10
	Albania	10
	Armenia	10

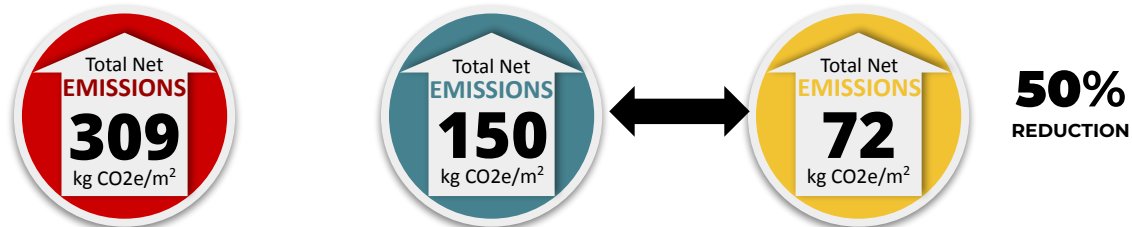
So how can you **reduce** the embodied carbon emissions in your building projects?

BfCA Study Results*

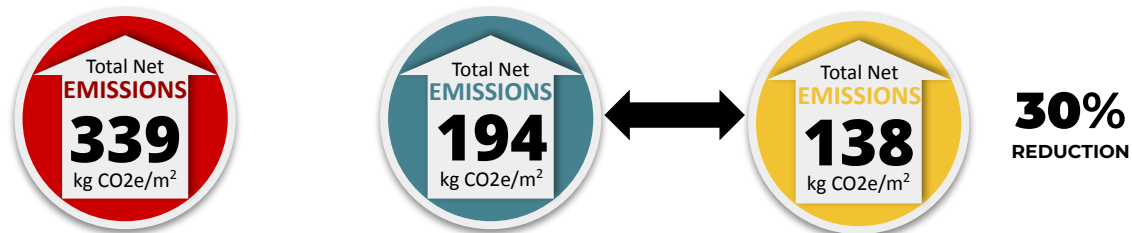
EMBARC Study
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City of Vancouver Study
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13 As-built homes



*All results based on A1-A3 analysis of structure, enclosure and partitions.
Area based on heated floor area.

A case study from Ontario...



Rosewood 'A' Model Net Zero Ready

	Ontario Code Minimum Baseline	2021 As-built	2022 minor insulation substitutions	NEAR TERM 1:1 SUBSTITUTIONS	MEDIUM-TERM 2-5 YEARS	FUTURE SCENARIO 5-10 YEARS
Total kg CO2e	48,266	66,087	52,087	22,854	11,309	183
Percent reduction			21%	65%	83%	99.7%



**NEAR TERM
1:1 SUBSTITUTIONS**

22,854
kg CO₂e

65%
reduction

Concrete → High slag (35-50%) concrete mix

EPS foam board → Replace ccSPF below slab

Cellulose insulation → replace other cavity insulation materials

Cork & linoleum flooring → replace carpet and hardwood

Engineered wood cladding → replace brick

A local case study

A Low Carbon Laneway House in Nelson

By Mike Coen



Operational Emissions

Tonnes CO₂e/yr

0.14

Material Emissions

Tonnes CO₂e

0.10

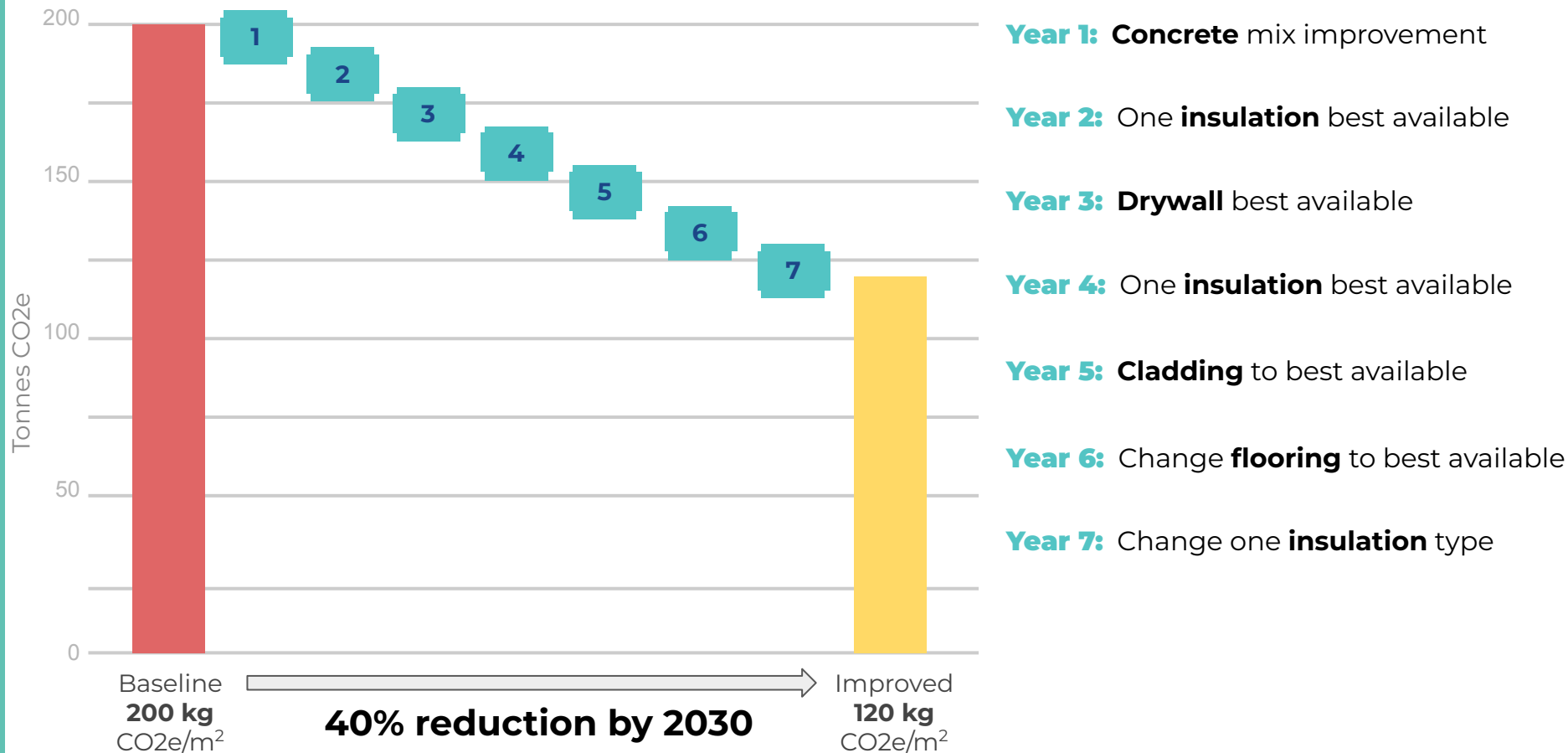
= 4.4

tonnes of total
emissions by
2050!

The **3** most significant actions
taken in this project:

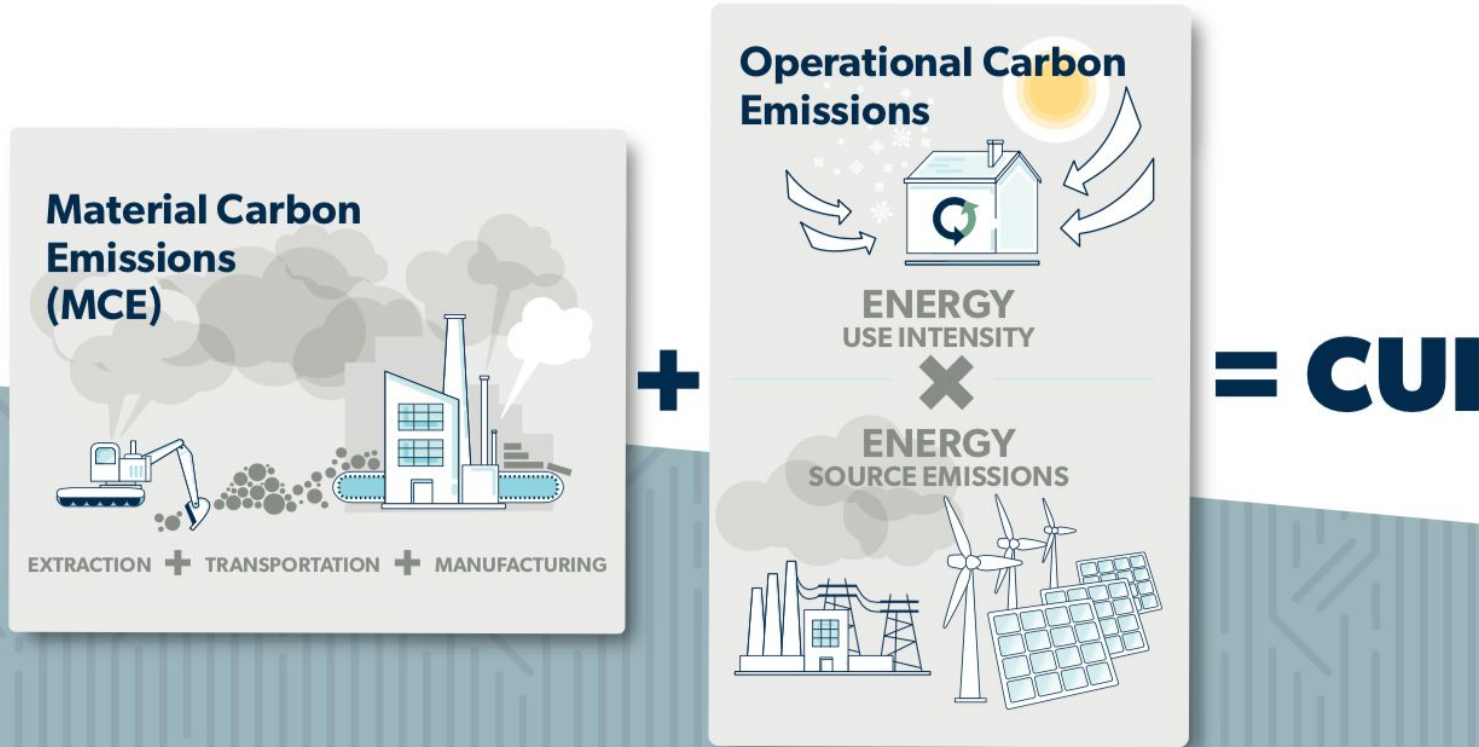
- built on **concrete piers** instead of a foundation wall
- substituted regular insulation for **cellulose**
- used **wood** siding

5% per year reductions

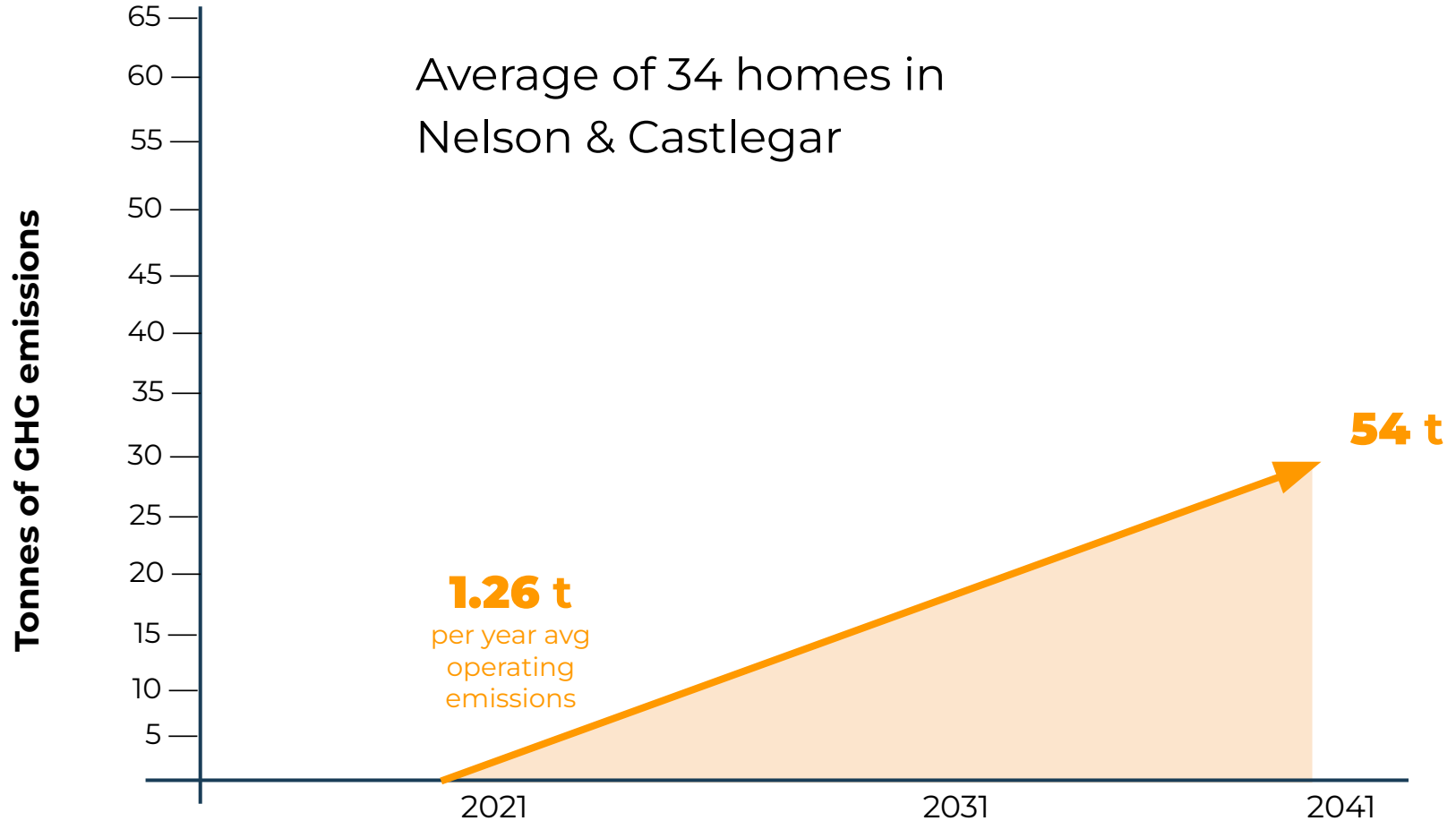


Addressing Carbon Use Intensity (CUI)

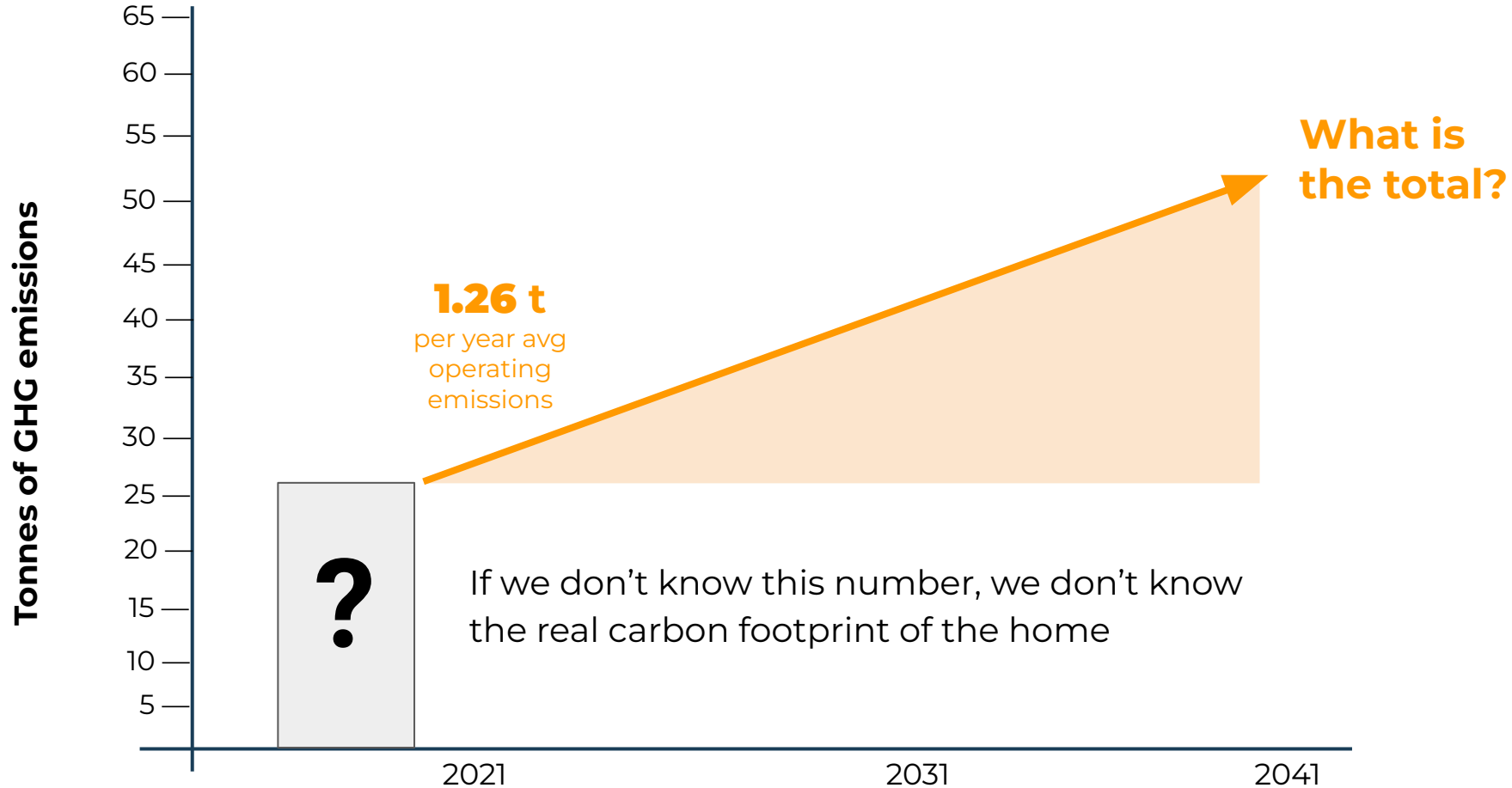
Our real goal.



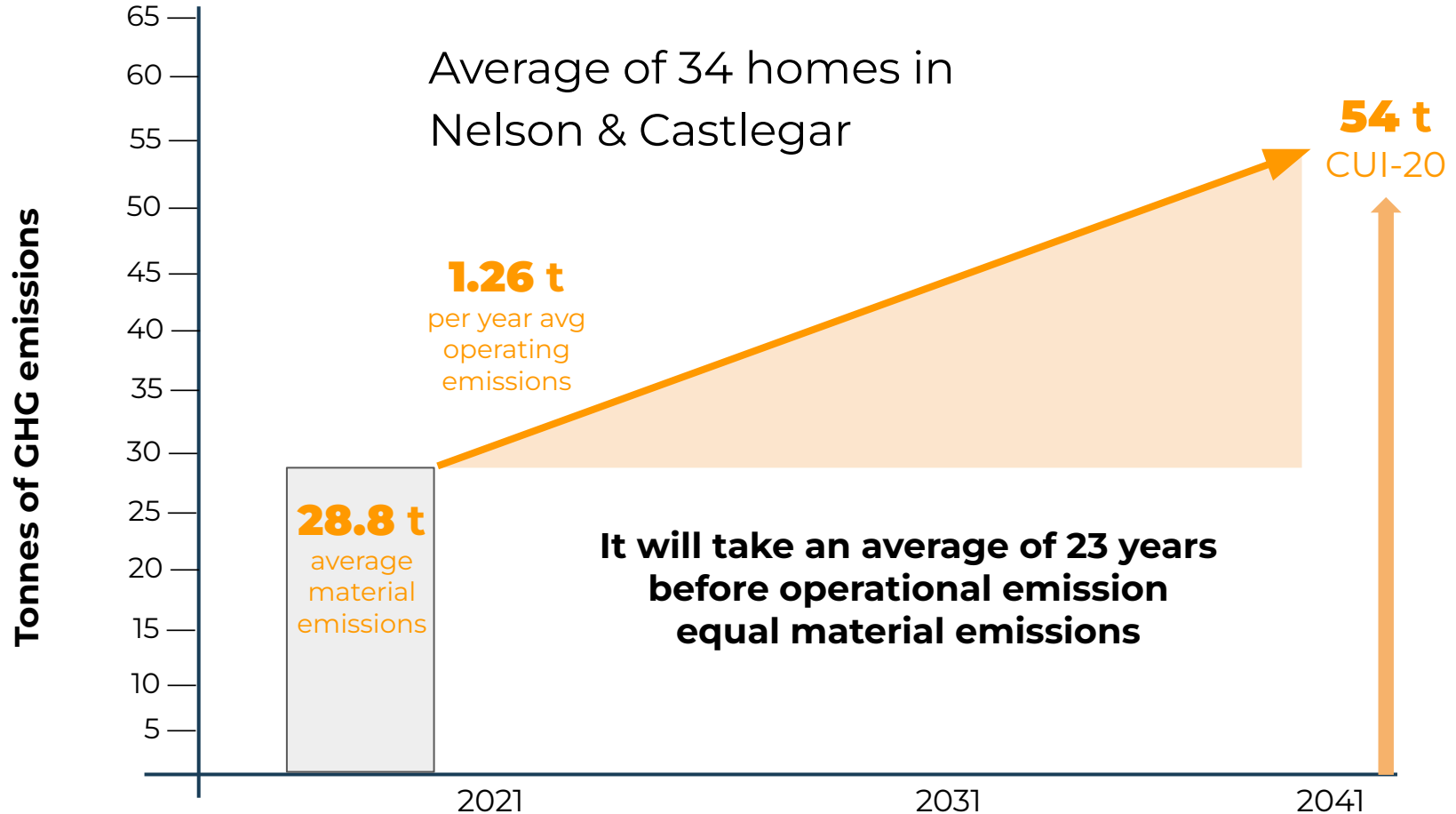
Measuring Operational Emissions



What about Material Carbon Emissions?

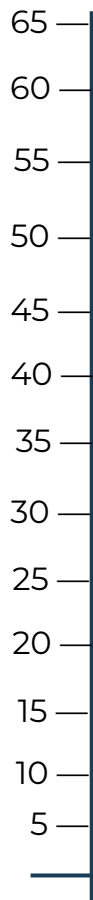


Carbon Use Intensity (CUI) - Nelson, BC



Carbon Use Intensity (CUI)

Tonnes of GHG emissions



40.7 t
material
emissions

4.9 t
per year avg
operating
emissions

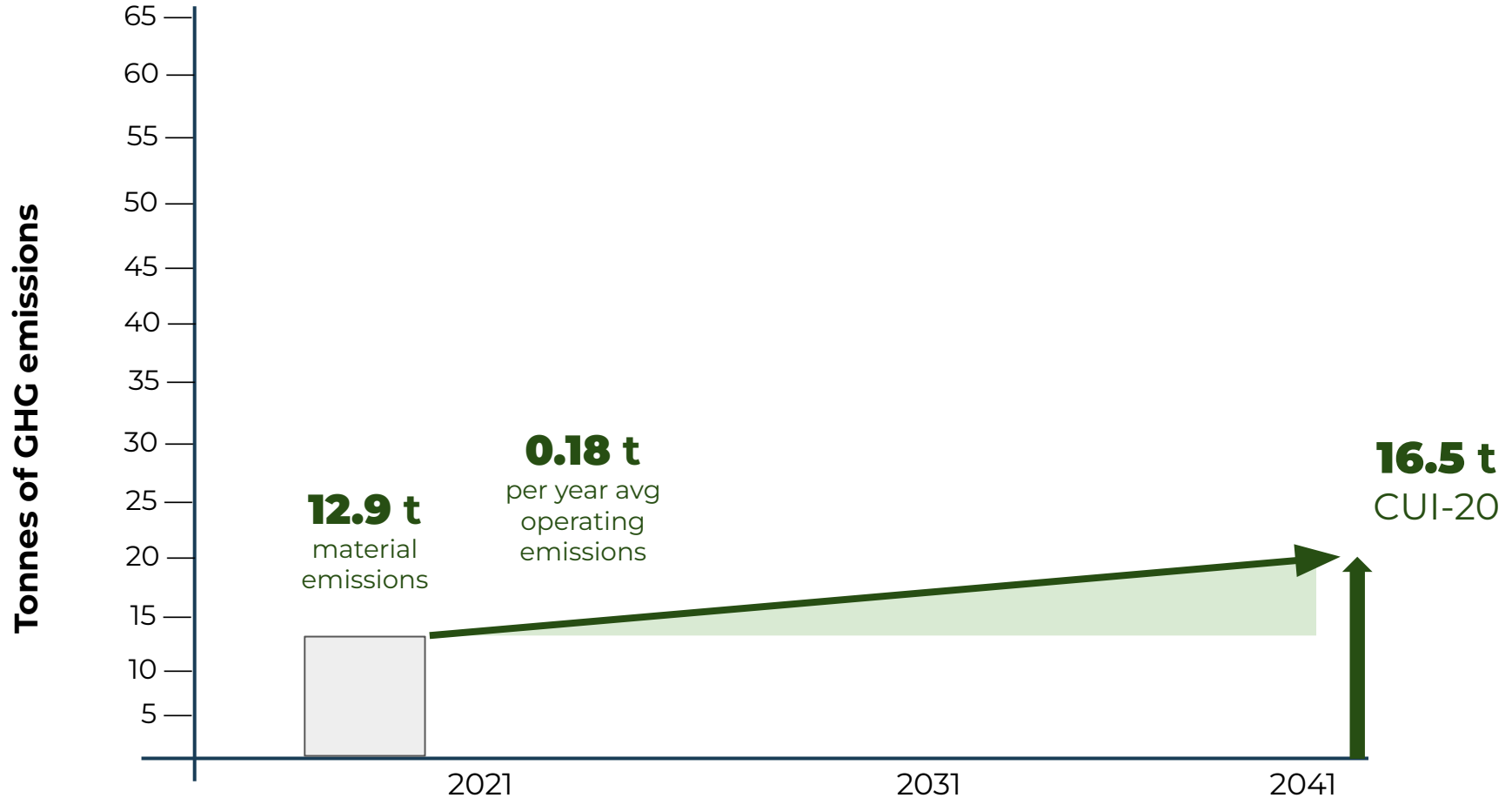
2021

2031

2041

139 t
CUI-20

Carbon Use Intensity (CUI)



Carbon Use Intensity (CUI) - Nelson, BC

MATERIAL
EMISSIONS



OPERATIONAL
EMISSIONS



CARBON USE
INTENSITY

40.7 t

4.9 t/yr

139 t CUI-20

12.9 t

4.9 t/yr

111 t CUI-20

28.8 t

1.26 t/yr

54 t CUI-20

40.7 t

0.18 t/yr

44 t CUI-20

12.9 t

1.26 t/yr

38 t CUI-20

12.9 t

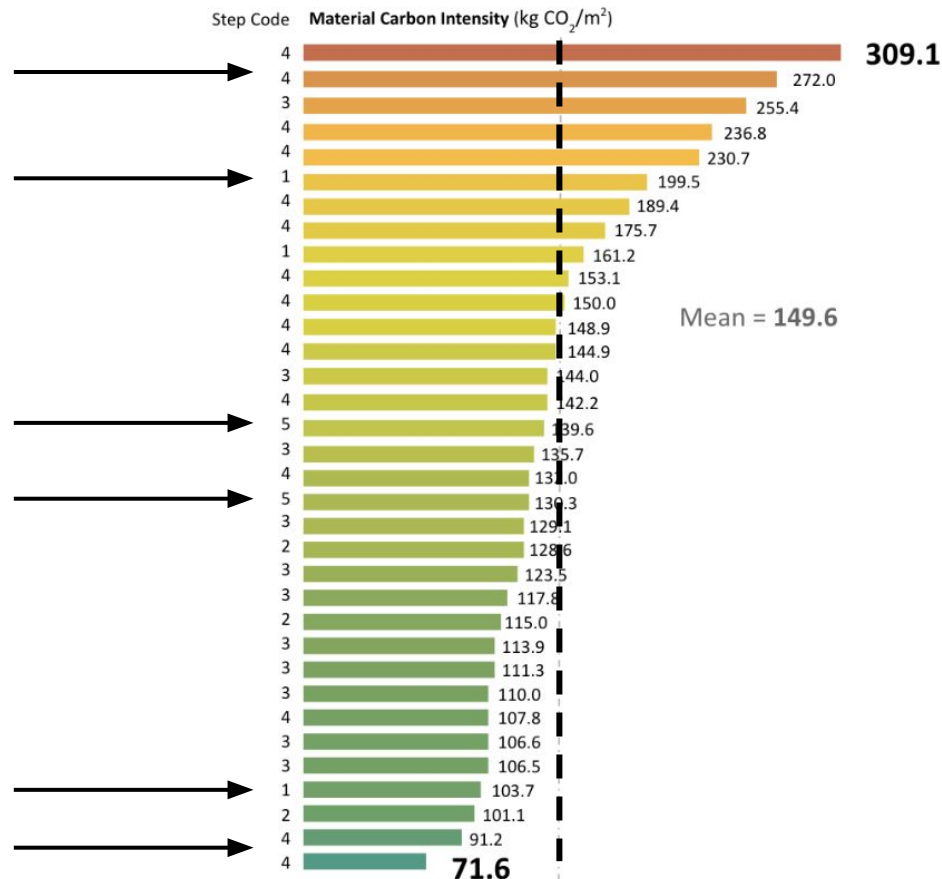
0.18 t/yr

17 t CUI-20

What about operating emissions?

“These results would suggest that **material selection and quantity is the leading factor** in driving MCI higher or lower, and that it is possible to achieve both high levels of energy efficiency and low MCI.”

*City of Nelson, 2021
Benchmarking Report*



Project flow stages

Schematic design phase

- To build or not to build?
- Location of building
- Size, shape, massing of building
- Basic material palette

→ Rough dimensions & basic materials examined in BEAM

Design development

- Assemblies
- Materials

→ Assemblies and materials compared in BEAM & building a full model

Construction documents

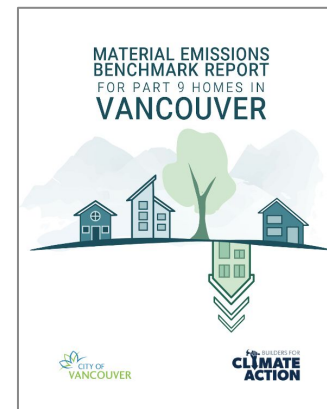
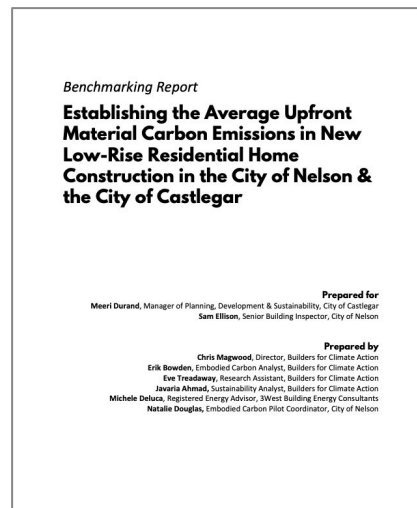
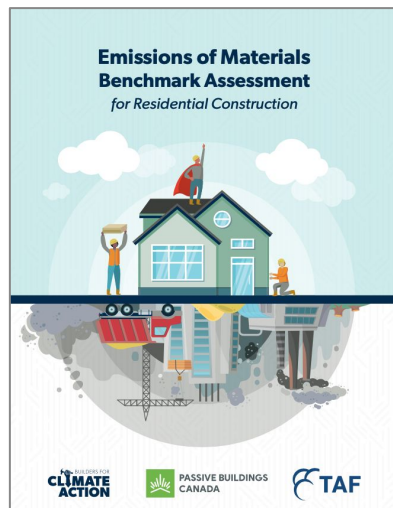
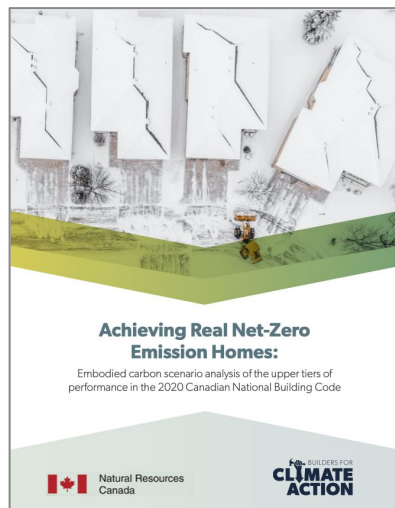
- Procurement

→ Specific materials selected in BEAM where possible

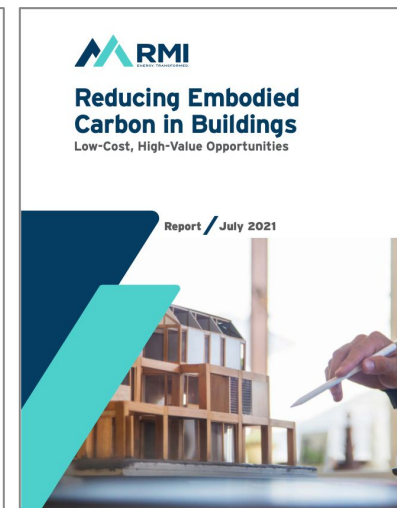
Don't lose sight of other goals...



More information:
www.buildersforclimateaction.org
www.rmi.org



hot off the press!



This workshop was made possible by **FortisBC** as part of the City of Nelson's Low Carbon Homes Pilot.

