



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:

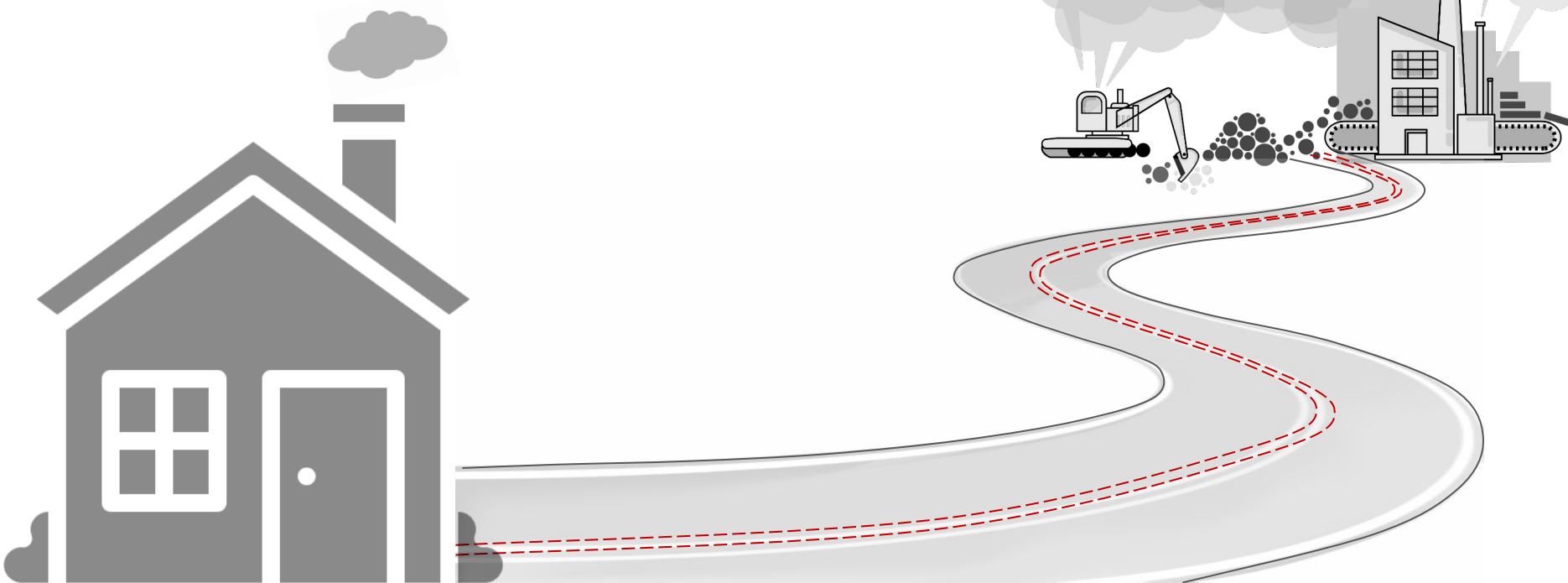
ENERGY USE
X
ENERGY SOURCE EMISSIONS



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



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



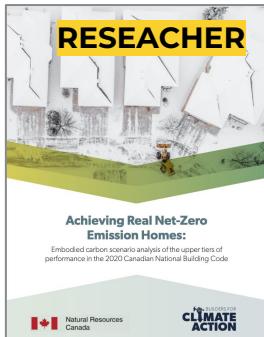
OWNER/BUILDER



CONTRACTOR



RESEACHER



AUTHOR



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)



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

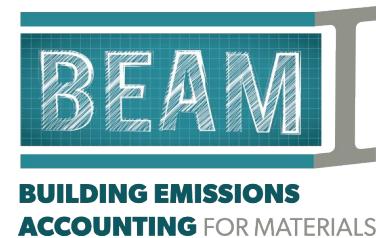
3.5" dia. post =

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 m²	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



...help you compare assemblies

ASSEMBLY 1

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

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

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



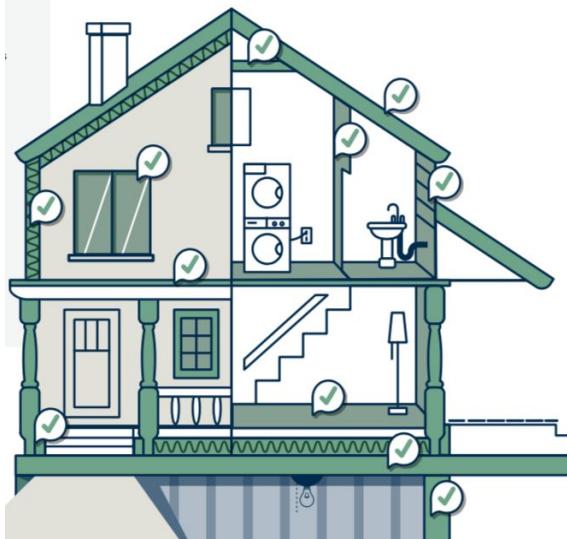
REVIEW OF SELECTED MATERIALS

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 / CRMCA / 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 / 6" x 6" x 6/8g / Norway	160	160	0
Footings & Slabs	CONCRETE SLAB FLOOR(S)	Concrete - 0.25 MPa, Canadian Benchmark Average / CRMCA / Can. /	2,258	2,258	0
Foundation Walls	CONCRETE WALLS	Concrete - 0.25 MPa, Canadian Benchmark Average / CRMCA / 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 W	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 (W12x20) / American Institute of Steel Constru	252	252	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W250x33 (W10x22) / American Institute of Steel Constru	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 W	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 4.3/inch	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 INSULAT	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 W	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 avei	108	108	0
Cladding	EXTERIOR CLADDING	Vinyl Siding / Vinyl Siding Institute / 0.040" Double 4.5"	67	67	0
Cladding	INTERIOR CLADDING FOR EXTERIOR WAL	Drywall 1/2" - Typical - CertainTeed - AVERAGE	328	328	0
Cladding	INTERIOR CLADDING	Drywall 5/8" / Includes American Gypsum, CertainTeed, Continen	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 W	16	16	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian W	40	40	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian W	153	153	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian W	153	153	0

SECTION	CATEGORY	MATERIAL	NET CARBON FOOTPRINT [kg CO2e]	CARBON EMISSIONS [kg CO2e]	CARBON STORAGE [kg CO2e]
Footings & Slabs	CRUSHED STONE BASE	Aggregate / Marlin Marietta / Avg construction aggregate (gravel &	1	1	0
Footings & Slabs	FOOTINGS & PADS	Concrete - 0.25 MPa, 35-50% Slag, GU / CRMCA / 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 / 6" x 6" x 6/8g / Norway	160	160	0
Footings & Slabs	CONCRETE SLAB FLOOR(S)	Concrete - 0.25 MPa, 35-50% Slag, GU / CRMCA / Can. Avg. /	1,772	1,772	0
Foundation Walls	CONCRETE WALLS	Concrete - 0.25 MPa, 35-50% Slag, GU / CRMCA / 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 W	191	191	0
Foundation Walls	CAVITY INSULATION	Cellulose - batt / CMS / R 3.6/inch / EcoCell	-1,331	318	1,049
Foundation Walls	INTERIOR WALL CLADDING	Drywall 1/2" / CertainTeed / Easi-Lite / 1/2" (12.7 mm)	14	14	0
Structural Elements	HEAVY TIMBER FRAMING	Wood framing & siding - SPF / American Wood Council & Canadian W	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 (W12x20) / American Institu of Steel Constru	252	252	0
Structural Elements	HEAVY STEEL COMPONENTS	Steel beam / W250x33 (W10x22) / American Institu of Steel Constru	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 W	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	2,827
Ext. Walls	GARAGE ATTACHMENT WALL INSULAT	Cellulose - batt / CMS / R 3.6/inch / EcoCell	-355	85	440
Ext. Walls	GARAGE ATTACHMENT WALLS	Wood framing & siding - SPF / American Wood Council & Canadian W	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 / 5/8" (8 mm)	599	599	0
Cladding	INTERIOR CLADDING FOR EXTERIOR WAL	Drywall 1/2" / CertainTeed / AirRenew / 1/2" (12.7 mm)	299	299	0
Cladding	INTERIOR CLADDING FOR EXTERIOR WAL	Drywall 5/8" / USG / EcoSmart Firecode / 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 W	16	16	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian W	40	40	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian W	153	153	0
Int. Walls	WOOD FRAME CONSTRUCTION	Wood framing & siding - SPF / American Wood Council & Canadian W	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 1 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



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



*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?



Average of
800 new
homes
across Canada



57 million m²
new low-rise residential
in Canada



~12 million tonnes
annual emissions

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
Greater Toronto Area, ON
503 As-built homes

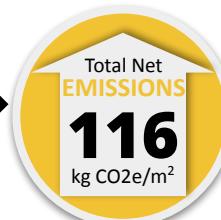
Highest
result



Average
result

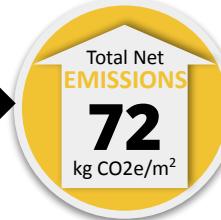


Lowest
result



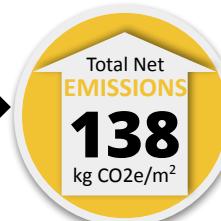
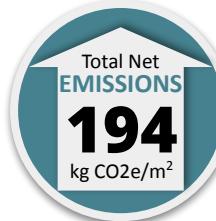
40%
REDUCTION

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



50%
REDUCTION

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



30%
REDUCTION

*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 CO ₂ e	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

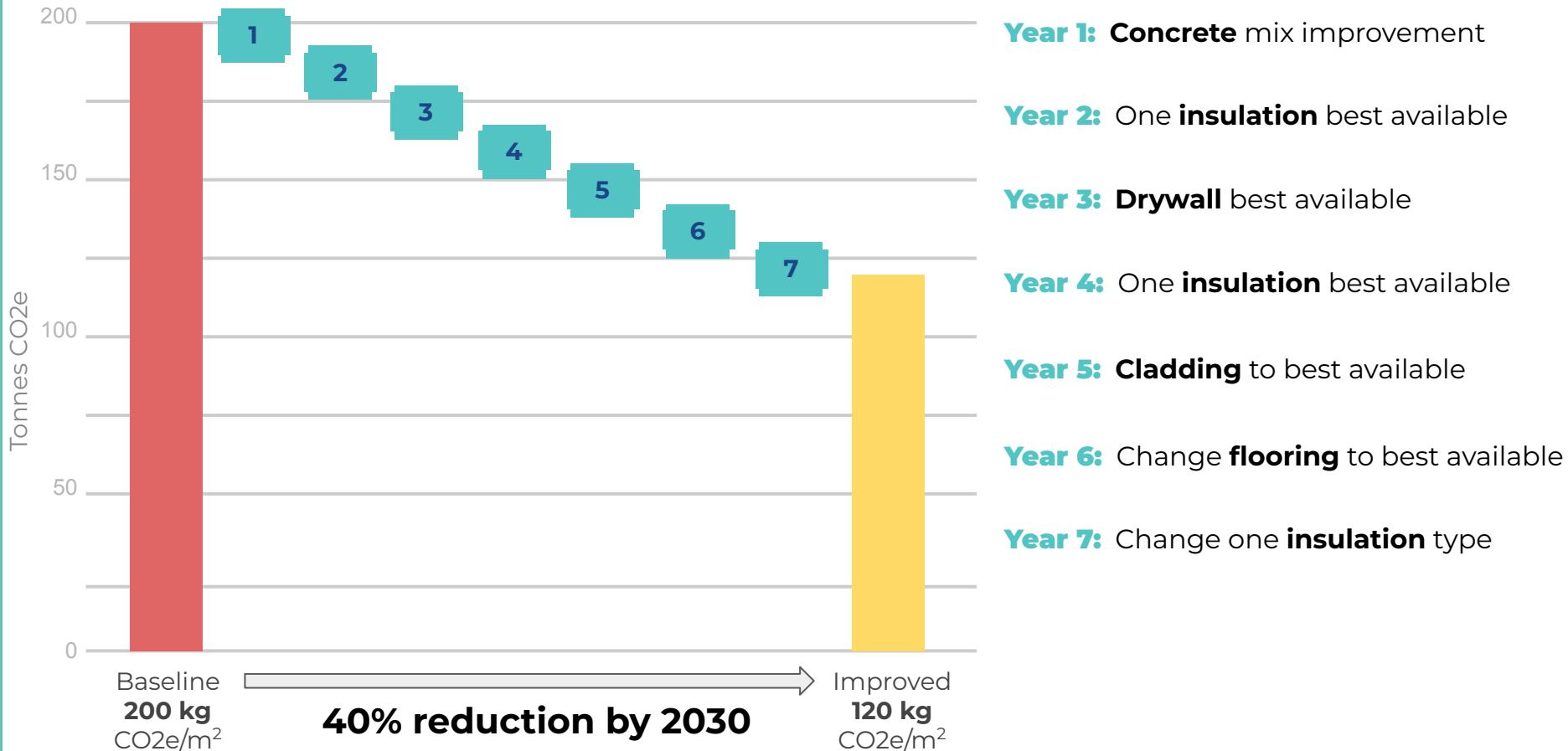
= **4.4**

tonnes of total
emissions by
2050!

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

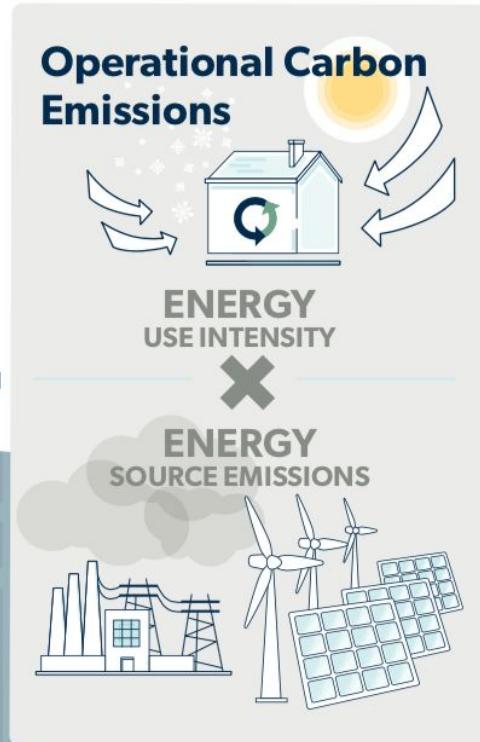
- built on **concrete piers** instead of a foundation wall
- substituted regular insulation for **cellulose**
- used **wood** siding

5% per year reductions



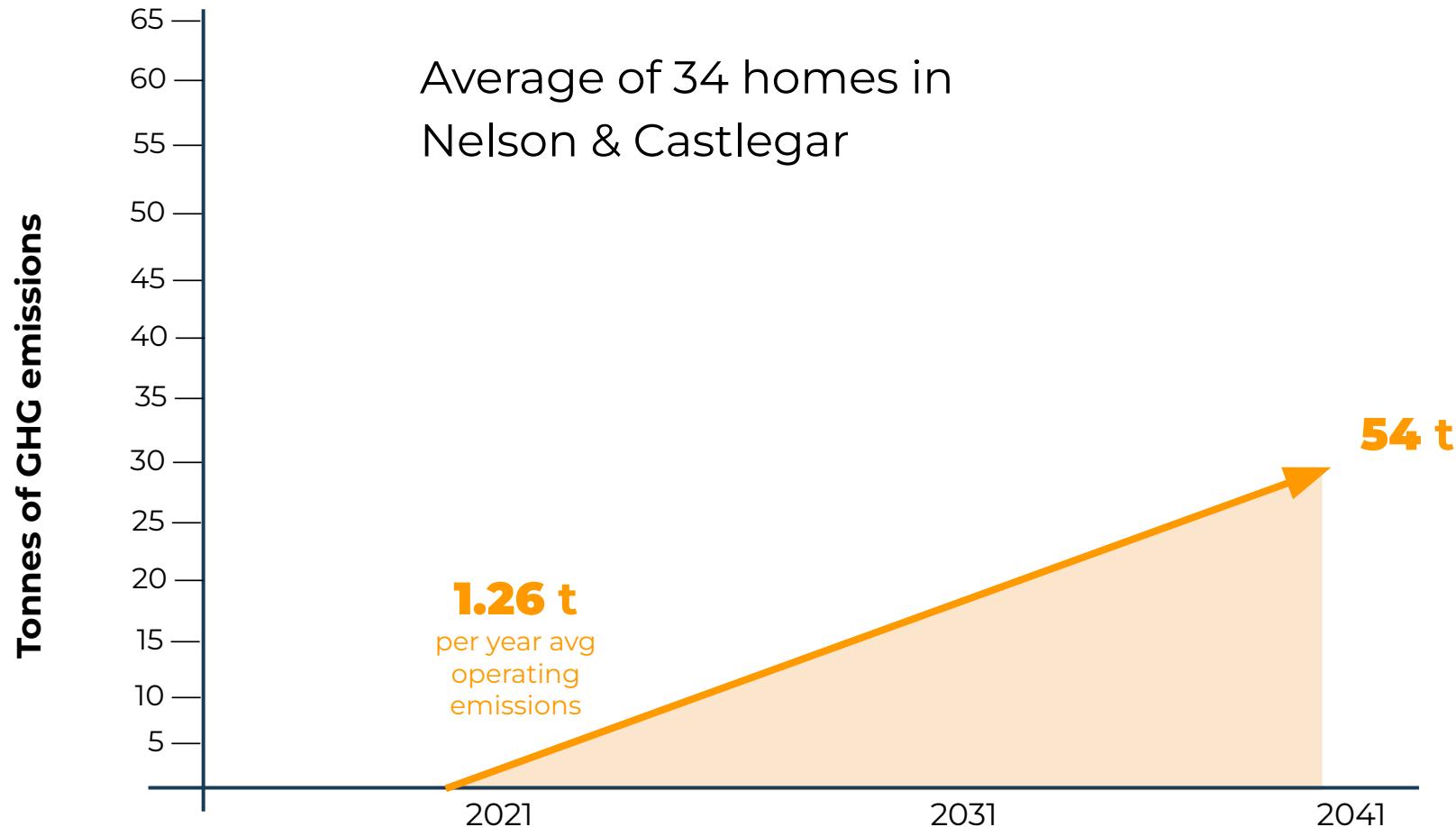
Addressing Carbon Use Intensity (CUI)

Our real goal.

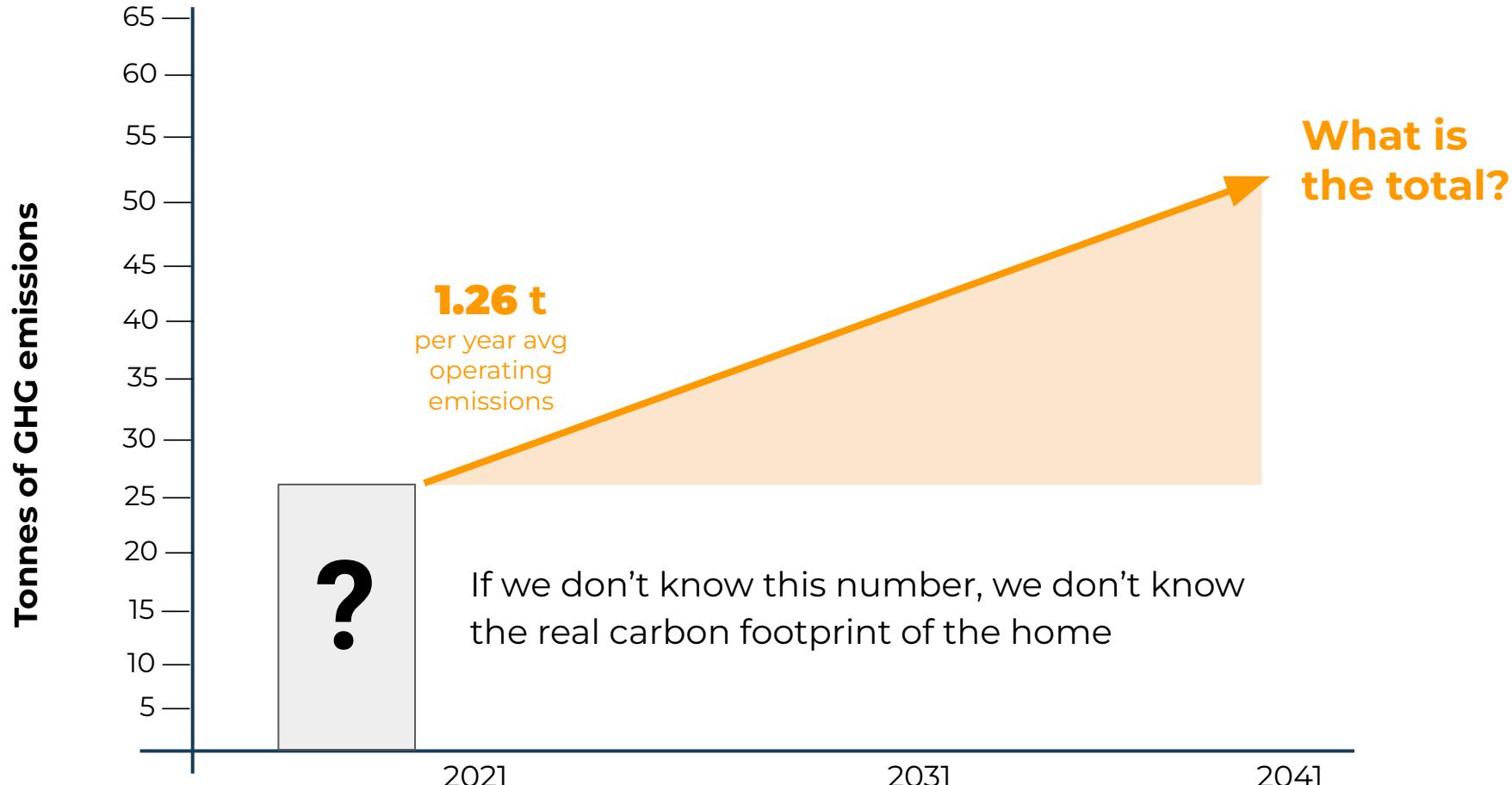


= CUI

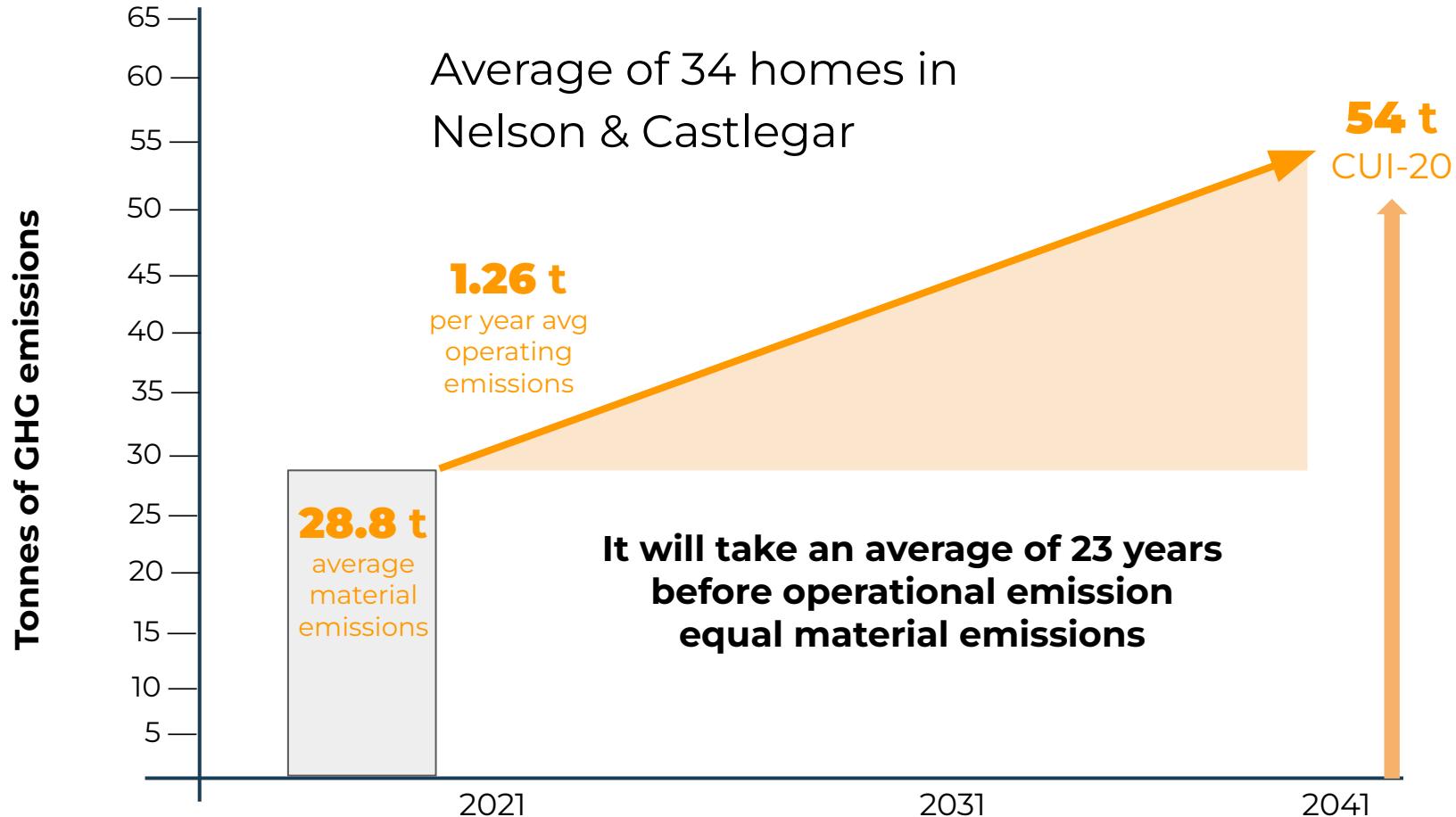
Measuring Operational Emissions



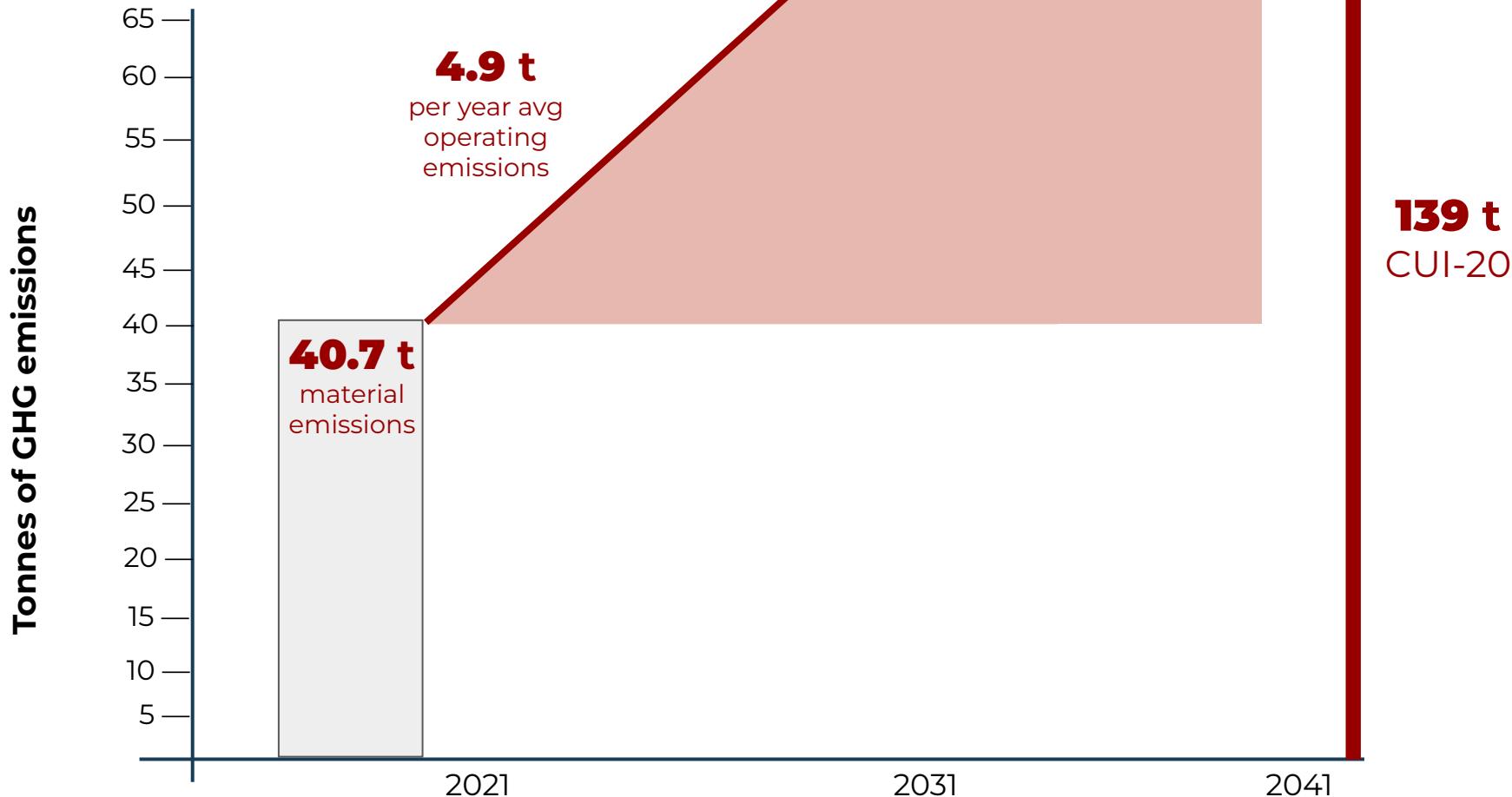
What about Material Carbon Emissions?



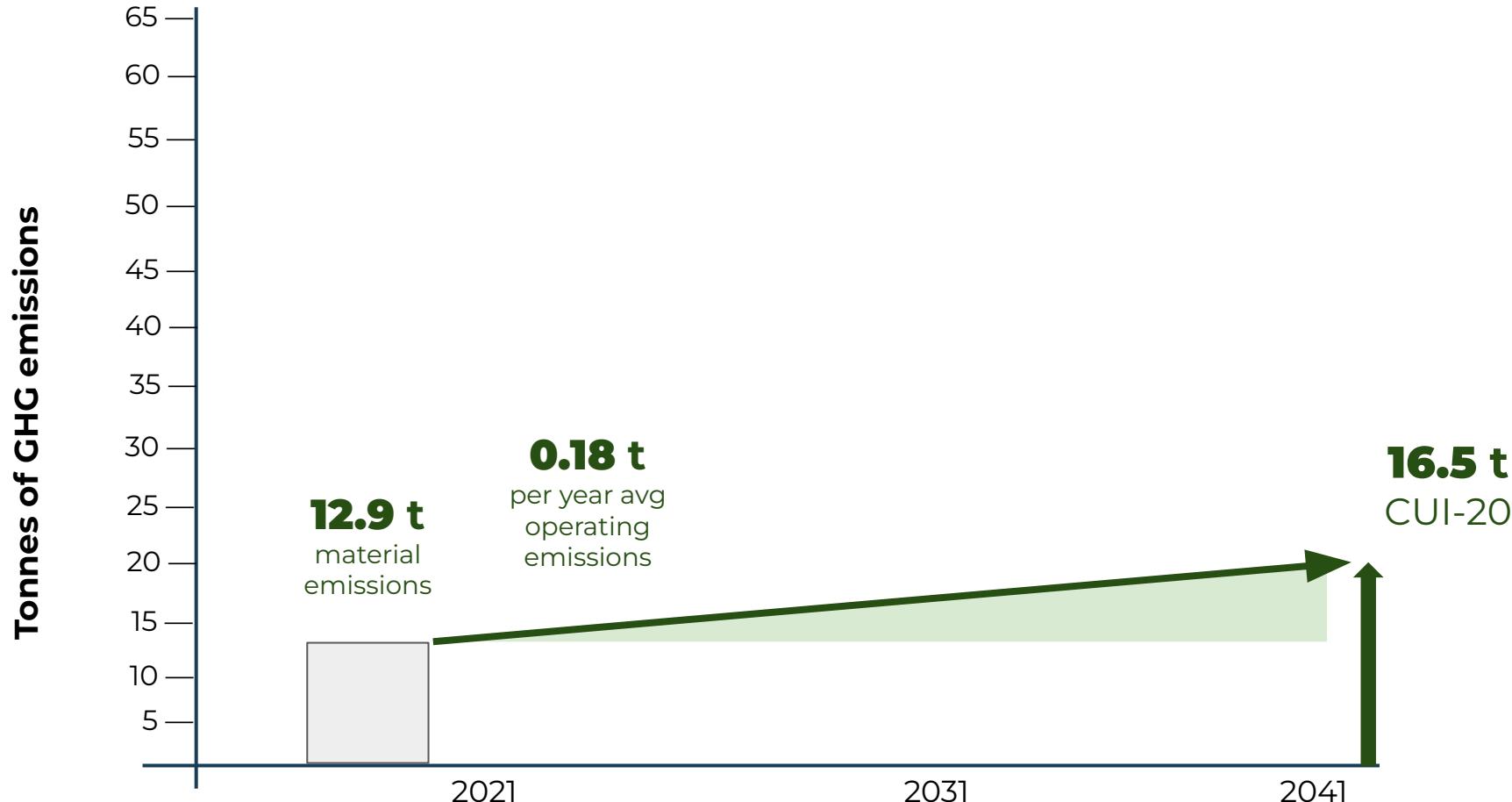
Carbon Use Intensity (CUI) - Nelson, BC



Carbon Use Intensity (CUI)



Carbon Use Intensity (CUI)



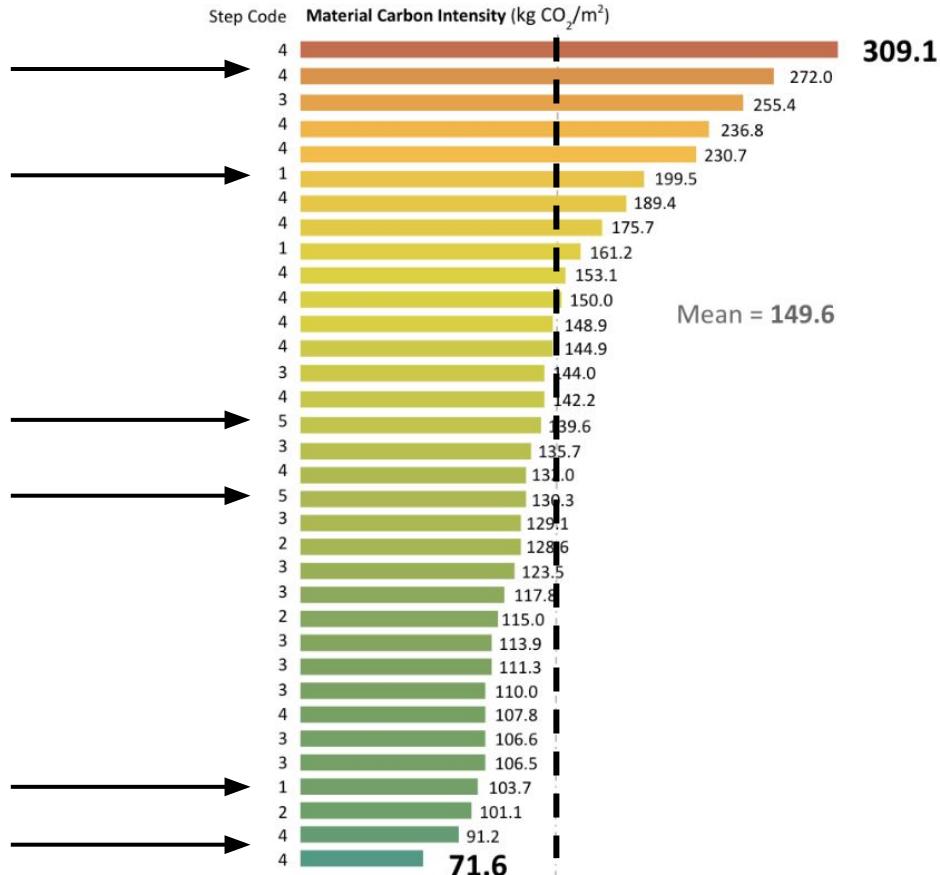
Carbon Use Intensity (CUI) - Nelson, BC

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

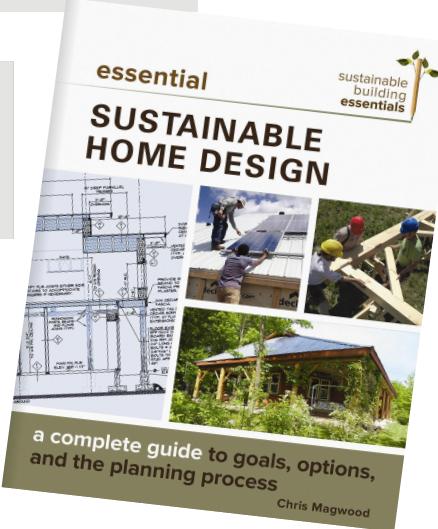
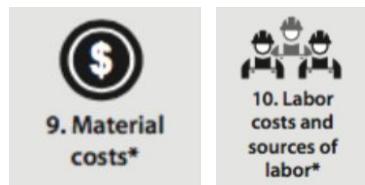
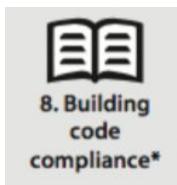
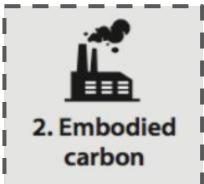
→ Assemblies and materials compared in BEAM & building a full model

Construction documents

- Procurement

→ Specific materials selected in BEAM where possible

Don't lose sight of other goals...



More information:

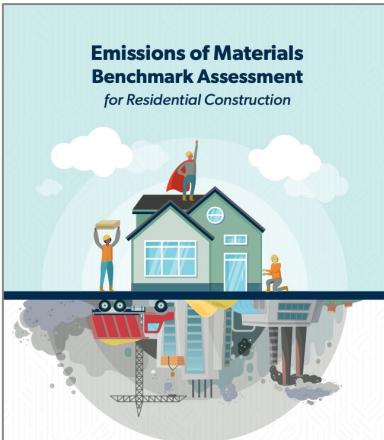
www.buildersforclimateaction.org

www.rmi.org



Achieving Real Net-Zero Emission Homes:
Embodied carbon scenario analysis of the upper tiers of performance in the 2020 Canadian National Building Code

Natural Resources Canada
BUILDERS FOR CLIMATE ACTION



Emissions of Materials Benchmark Assessment for Residential Construction

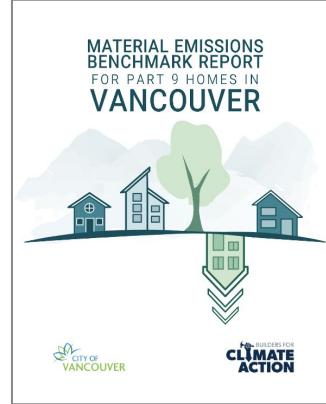
PASSIVE BUILDINGS CANADA
TAF

Benchmarking Report

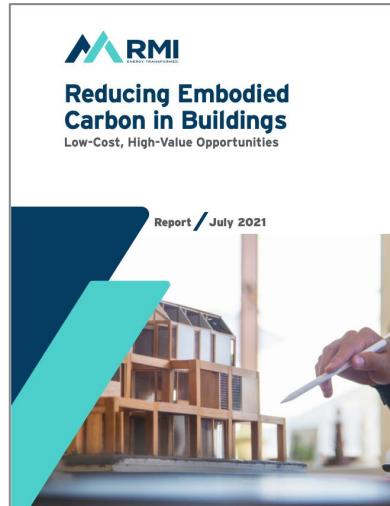
Establishing the Average Upfront Material Carbon Emissions in New Low-Rise Residential Home Construction in the City of Nelson & the City of Castlegar

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