BUILDING BETTER WORKSHOP SERIES

Embodied Carbon Reduction Strategies w/ Chris Magwood

October 11, 2022

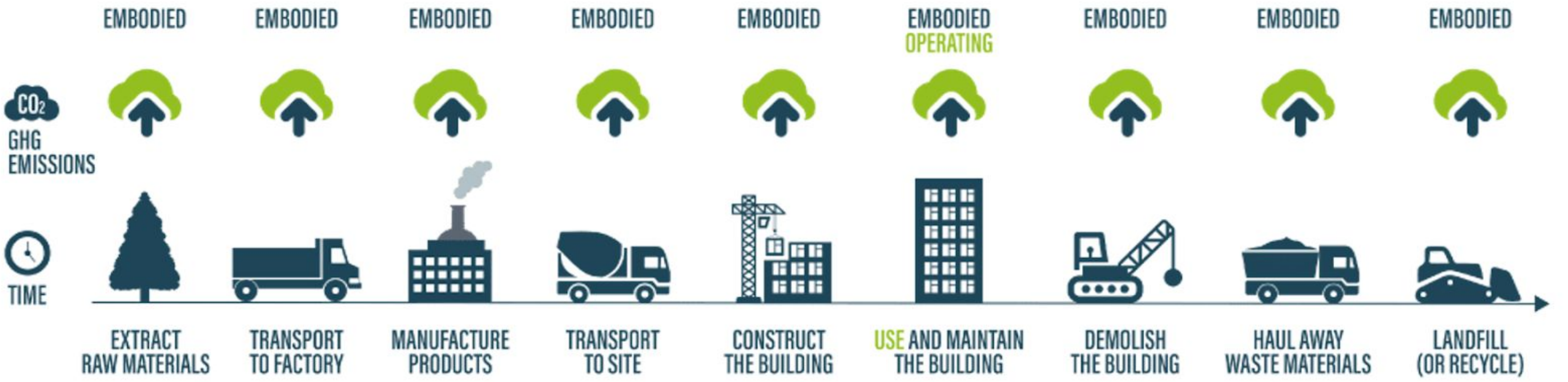
City of NELSON

BUILDERS FOR CLIMATE ACTION

FORTIS BC™

Energy at work

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%

6-10%

8-15%

3-15%

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."***

e.g.,

TIMBER - 42.56 kg CO_2e/m^3
STEEL - 1.16 t CO_2e/ton
CONCRETE - 304.53 kg CO_2e/m^3

Estimating Material Carbon Emissions (MCE)

A1-A3 GWP factors from EPDs

−

A1-A3 biogenic carbon storage

×

Material quantity (based on dimensions)

FOUNDATION WALL AREA	74.3	m²
FOUNDATION SLAB AREA	55.7	m²
EXTERIOR WALL AREA	100.0	m²
WINDOW AREA	18.7	m²

=

Net emissions kg CO2e

8,292

NET EMISSIONS ($kg\ CO_2e$)

BEAM

BUILDING EMISSIONS ACCOUNTING FOR MATERIALS

Estimating Material Carbon Emissions (MCE)

TIMBER

42.56 kg CO_2e/m^3

6x6 post =

4 kg CO_2e

CONCRETE

304.53 kg CO_2e/m^3

6” dia. post =

12 kg CO_2e

STEEL

1.16 t CO_2e/ton

3.5” dia. post =

73 kg CO_2e

Now we can start to make informed decisions!

The BEAM tool can help you compare materials

BUILDERS FOR CLIMATE ACTION

BEAM

BUILDING EMISSIONS ACCOUNTING FOR MATERIALS

CAVITY INSULATION		R-VALUE 20.0			
HIGH R-VALUE CAVITY INSULATION					
	Aerogel blanket / Aspen Aerogels / R9.6/inch	100.0 m²	100%	☐	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 m²	100%	☐	5,995
	Spray polyurethane foam - High Density (HFO gas) / R 6.5/inch / SPFA [Industry Avg | US & CA]	100.0 m²	100%	☐	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 m²	100%	☐	4,635
	Spray polyurethane foam - Closed Cell (HFO gas) / R 6.6/inch / SPFA [Industry Avg | US & CA]	100.0 m²	100%	☐	1,465
	Spray polyurethane foam - Closed Cell (HFO gas) / Huntsman / Heatlok Soya HFO & Heatlok HFO / R 6.5/inch	100.0 m²	100%	☐	882
SPRAY POLYURETHANE FOAM – OPEN CELL					
	Spray polyurethane foam - Open Cell / R 4.1/inch / SPFA [Industry Avg | US & CA]	100.0 m²	100%	☐	500
SHEEP WOOL INSULATION					
	Wool / Havelock Wool / Loose-fill / R 4.4/inch	100.0 m²	100%	☐	271
	Wool / Havelock Wool / Batts / R 3.6/inch	100.0 m²	100%	☐	354
MINERAL WOOL BATT INSULATION					
	Mineral wool batt / Owens Corning / Thermafiber UltraBatt / R 4.3/inch	100.0 m²	100%	☐	1,409
	Mineral wool batt / Rockwool / ComfortBatt R24 (5.5") / R 4.4/inch	100.0 m²	100%	☐	600
	Mineral wool batt / [BEAM Avg]	100.0 m²	100%	☐	597
	Mineral wool batt / Rockwool / ComfortBatt R15 (3.5") / R 4.3/inch	100.0 m²	100%	☐	461
	Mineral wool batt / Rockwool / Safe'n'Sound, ComfortBatt / R 3.8/inch	100.0 m²	100%	☐	461
	Mineral wool batt / Rockwool / ComfortBatt R14 (3.5") / R 4.0/inch	100.0 m²	100%	☐	415
	Mineral wool batt / Rockwool / ComfortBatt R22 (5.5") / R 4.0/inch	100.0 m²	100%	☐	415

...help you compare assemblies

BUILDERS FOR CLIMATE ACTION

ASSEMBLY 1

			1,564	1,564	0
SECTION	CATEGORY	MATERIAL	NET EMISSIONS ($kg\ CO_2e$)	CARBON EMISSIONS ($kg\ CO_2e$)	CARBON STORAGE ($kg\ CO_2e$)
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 ($kg\ CO_2e$)	CARBON EMISSIONS ($kg\ CO_2e$)	CARBON STORAGE ($kg\ CO_2e$)
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 ($kg\ CO_2e$)	CARBON EMISSIONS ($kg\ CO_2e$)	CARBON STORAGE ($kg\ CO_2e$)
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

BUILDERS FOR CLIMATE ACTION

BUILDERS FOR CLIMATE ACTION | BEAM

REVIEW OF SELECTED MATERIALS

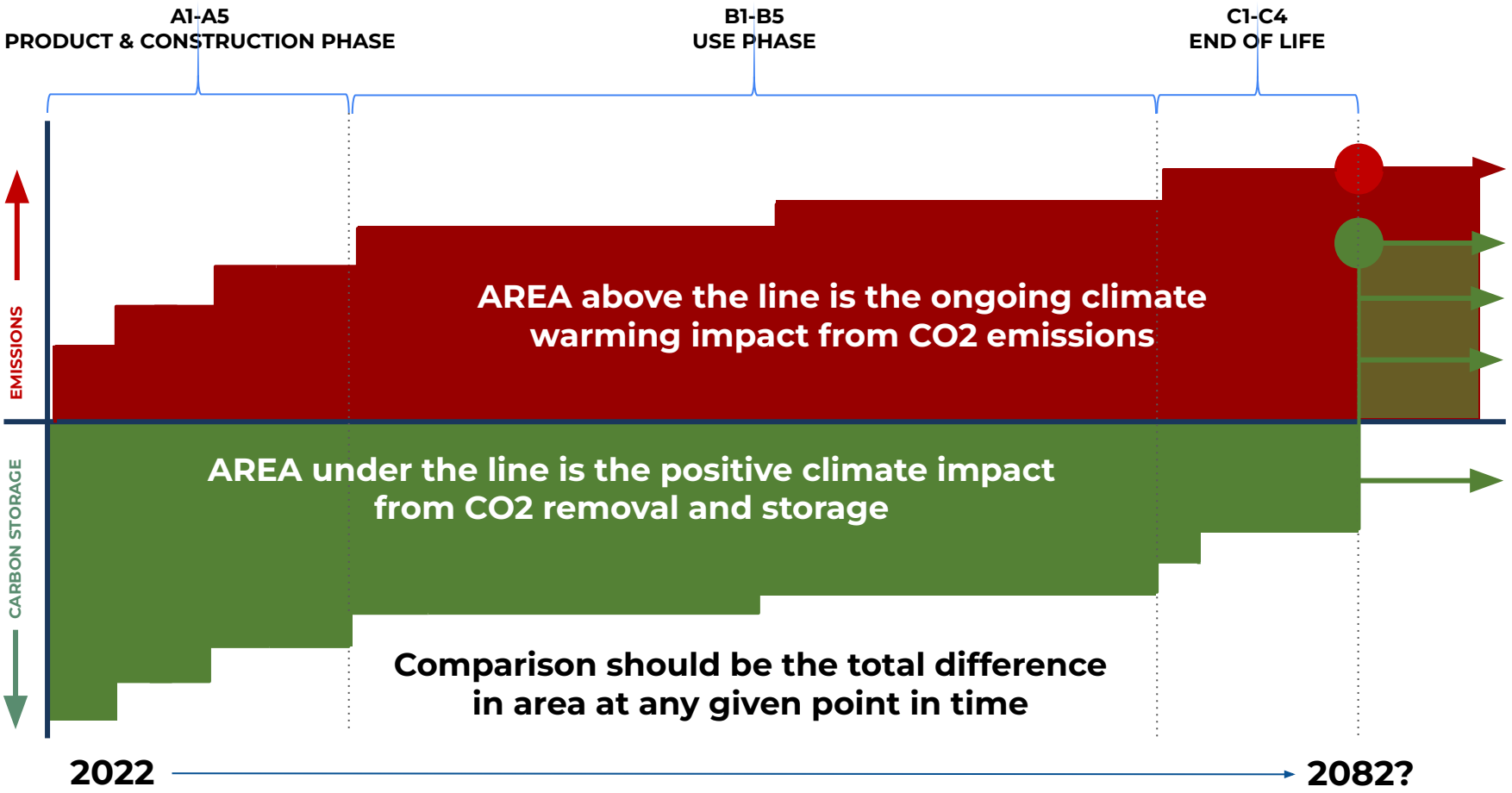
			81,510	83,421	1,911
SECTION	CATEGORY	MATERIAL	NET CARBON FOOTPRINT [kg CO2e]	CARBON EMISSIONS [kg CO2e]	CARBON STORAGE [kg CO2e]
Footings & Slabs	CRUSHED STONE BASE	Aggregate / / / Avg construction aggregate (gravel & sand)	4	4	0
Footings & Slabs	FOOTINGS & PADS	Concrete - 0-25 MPa, Canadian Benchmark 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 6/6g / 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 \	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 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 \	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	276	276	0
Ext. Walls	CAVITY INSULATION	Mineral wool batt / Owens Corning / Thermafiber UltraBatt / R 4.3/inc	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 INSULATI(	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 / Arriscraft / 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 WAL	Drywall 1/2" Typical - CertainTeed - AVERAGE	328	328	0
Cladding	INTERIOR CLADDING for EXTERIOR WAL	Drywall 5/8" / / Includes American Gypsum, CertainTeed, Continenta	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

BUILDERS FOR CLIMATE ACTION | BEAM

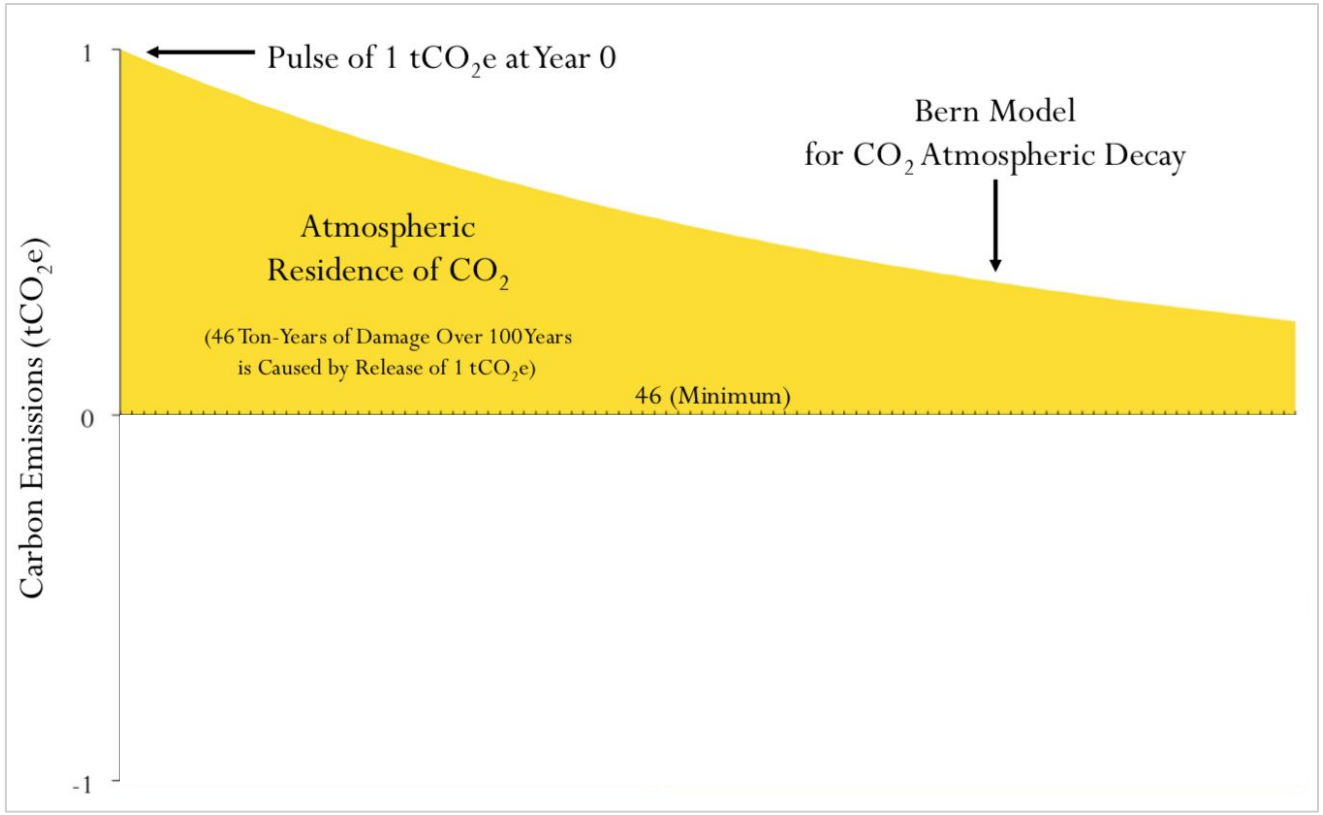
REVIEW OF SELECTED MATERIALS

			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 / 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 6/6g / 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 \	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 / Easi-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 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 \	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 INSULATI(	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 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 \	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 I 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

Impact of carbon storage on climate change



Value of carbon storage on climate change



Ton year accounting

Storing 1 ton of CO_2 for 46 years is equivalent to eliminating the damage of 1 tonne of CO_2 emissions

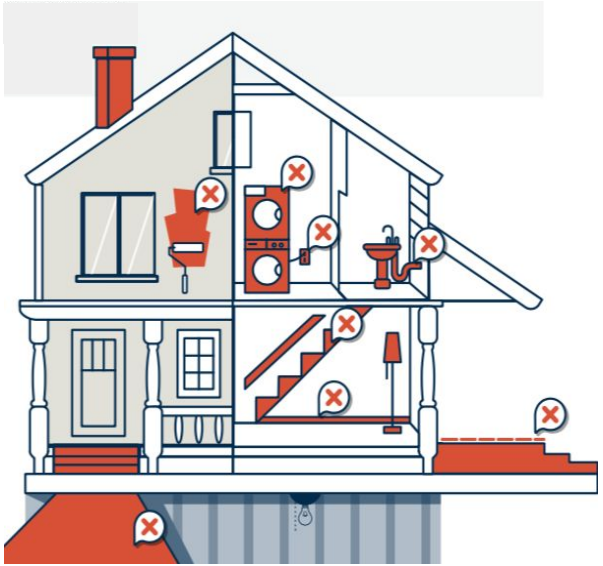
Establishing a Carbon Offset Equivalence
for Temporary Biogenic Carbon Storage in Buildings

http://www.aureusearth.com

What's accounted for? BEAM methodology for benchmark studies

Structure, enclosure & partitions

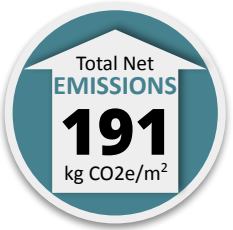
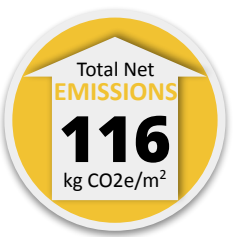
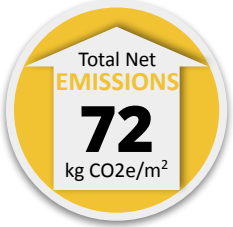
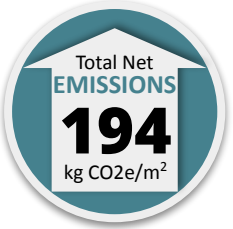
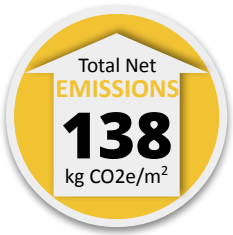
- Largest data set
- Long life span for materials
- Most actionable analysis for users



MEP, appliances, finishes, millwork, yardwork

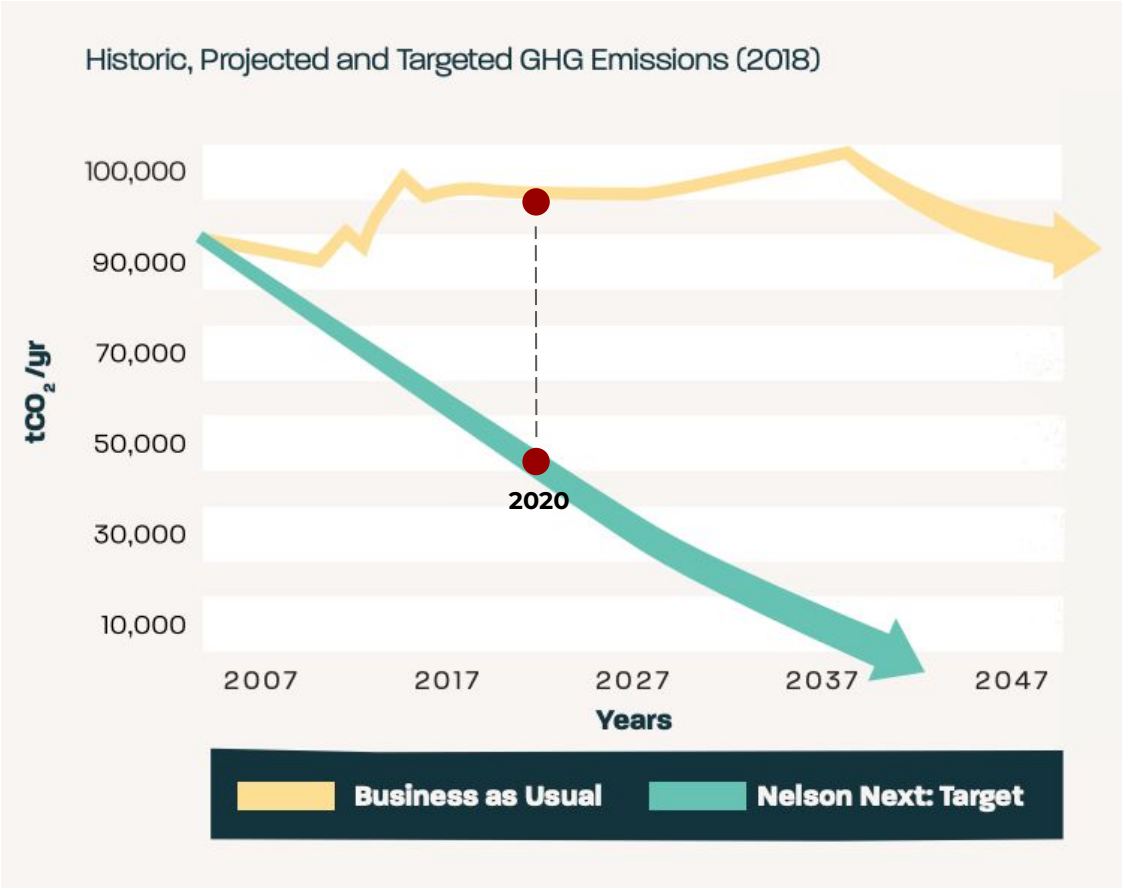
- Lack of data
- Less actionable analysis for users

BfCA Study Results*

	Highest result	**Average** result	**Lowest** result
EMBARC Study Greater Toronto Area, ON 503 As-built homes			
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.

Nelson implications



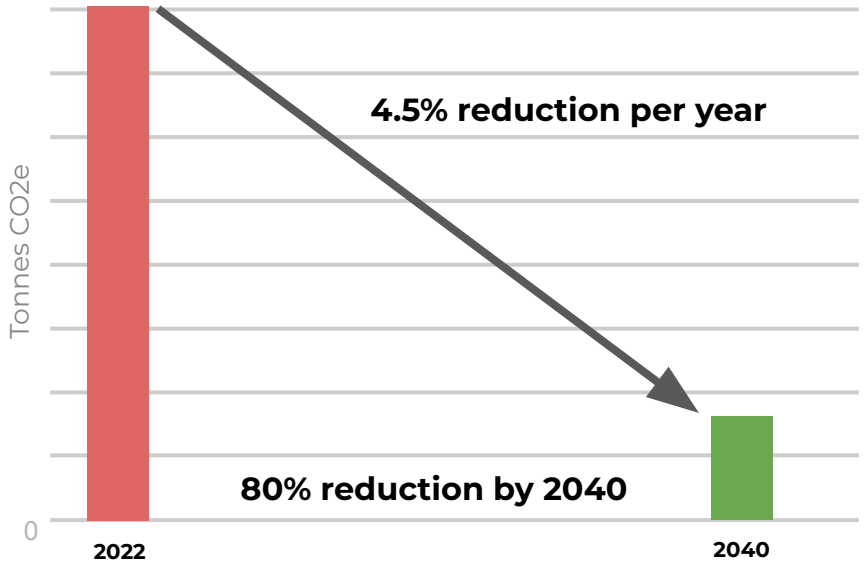
Nelson has a 80% reduction target for 2040 (17 years away)

The 2020 Nelson-Castlegar study indicates annual emissions from new home materials is ~2,100 - 4,200 tonnes

80% reduction in our MCI
150 kg of CO2e/m^2 -> 30

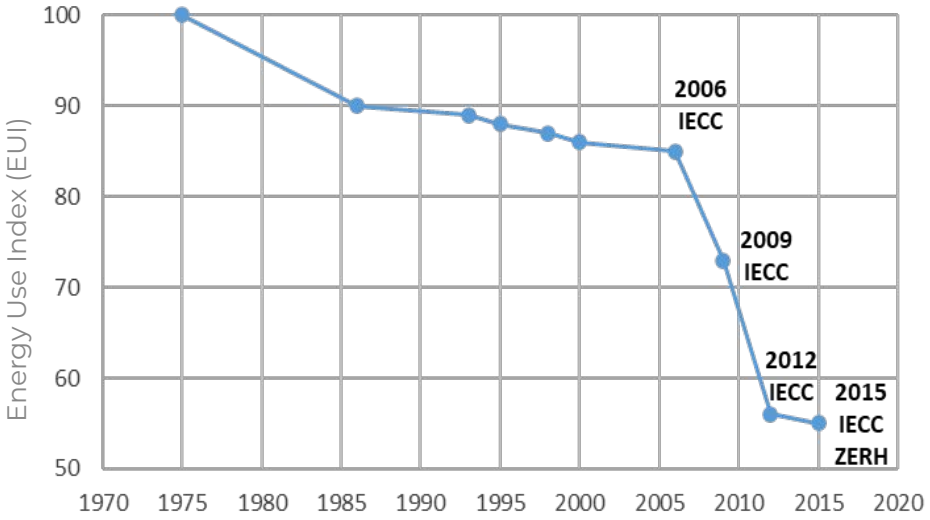
Planning the pathway

Embodied Carbon Reductions



We've seen this curve before!

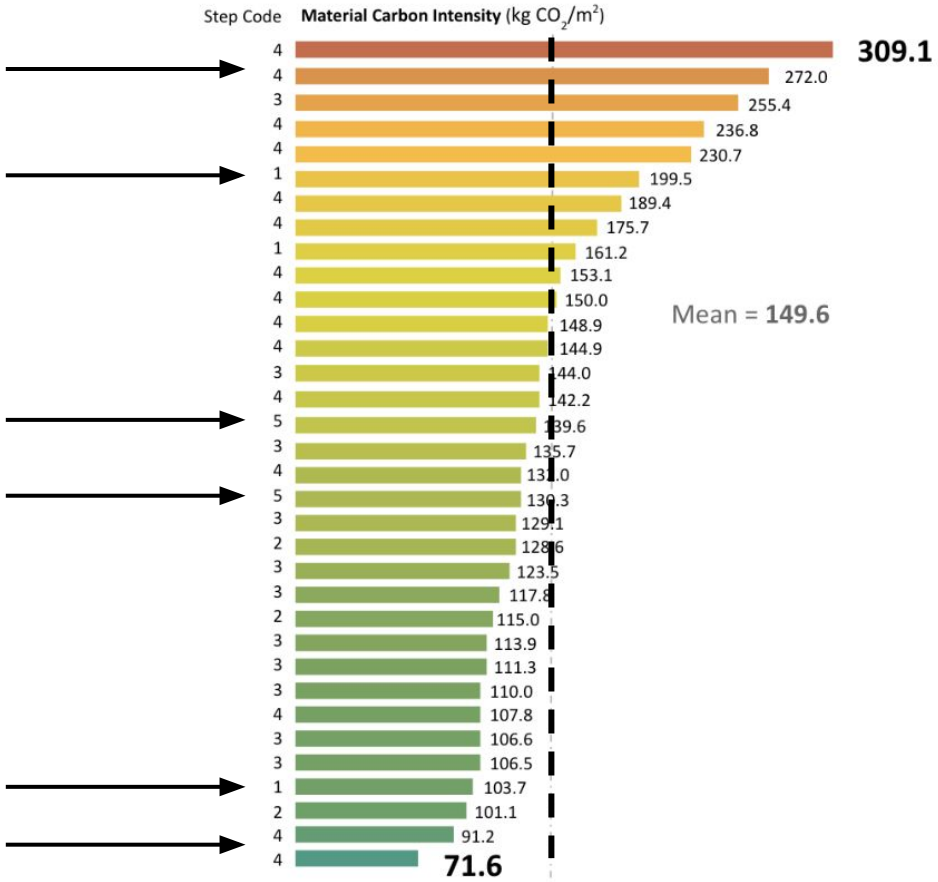
Residential Code Improvement



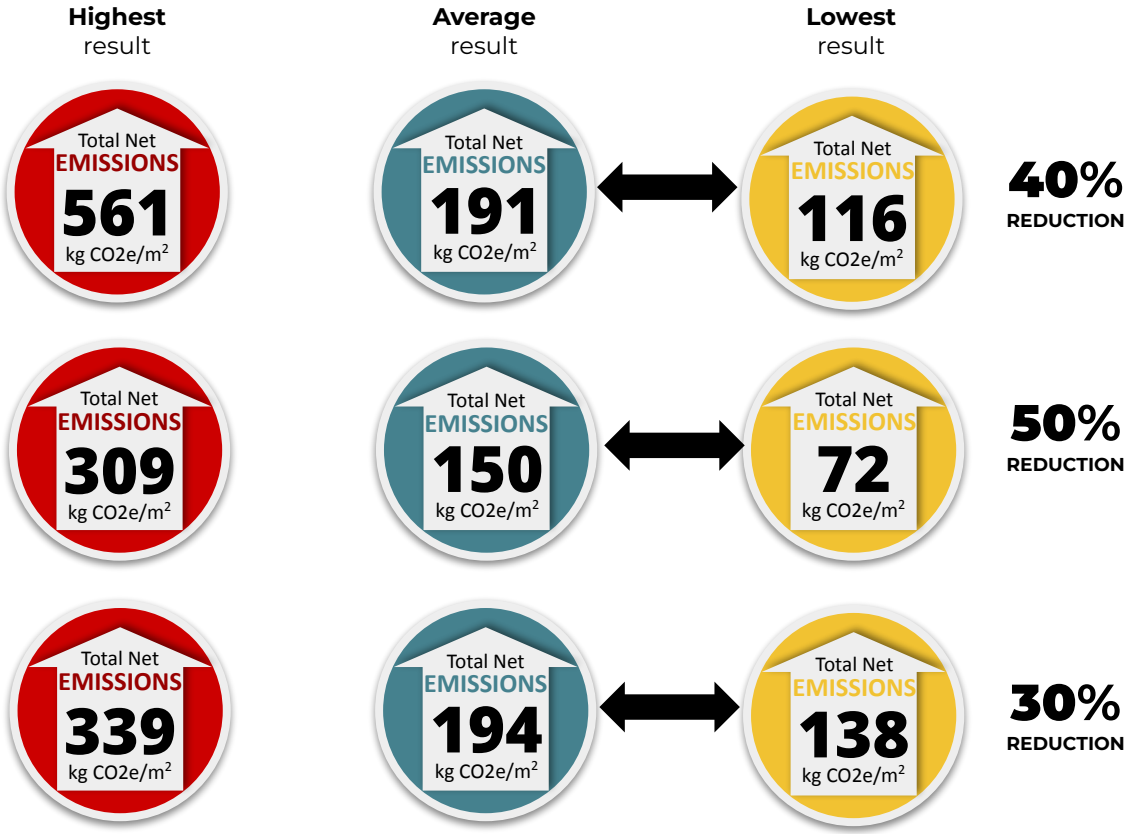
What about operating emissions?

"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



BfCA Study Results*



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

Material substitutions - High MCI

Single detached 4 bedroom house

44% reduction

96% reduction

As-Built Materials		Best Available Materials Subsitutions		Best Possible Materials Subsitutions	
Cavity insulation : Fiberglass	2 137	**Cavity insulation :** Cellulose	-3 670	**Cavity insulation :** Straw	-13 484
Continuous insulation : Mineral wool board	6 811	**Continuous insulation :** Wood fiberboard	-11 192	**Continuous insulation :** Wood fiberboard	-26 622
Cladding: Wood cladding	994	**Cladding:** Wood cladding	831	**Cladding:** Bamboo cladding	-2 312
Drywall	3 485	Drywall lowest option	2 188	Lime cork plaster	-3 523
Hardwood flooring	1 614	Bamboo flooring	-1 013	Bamboo flooring	-1 013
Below grade insulation: mineral wool board, VIP, XPS	5 662	**Below grade insul.:** lowest mineral wool board, VIP, XPS	5 103	**Below grade insulation:** Cork board	-8 397
Average Concrete	54 492	Average BC Concrete (from EC3 database)	32 825	Lowest BC Concrete (from EC3 database)	18 872
Sub slab insulation: Mineral wool board	16 309	**Sub slab insulation:** Lowest Mineral wool board	9 108	**Sub slab insulation:** Foam glass aggregate	1 393
MCE : 140 139 kg CO2e / MCI : **227 kg CO2e/m²**		MCE : 78 492 kg CO2e / MCI : **127 kg CO2e/m²**		MCE : 5 367 kg CO2e / MCI : **9 kg CO2e/m²**	

Material substitutions - LOW MCI

Laneway house 1 bedroom

68% reduction

130% reduction

As-Built Materials		Best Available Materials Subsitutions		Best Possible Materials Subsitutions	
Cavity insulation: Fiberglass	597	**Cavity insulation:** Cellulose	-1 777	**Cavity insulation:** Straw	-4 655
Cladding: Cedar siding	203	**Cladding:** Bamboo cladding	-789	**Cladding:** Bamboo cladding	-789
Drywall	835	Drywall lowest option	509	Lime cork plaster	-701
Hardwood flooring	364	Bamboo flooring	-186	Bamboo flooring	-186
Below grade insulation: XPS foam	363	**Below grade insulation:** lowest XPS	71	**Below grade insulation:** Cork board	-253
Average Concrete	3 695	Average BC Concrete (from EC3 database)	2 217	Lowest BC Concrete (from EC3 database)	875
Sub slab insulation: EPS foam board	434	**Sub slab insulation:** EPS foam w/ graphite	311	**Sub slab insulation:** Foam glass aggregate	56
MCE : 10 466 kg CO2e	MCI : **138 kg CO2e/m²**	MCE : 3 329 kg CO2e	MCI : **44 kg CO2e/m²**	MCE : -3 212 kg CO2e	MCI : **-42 kg CO2e/m²**

Embodied carbon study

DOUG TARRY HOMES

Rosewood ‘A’ Model					
EC Model	AS-BUILT	AS-BUILT, revised insulation	NEAR TERM 1:1 SUBSTITUTIONS	MEDIUM-TERM 2-5 YEARS	FUTURE SCENARIO 5-10 YEARS
Total kg CO2e	**66,087**	**52,087**	**22,854**	**11,309**	**183**
Percent reduction		**21%**	**65%**	**83%**	**99.7%**

Footings & Slab - Doug Tarry Homes, Rosewood A Model

CATEGORY	MATERIAL	NET CARBON FOOTPRINT [kg CO2e]				
FOOTINGS & PADS	Concrete - 0-25 MPa, Canadian Benchmark Average	1,572	1,572			
	Concrete - 0-25 MPa, 35-50% Slag, GU / CRMCA			1,234	1,234	1,234
REBAR FOR FOOTINGS	Rebar / Concrete Reinforcing Steel Institute / / 15M	228	228	228	228	228
REINFORCING MESH	Welded wire mesh	250	250	250		
CONCRETE SLAB FLOOR(S)	Concrete - 0-25 MPa, Canadian Benchmark Average	4,238	4,238			
	Concrete - 0-25 MPa, 35-50% Slag, GU / CRMCA			3,326		
OTHER SLAB FLOOR(S)	Plywood / 3/4" - "Slabless slab"				1,275	
	Cob Floor / Site made 4"					53
SUB-SLAB INSULATION	Spray polyurethane foam - Closed Cell (HFC)	3,536				
	Spray polyurethane foam - Closed Cell (HFO)		**1,118**			
	EPS foam board with graphite / BASF / Neopor /Type IX			919		
	Foam glass aggregate / Misapor / Glavel				616	616
BASEMENT FLOORING	Vinyl flooring - AVERAGE	89	89			
	Carpet / / / Average from 150 samples in EC3	1,894	1,894			
	Linoleum flooring - AVERAGE 2.5 mm			8	8	
	Cork flooring			**-390**	**-390**	

Foundation Walls - Doug Tarry Homes, Rosewood A Model

Element	Product	As-built	As-built (best insulation)	1:1 substitutions	Near-term substitutions	5-10 year substitutions
Concrete walls	Concrete: Canadian avg. mix	**8,826**	**8,826**			
	Concrete: 35-50% slag mix			**6,927**		
Rebar	Avg. rebar					
ICF - Wood/cement	14” with cork inserts				**-497**	**-248**
	Concrete: 35-50% slag mix				**3,114**	**1,551**
Continuous insulation	XPS foam board: average	**9,846**				
	XPS foam board: DuPont reduced GWP		**6,412**			
	XPS foam board: Sopra			**338**		
Interior framing	SPF 2x6 avg.	**258**	**258**	**258**		
Cavity insulation	Rockwool R22	**607**	**607**			
	Cellulose batt R20			**-953**		
Interior wall cladding	Drywall ½” avg.	**324**	**324**	**324**	**324**	
	TOTAL kg CO2e	**19,861**	**16,427**	**6,894**	**2,941**	**1,303**

Exterior Walls - Doug Tarry Homes, Rosewood A Model

Element	Product	As-built	As-built (best insulation)	1:1 substitutions	Near-term substitutions	5-10 year substitutions
Wood framing	SPF 2x6 @ 16” OC	206	206	206		
Structural sheathing	OSB, ZIP system 7/16”	425	425	425		
Prefab panel	Complete system				-1,602	-3,069
Cavity insulation	Fiberglass batt, R20, average	305	305			
	Cellulose batt, R20			-925	-601	
Continuous insulation	XPS foam, average	9,557				
	XPS foam, DuPont low GWP		6,224			
	XPS foam, Sopra			328		
Shared garage wall	SPF 2x6 @ 16” OC	44	44	44		
Exterior cladding	Brick, clay, average	4161	4161			
	Stone, Arriscraft	211	211			
	Fiber cement, average	107	107	107	107	107
	Vinyl siding, average	40	40	40	40	40
	Engineered wood, Smartside			257	257	586
Interior cladding	Drywall, ½”, average	314	314	314	314	602
	TOTAL kg CO2e	**15,370**	**12,037**	**796**	**-1,485**	**-2,887**

Trent University
Forensic Crime Scene Building

Key carbon-storing materials:

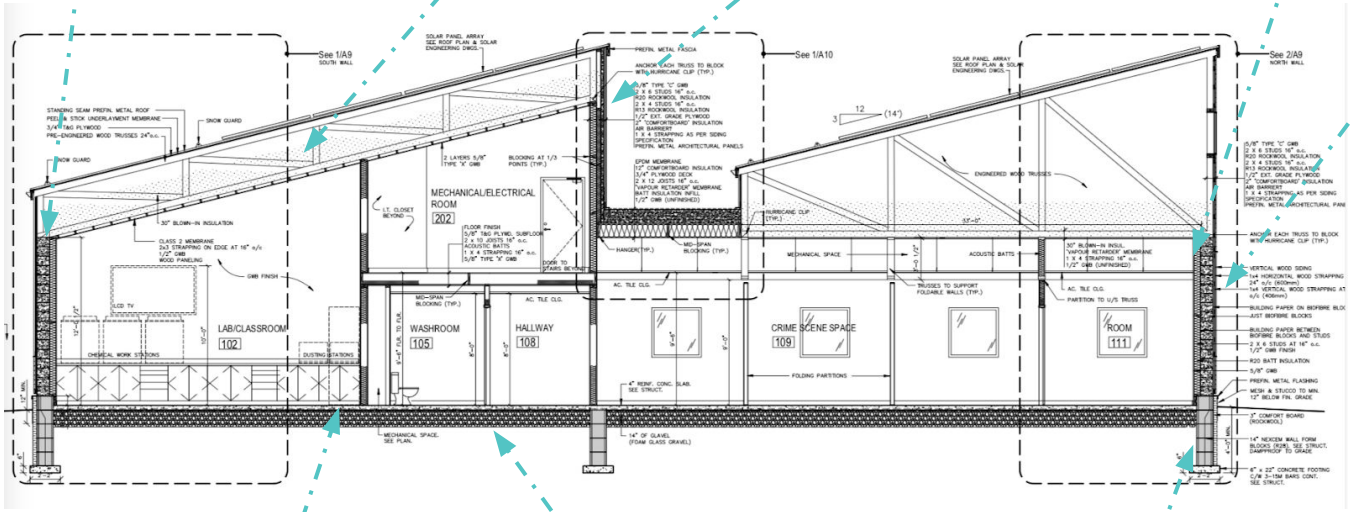
Hempcrete block walls

Cellulose insulation

Wood fiber board insulation

Hemp batt insulation

Charred wood siding



Key low-carbon materials:

Low-carbon concrete (50% SCM content)

Foam glass gravel for sub-slab insulation

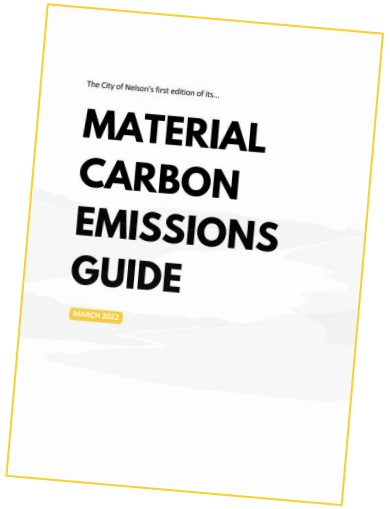
Wood-chip ICF foundation

Trent University Forensic Building Material Carbon Emissions (MCE)

Building Element	Base Case kg CO2e	Material change	As-Built kg CO2e	As-Built, incl. timber storage
Footings & Slabs	29,516	Low carbon concrete & foam glass gravel	13,503	13,503
Foundation walls	13,108	Wood chip ICF & low carbon concrete	9,866	1,128
Exterior walls	123,900	Hemp block with hemp batt	-6,967	-18,043
Exterior cladding	11,327	Charred wood	6,263	2,861
Windows & doors	3,378		3,378	3,378
Interior walls	6,968	Hemp batt insulation	-4,900	-3,580
Floors	858	Linoleum flooring	-15	-679
Ceilings	963	Best in category drywall	227	227
Roof system	21,138	Wood trusses & cellulose insulation	4,130	-5,624
NET TOTAL	**211,156**		**25,484**	**-6,829**
MCE Reduction			**88%**	**103%**
Net Carbon Intensity, kg CO2e/m²	**498**		**60**	**-16.1**

As-Built Materials	Best Conventional Material Substitution	Best Possible Material Substitution
Average concrete	High SCM concrete	High SCM concrete
EPS sub slab insulation	-	Foam glass gravel
EPS ICF	Wood chip ICF	Treated wood foundation
Mineral wool cavity insulation	Cellulose	Straw bale
Continuous insulation	Wood fiberboard	-
Hardwood floors	½ linoleum flooring	Linoleum & cork flooring
Mineral wool roof insulation	Cellulose	Cellulose
309.1 kg CO2e/m2	**151.3** kg CO2e/m2	**55 kg** CO2e/m2

Table 1. *This table demonstrates the impact that material selection can have on overall material carbon emissions.*



200 m² basement floor

- With 4-inch slab: **6,520** kg CO2e
- With 2x4 sleepers & two layers of ⅝-inch plywood: **1,500** kg CO2e

77% reduction!

HOUSES BY DESIGN

Building a Concrete-Free “Slab”-on-Grade Foundation

Northern Minnesota designer Randy Williams omitted the concrete under the floors in this new house—a growing trend among builders of energy-efficient homes.

By **Kiley Jacques**

200 m² main floor

- With 4-inch slab: **4,235** kg CO2e
- With 2x4 sleepers & ¾-inch bamboo: **-850** kg CO2e

165% reduction!

200 m^2 basement floor

- With 4-inch slab: **6,520** kg CO2e
- With 2x4 sleepers & two layers of ⅝-inch plywood: **1,725** kg CO2e

74% reduction!

200 m^2 main floor

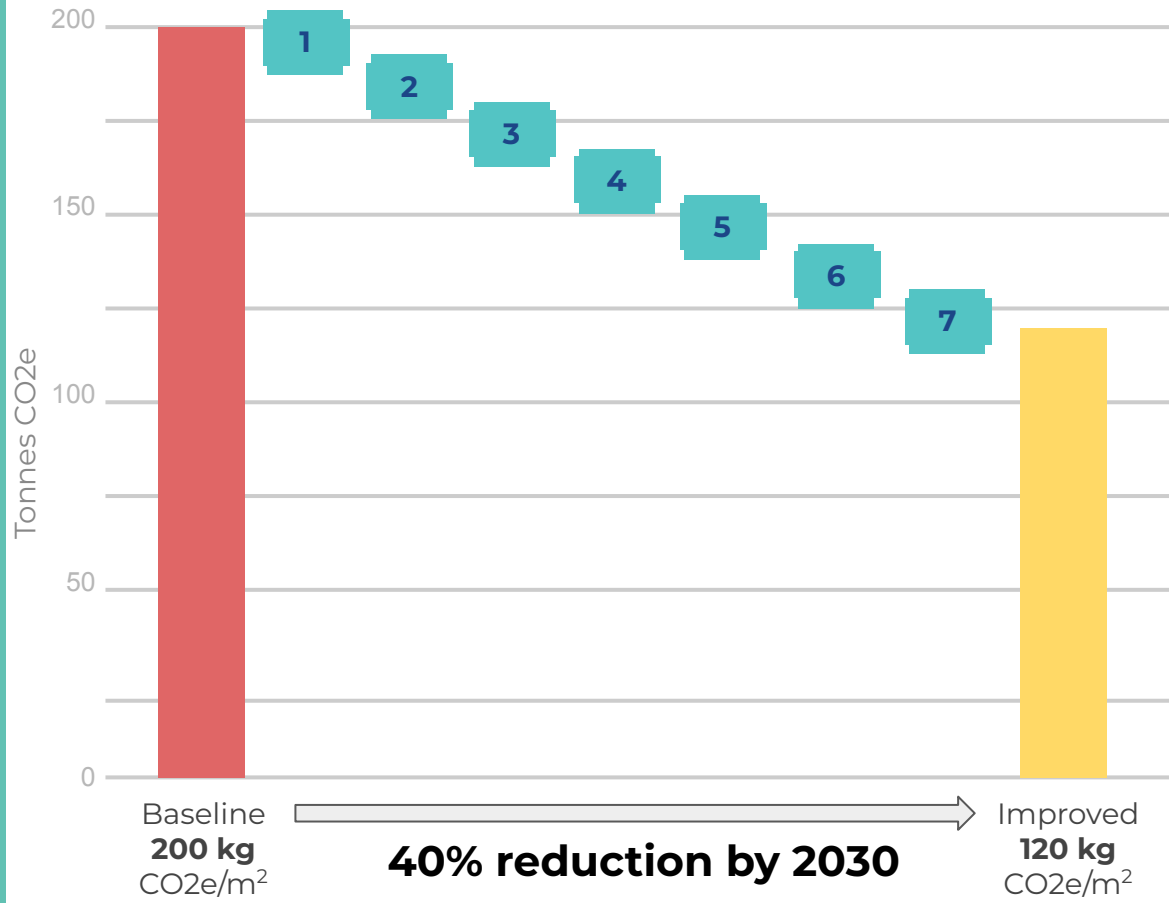
- With 4-inch slab: **6,520** kg CO2e
- With clay floor: **-130** kg CO2e

98% reduction!

Or, be more ambitious:

Projects near and below net zero embodied carbon

5% per year reductions



Year 1: **Concrete** mix improvement

Year 2: One **insulation** best available

Year 3: **Drywall** best available

Year 4: One **insulation** best available

Year 5: **Cladding** to best available

Year 6: Change **flooring** to best available

Year 7: Change one **insulation** type

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…

1. Ecosystems impacts

2. Embodied carbon

3. Energy efficiency

4. Indoor environment quality

5. Waste

6. Resilience*

7. Occupant Input and Durability*

8. Building code compliance*

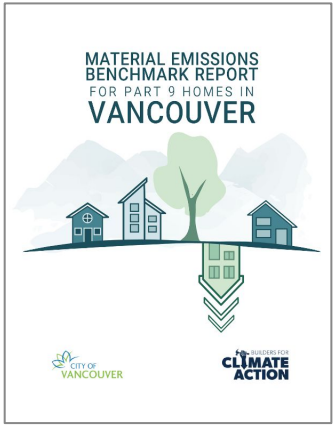
9. Material costs*

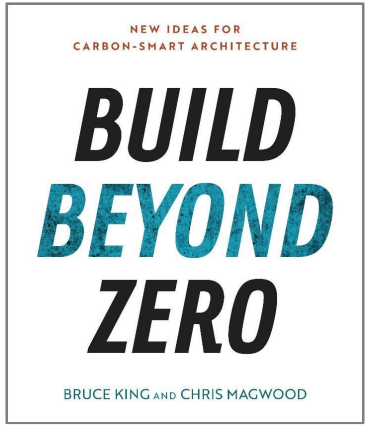
10. Labor costs and sources of labor*

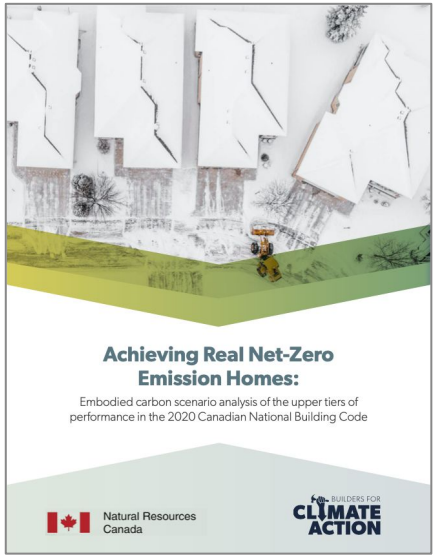
More information:

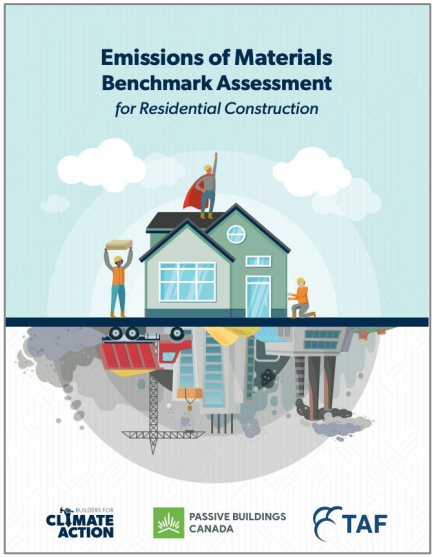
www.buildersforclimateaction.org

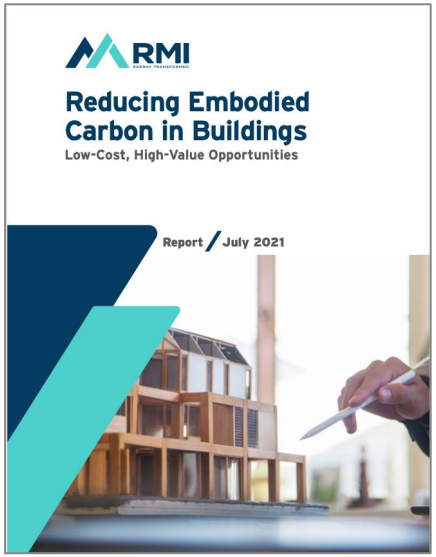
www.rmi.org

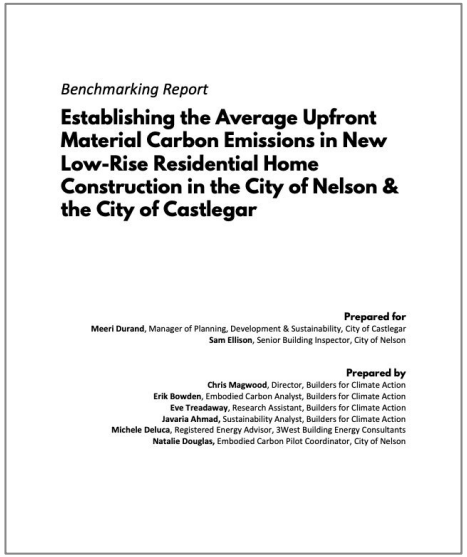












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