BUILDING SCIENCE LIVE

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Considering Carbon in the Design of Building Enclosures

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2

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- Please use chat for housekeeping questions.
- Please use Q&A box for questions for the speaker.
  - We will break at the end for questions.
  - Use upvote feature to let us know what you're most curious about!

More questions? Please contact us at **events@learnbuildingscience.com**

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3

Graham Finch

Principal, Senior Building Science Specialist

Graham works across a wide spectrum of RDH's disciplines and is directly involved with new buildings projects, existing buildings investigation work, research and product development related to building materials and building enclosures across the world.

He regularly works with industry organizations, building product manufacturers and other clients on product research and development, performance monitoring, forensic investigations, and field testing. He also works closely with architects, developers and manufacturers to support the design of high-performance building enclosures and façade systems.

He is a leader in knowledge sharing and is regularly invited to present at conferences and speaking opportunities around North America on a range of building science topics. He also contributes to the education of the industry through the development and delivery of best practice guidelines and bulletins.

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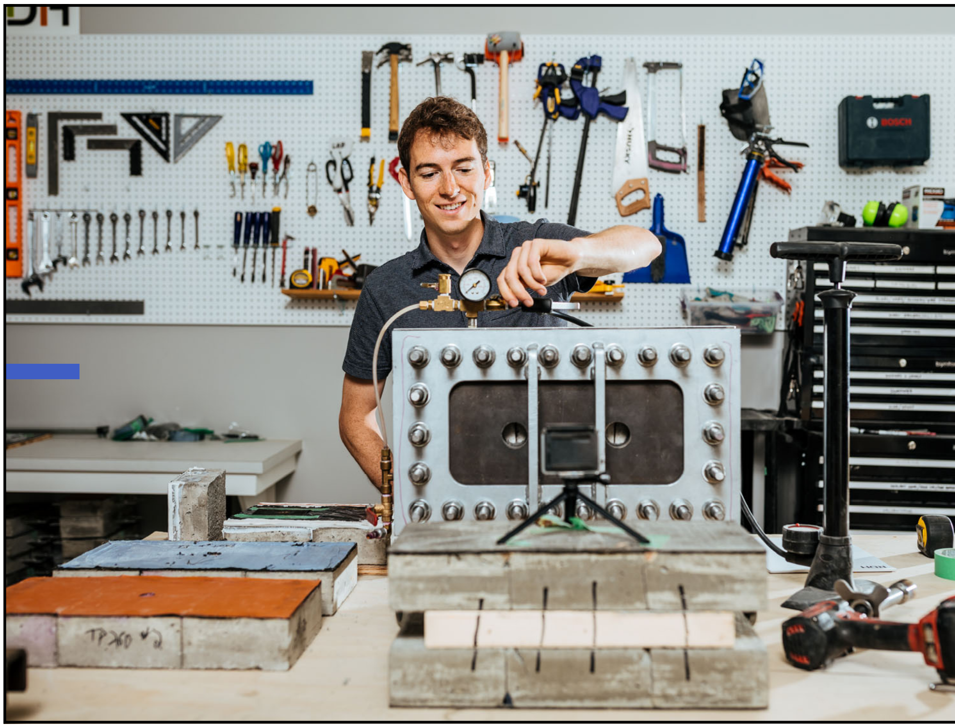
4

5



270+ staff

9 offices

Projects across North America

Focus on building science
& building enclosures

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Education for Professionals

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7

Agenda

- →Introduction to High Performance Enclosures & How to Properly Account for Carbon
- →Case Study House Example: How to Understand & Consider Informed Carbon Reductions by Design and Operations
- →Evolving Standard Enclosure Designs to Evaluate Embodied Carbon – Below to Above Grade Assemblies
- →Pitfalls and Challenges – Making Informed Decisions

8

The Building Enclosure…

- →Separates indoors from outdoors by controlling:
  - → Water penetration
  - → Condensation
  - → Air flow
  - → Vapor diffusion (wetting & drying)
  - → Heat flow
  - → Light and solar radiation
  - → Noise, fire, and smoke
- →While at the same time:
  - → Transferring structural loads
  - → Being durable and maintainable
  - → Being economical & constructible
  - → Looking good!

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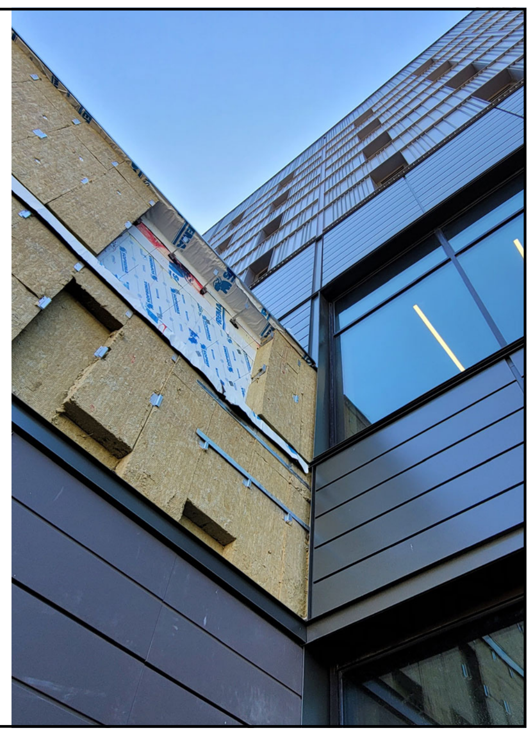

9

A Brief History of Building Enclosure Control

→**Older Buildings:**
One layer does (controls) everything

→**Newer Buildings:**
Control by separate layers & separate functions

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What is a High-Performance Enclosure?

- →High levels of control (heat, air, rain)
- →**But** poor continuity limits performance
- →**And** poor continuity causes most problems:
  - →Air leakage condensation
  - →Rainwater leakage
  - →Surface condensation
  - →Fungal growth
  - →Cold windows
  - →Drafts and discomfort
- →Thus: ***continuity + high levels of control***

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What about Sustainability and Low-Carbon?

→High performance buildings are typically sustainable and use less energy however *may or may not* have by default low-carbon emissions

→Carbon Emissions consist of:
- →**Operating** energy and carbon emissions (energy efficiency and fuel type dependent)
- →**Embodied** Carbon within the materials used to construct the building

→High performance buildings with uniformed material choices or that use high carbon intensity energy sources are *not sustainable*

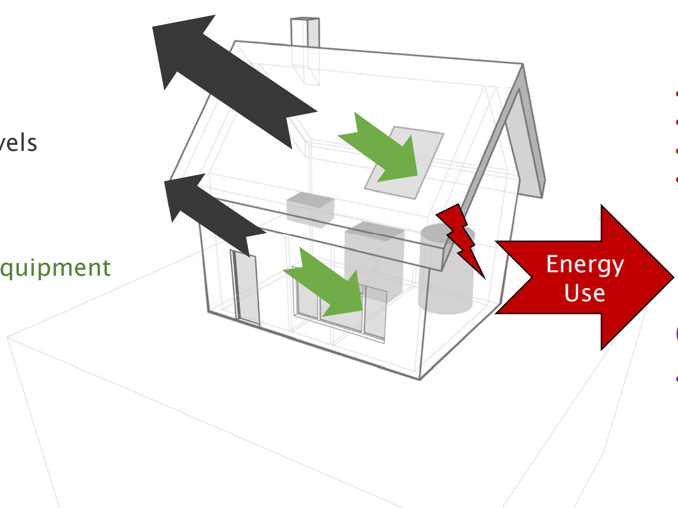
→Sustainable buildings are designed with both embodied and operating carbon decisions in mind

12

A Brief History of Considering Carbon in Operations

Losses
- Air tightness
- Insulation levels

Gains
- Solar gain
- People and equipment



Energy Use
- Heating/cooling
- Water heating
- Ventilation
- Lights and plug loads

Operating Carbon
- Energy use by fuel type X industry carbon factors

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A Brief History of Considering Carbon in Materials

→Simple-ish

→Much more Complex

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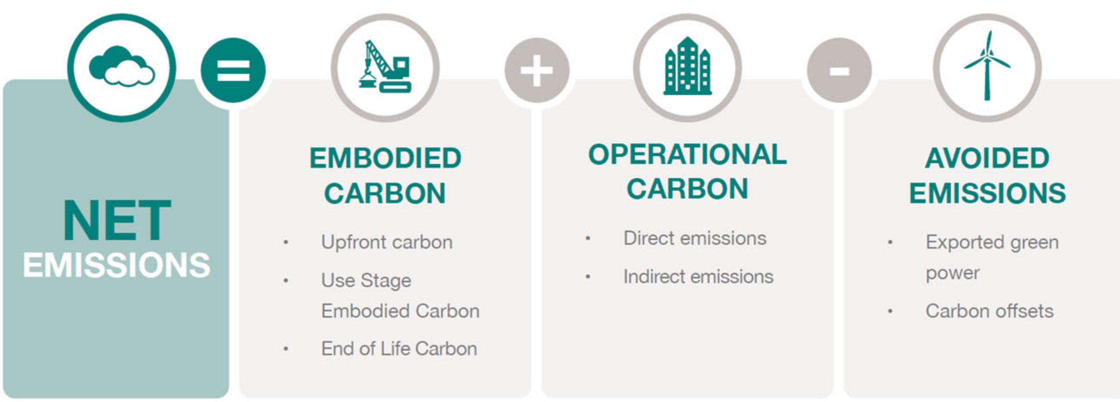
14

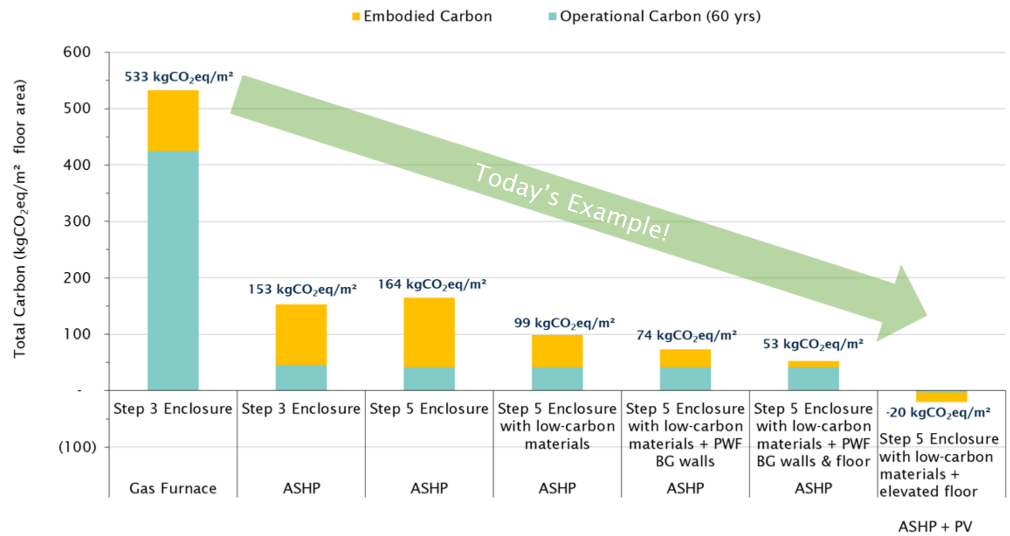
Goal for Low Net Carbon Emissions Buildings



Source: Canadian Green Building Council (CaGBC) Zero Carbon Building Standard V2

15

Possibility of Net Zero Carbon Buildings by Informed Design



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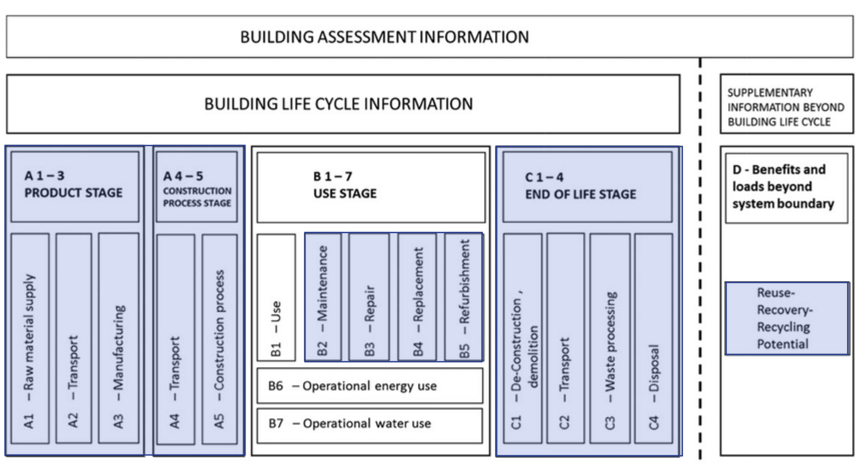
16

Life Cycle Analysis (LCA) Modules

Where does Embodied Carbon occur?



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17

17

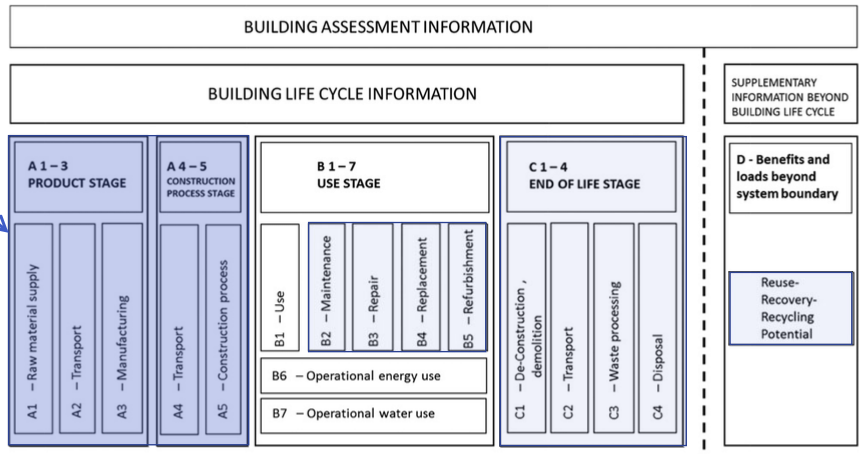
Life Cycle Analysis (LCA) Modules

Where does Embodied Carbon occur?

Most emissions occur during A1-A5

A1-A3, cradle to gate

A1-C4 cradle to grave



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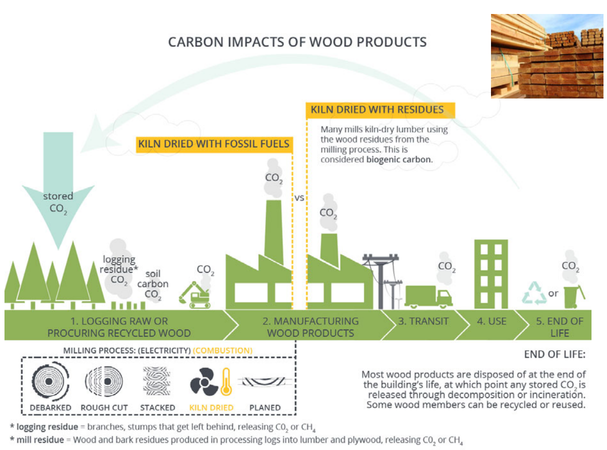
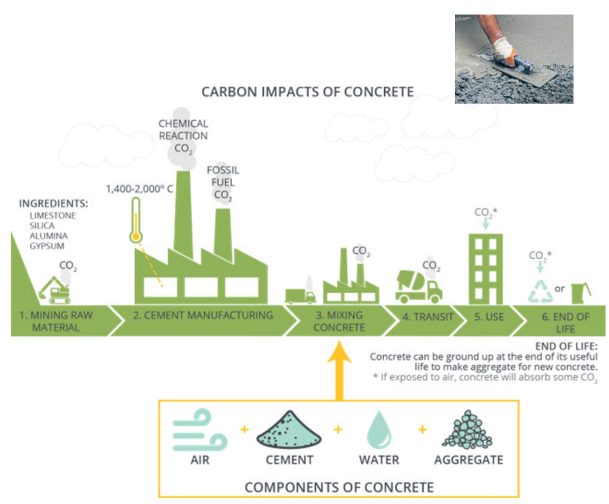
18

Where do Carbon Emissions for Materials Come From?

(e.g. Wood & Concrete)





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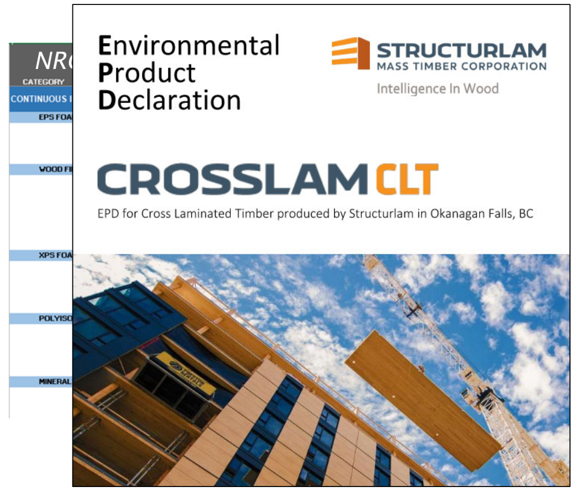
19

Where does Embodied Carbon data come from?

- Generic & Proprietary Material Databases
  - Inventory of Carbon and Energy (ICE) Database
  - Programs like Athena, BEAM Estimator etc.
  - Spreadsheets like Material Carbon Emissions Calculator MCE2 (NRCan), In-house collections etc.
- Environmental Product Declarations (EPDs)
  - Industry-wide coverage using averaged data
  - Manufacturer-specific for a given product
  - Always use the latest data and information – constantly evolving industry
- All require expertise in review to evaluate and select the most appropriate data



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20

20

So… What Makes a High-Performance & Low-Carbon Building Enclosure?

- **Low Operating Carbon** in space conditioning energy requirements
  - **Very airtight** *(air barrier continuity)*
  - Encompassing **Highly insulated enclosure** with minimal thermal bridges *(thermal continuity)*
  - Careful selection & installation of **high-performance windows & doors**
  - Well detailed and **Redundant Reliable Water Control** *(water control continuity & material durability)*
- **Low Embodied Carbon** in Material Selection of the above materials and more

23

What is Going to Change with Enclosure Designs?

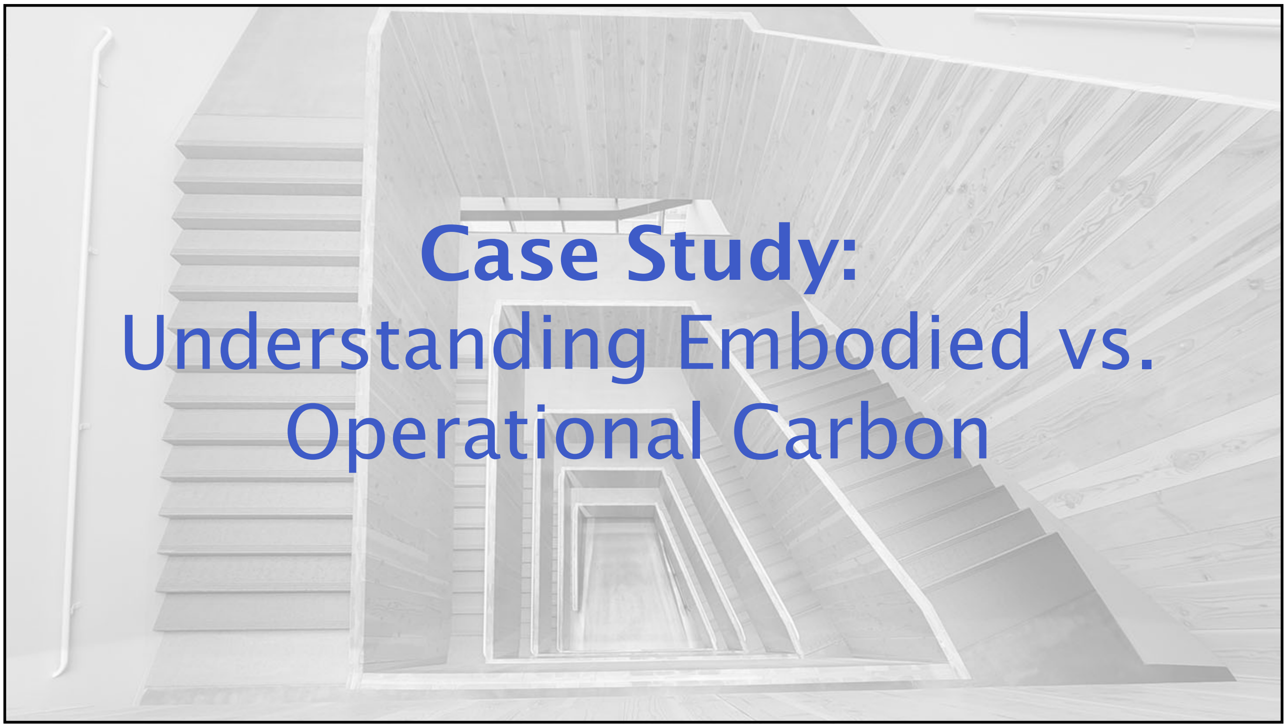
- Already seeing a more critical review of all enclosure materials with carbon in mind
  - Consider source material & embodied carbon
  - Shift towards more locally available products with less transportation emissions (though always evaluate in context!)
  - Use of more biogenic (carbon sequestering) natural materials
  - Need to be more careful with biogenic materials & moisture = more thinking!
- Use of lower carbon energy sources, de-carbonization of the grid
- Energy optimal design not always lowest total carbon over life of building
- Life cycle assessments

24

More Information = More Informed & Better Decisions

- ★★★★★ Cost Efficiency / Affordability
- ★★★★★ Constructability & Detailing
- ★★★★★ Performance (R-value/Airtightness)
- ★★★★★ Moisture Durability & Resilience
- ★★★★★ Embodied Carbon in Materials & Sustainability

25



26

Case Study House Example

- Archetypical 2600 sq.ft, 2-story single family home in Kelowna, BC (Climate Zone 5) with 2 car garage and below-grade basement
- Targeting Step 3 (of 5) of BC Energy Step Code *(becomes code minimum in 2023)*
- Building enclosure prescriptively following BCBC 9.36 minimum thermal performance, + assumed 2.5 ACH50 airtightness
- High efficiency natural gas furnace for space heating w/ AC through furnace ductwork for cooling (base case) + later evaluate heat pump
- Electric hot water tank
- Heat recovery ventilation (HRV)
- Carbon Data from: Athena, NRCan MCE2, EPDs

27

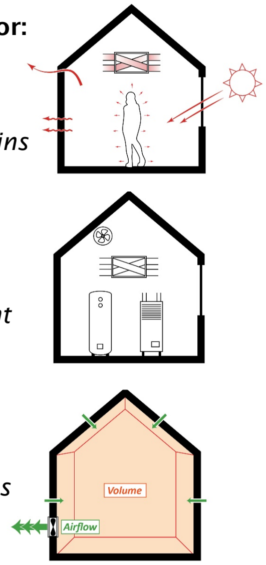
What is the British Columbia (BC) Energy Step Code ?

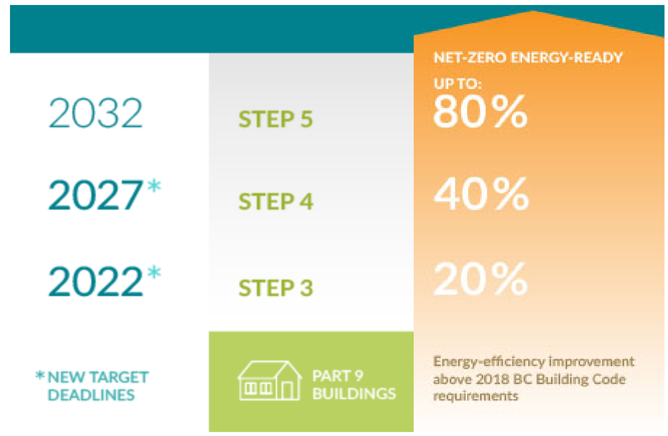
Energy Performance Code with Targets for:

Thermal Energy Use (Enclosure Losses/Gains and Ventilation

Mechanical Equipment System Use, and

Enclosure Airtightness



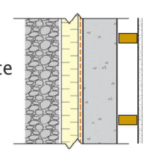


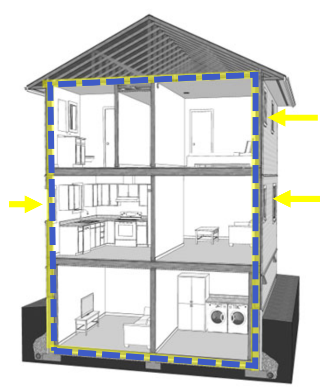
Part 9 – small buildings/homes. 9.36 enclosure = minimum prescriptive requirements for thermal performance

28

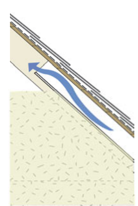
Baseline Building Enclosure Design

Below Grade Wall ***(R-20)***
- Exterior/Gravel fill
- 5" EPS Insulation
- Waterproofing
- 8" reinforced concrete
- 2x4 wood framing
- Gypsum board

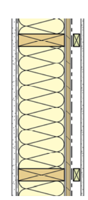




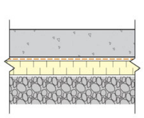
Sloped Roof (R-39 eff.)
- Asphalt shingles
- Roofing underlayment
- Plywood sheathing
- Wood trusses
- 15" blown fiberglass insulation
- Polyethylene AB/VB
- Gypsum board



Windows ***(U-0.27)***
- Double glazing, low-e, argon fill
- Fiberglass frames



Above Grade Wall (R-17 eff.)
- Vinyl siding
- Rainscreen strapping
- House-wrap
- Plywood sheathing
- 2x6 wood framing
- Mineral wool batt
- Polyethylene AB/VB
- Gypsum board



Floor Slab ***(R-10)***
- Floor finish
- 6" concrete slab
- Polyethylene AB/VB
- 2.5" EPS insulation
- Compacted gravel fill

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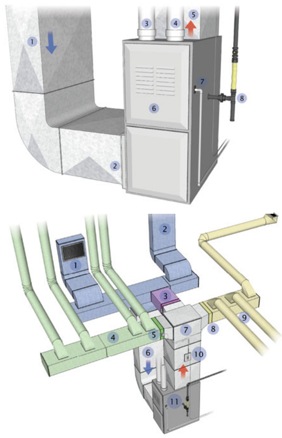
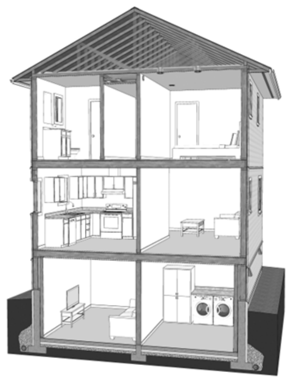
Airtightness = 2.5 ACH @ 50 Pa

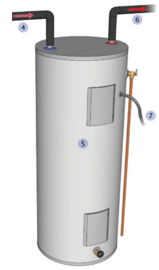
29

Baseline Mechanical System Design

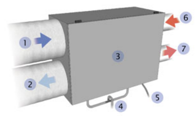
Natural Gas Furnace (90% AFUE) w/ Forced Air Distribution & AC heat pump unit for cooling only



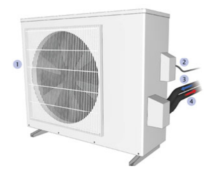




Electric Hot Water Tank



Heat Recovery Ventilator (HRV), 70% efficiency ducted into furnace



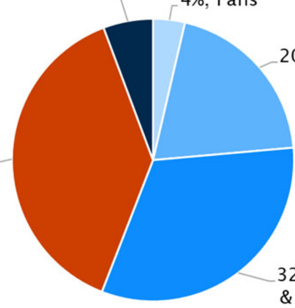
Heat Pump for Combined Heating & Cooling as Option

30

Energy Use and Carbon in Operations: Case Study House w/ Gas Heating

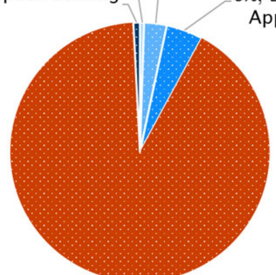
Annual Energy Consumption

Total Energy per Floor Area = **91** kWh/m²/yr



Annual Operational Carbon

Operative Emissions per Floor Area = **7.1** $kgCO_2eq/m^2/yr$



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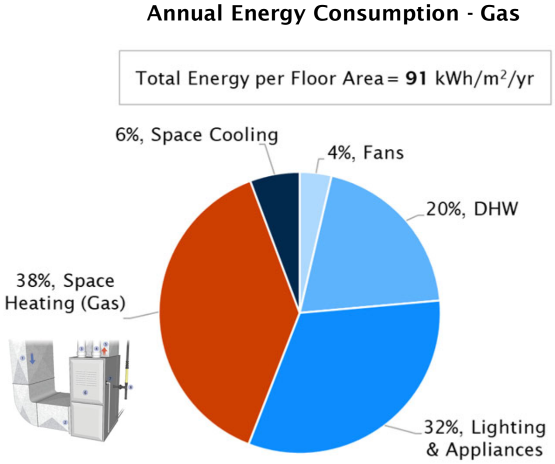
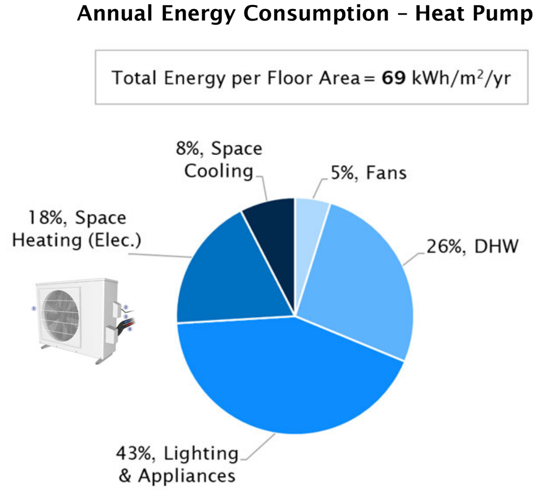
Equivalent kWh includes gas & electricity combined

31

Energy Use and Carbon in Operations: Case Study House w/ Heat Pump/Electric Heat





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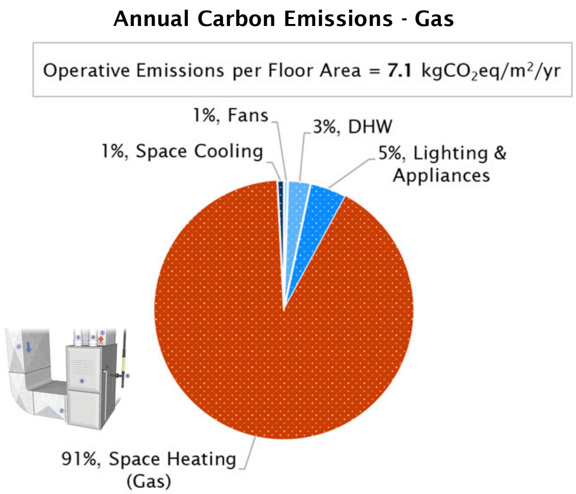
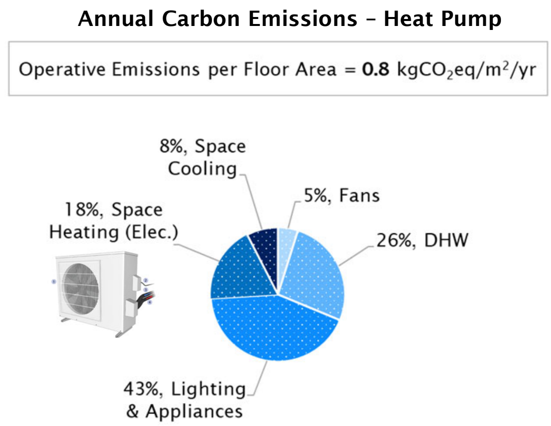
32

Energy Use and Carbon in Operations: Case Study House w/ Heat Pump/Electric Heat





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33

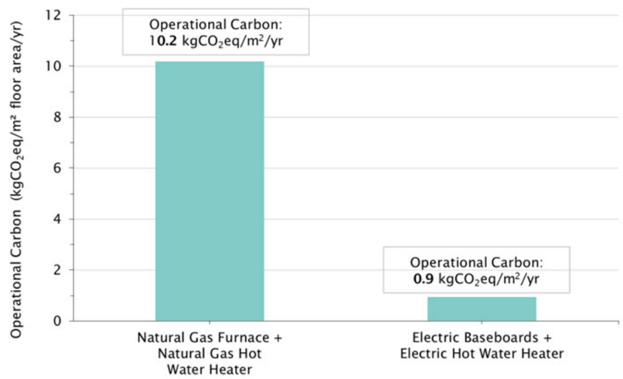
Why Does Fuel Type Matter So Much for Operational Carbon in Example?

Natural gas emits 17 times more CO_2eq than electricity in BC (Hydro dominated grid) for the same amount of energy.

Table 1.2 Emissions Factors by Fuel Type

Fuel Type	Emissions Factor ($kgCO_{2e}/kWh$)
Natural Gas	0.185
Electricity	0.011

Source: City of Vancouver Energy Modelling Guidelines v.2



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34

Consider Carbon Emissions by Fuel Type *(Easy)* & Electrical Grid *(Complicated & Changing)*

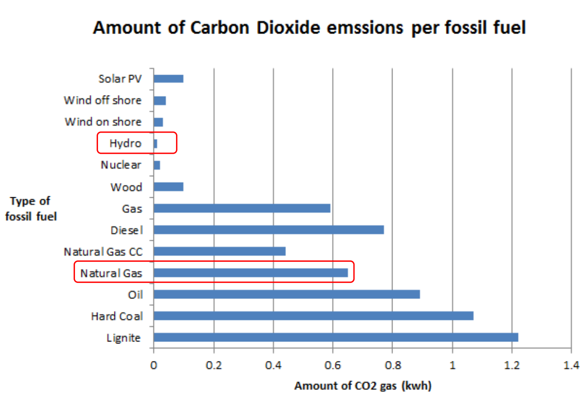

Image from wikiversity – based on data from https://www.sciencedirect.com/science/article/abs/pii/S0301421509005436

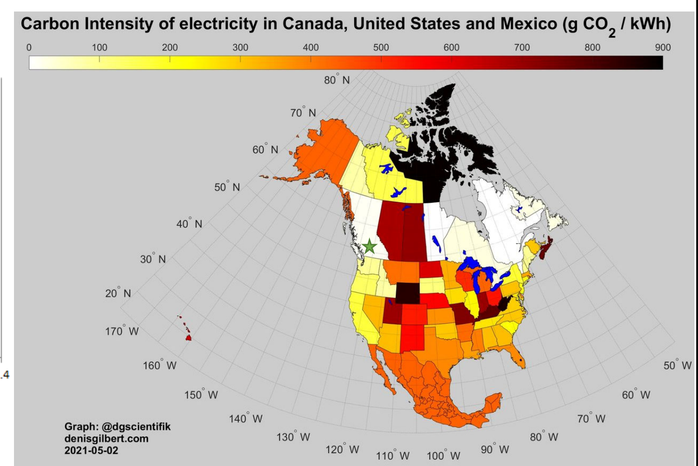

Image from: https://denisgilbert.com/blog/f/carbon-intensity-of-electricity-in-canada-mexico-usa

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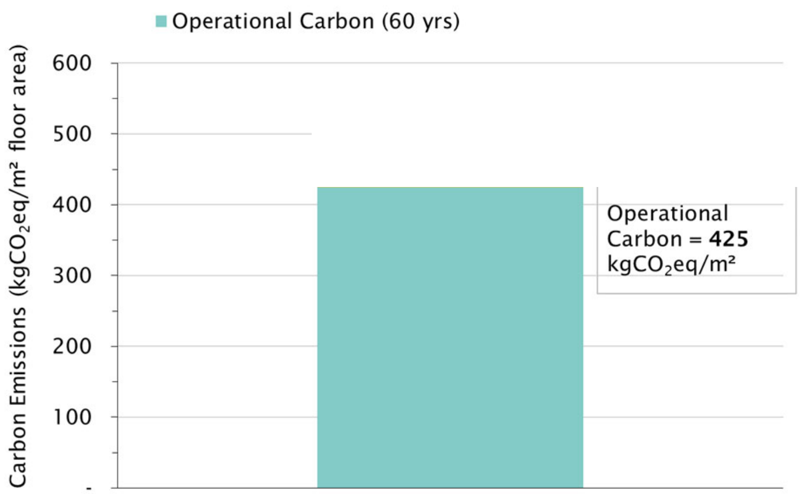
Case Study House: Carbon = Embodied + Operational

(Gas Furnace & Minimum 9.36 enclosure)



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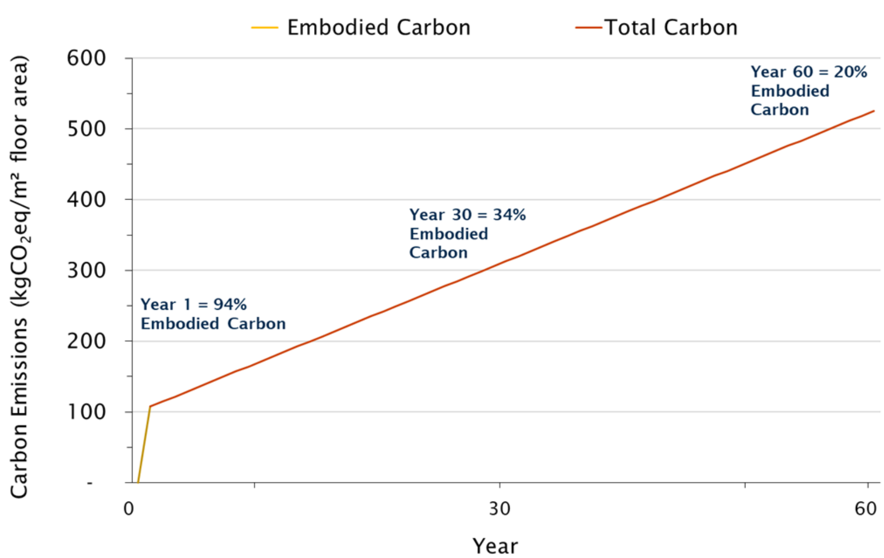
36

Carbon Emissions Life Cycle

(Gas Furnace & Minimum 9.36 enclosure)



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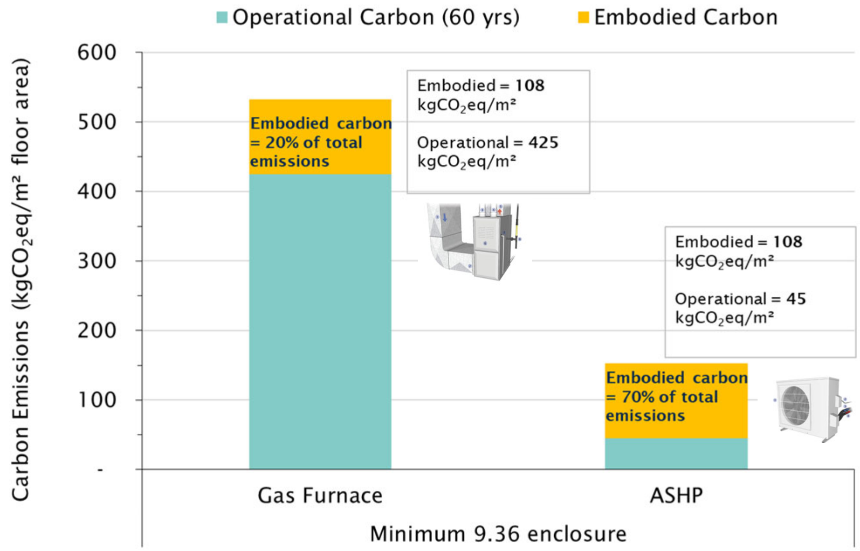
37

Electrification = Increased Focus on Embodied Carbon in Materials



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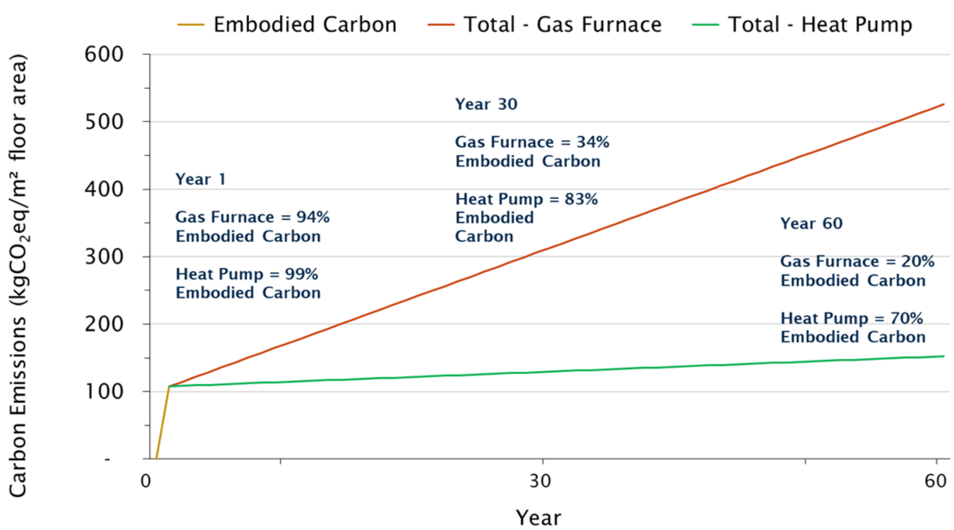
38

Electrification = Increased Focus on Embodied Carbon in Materials



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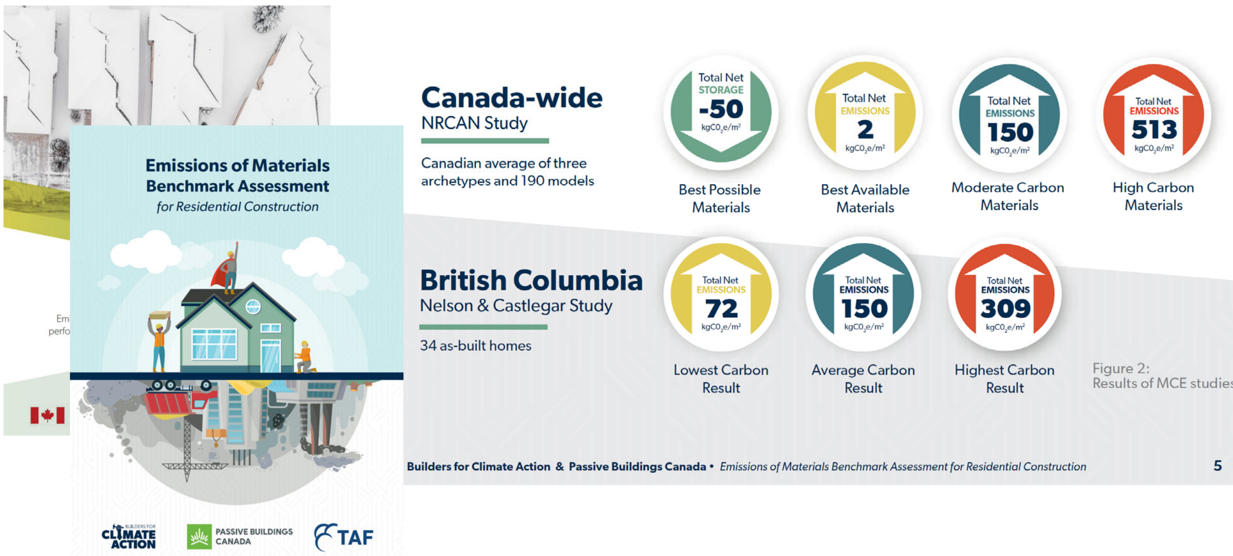
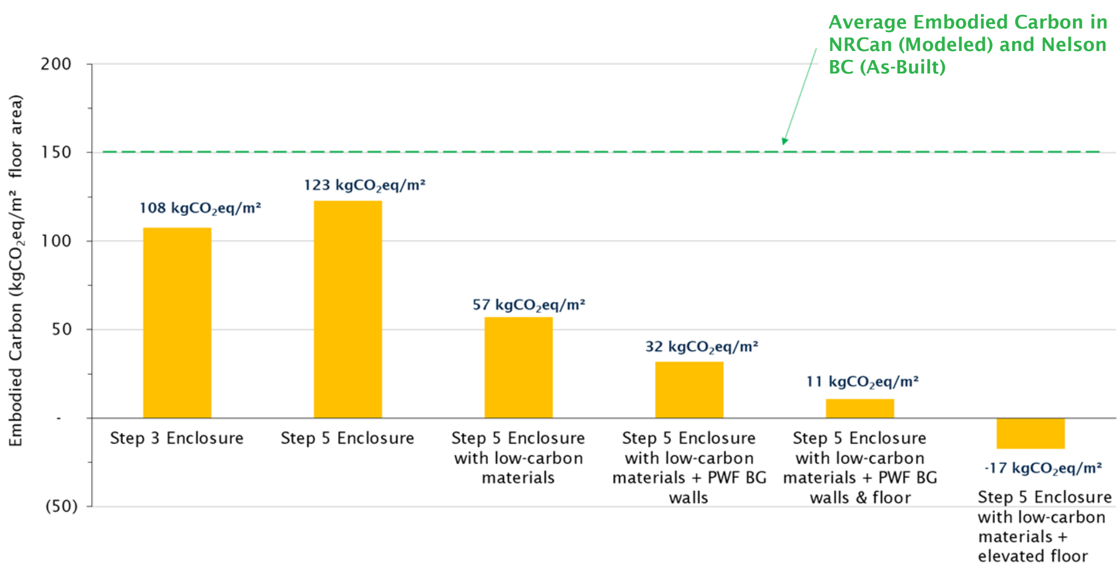
39

What to Compare Embodied Carbon Numbers To?



40

Case Study House Compared to Others?



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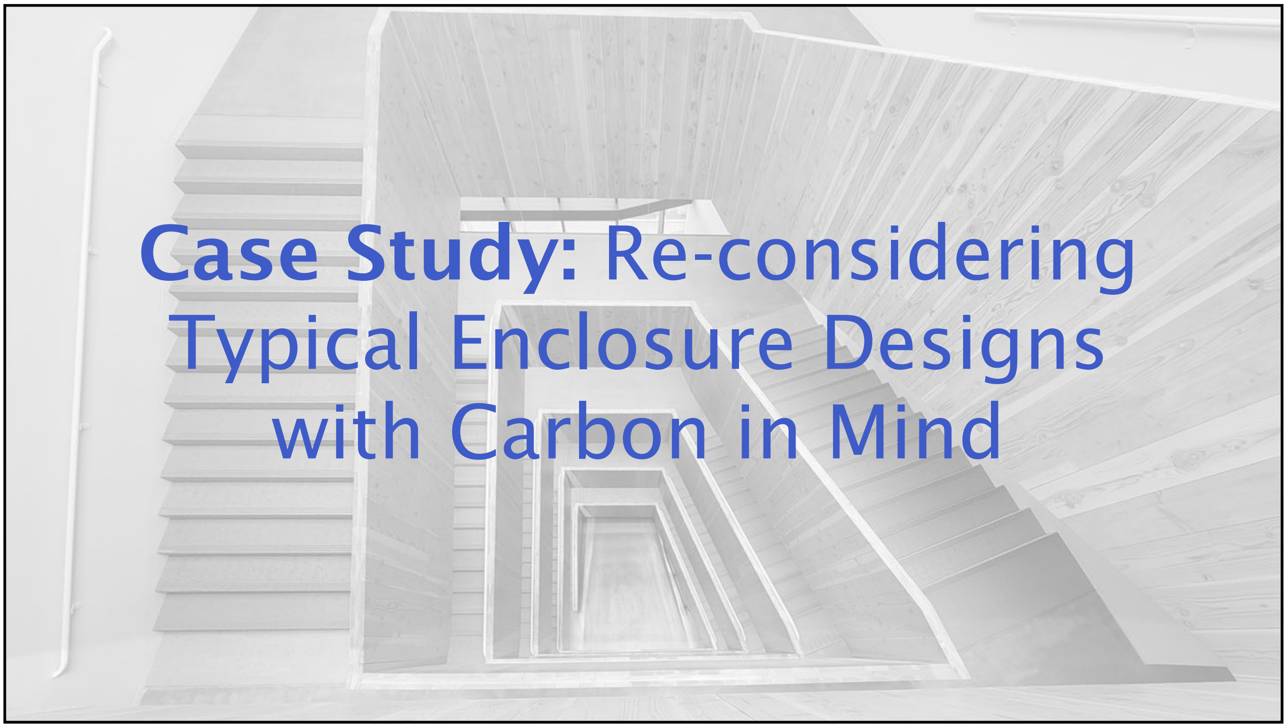
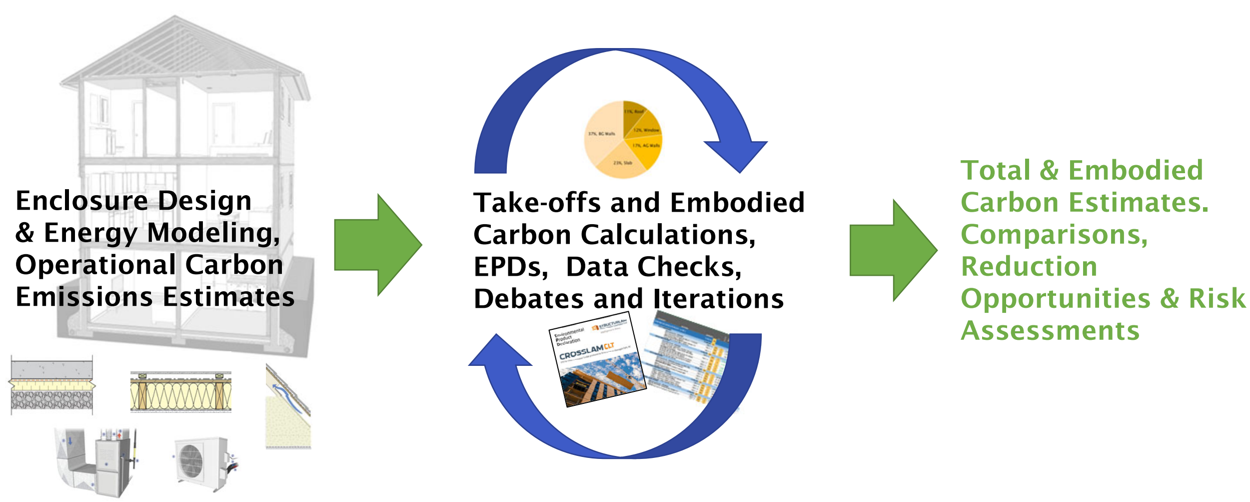
41



42

The RDH Approach to Embodied Carbon



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43

Baseline Building Enclosure Design – Embodied Carbon

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- Waterproofing
- 8" reinforced concrete
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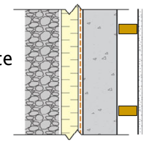
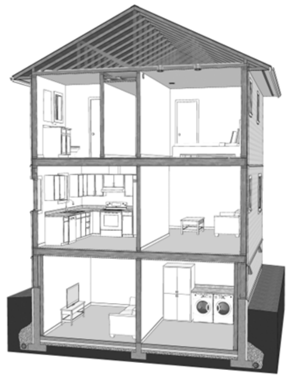
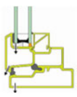
- Gypsum board







Windows *(U-0.27)*
- Double glazing, low-e, argon fill
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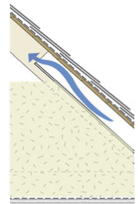

Sloped Roof (R-39 eff.)
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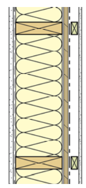

Above Grade Wall (R-17 eff.)
- Vinyl siding
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- House-wrap
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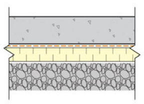
- Polyethylene AB/VB
- Gypsum board



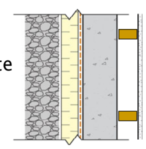
Floor Slab *(R-10)*
- Floor finish
- 6" concrete slab
- Polyethylene AB/VB
- 2.5" EPS insulation
- Compacted gravel fill

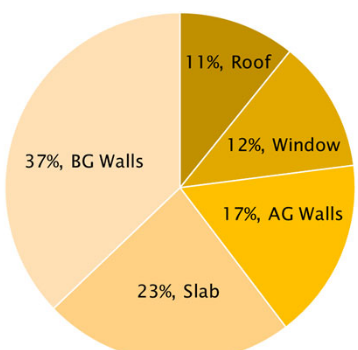
RDH

44

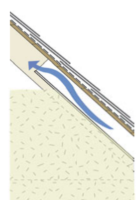
Baseline Building Enclosure Design – Embodied Carbon

Below Grade Wall *(R-20)*
- Exterior/Gravel fill
- 5" EPS Insulation
- Waterproofing
- 8" reinforced concrete
- 2x4 wood framing
- Gypsum board

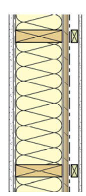




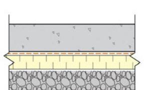
Windows *(U-0.27)*
- Double glazing, low-e, argon fill
- Fiberglass frames



Sloped Roof (R-39 eff.)
- Asphalt shingles
- Roofing underlayment
- Plywood sheathing
- Wood trusses
- 15" blown fiberglass insulation
- Polyethylene AB/VB
- Gypsum board



Above Grade Wall (R-17 eff.)
- Vinyl siding
- Rainscreen strapping
- House-wrap
- Plywood sheathing
- 2x6 wood framing
- Mineral wool batt
- Polyethylene AB/VB
- Gypsum board



Floor Slab *(R-10)*
- Floor finish
- 6" concrete slab
- Polyethylene AB/VB
- 2.5" EPS insulation
- Compacted gravel fill

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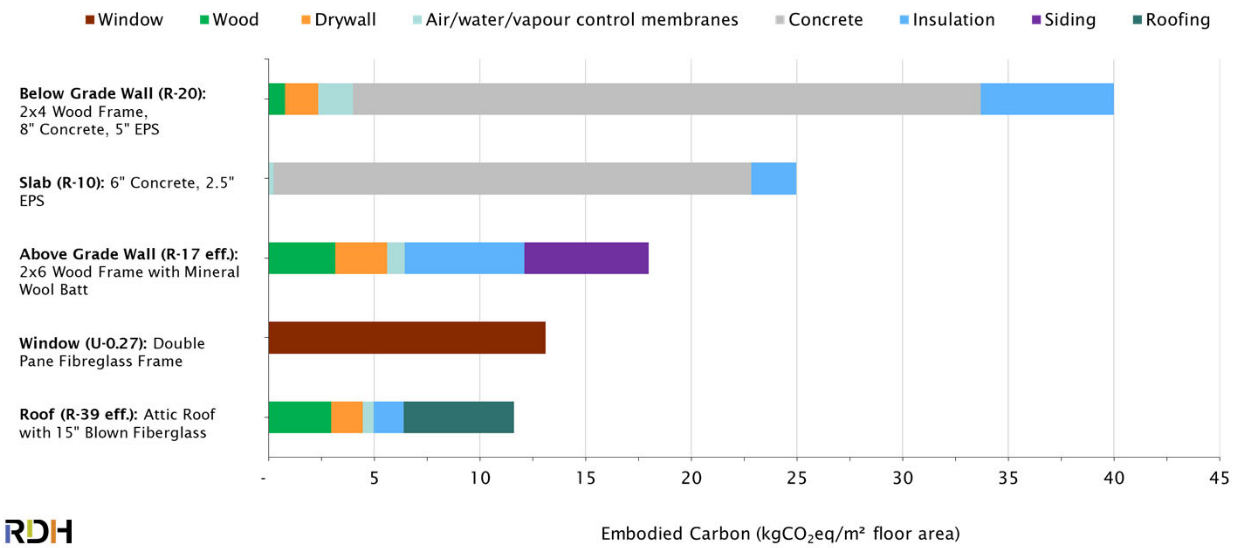
45

Embodied Carbon in Baseline Building Enclosure

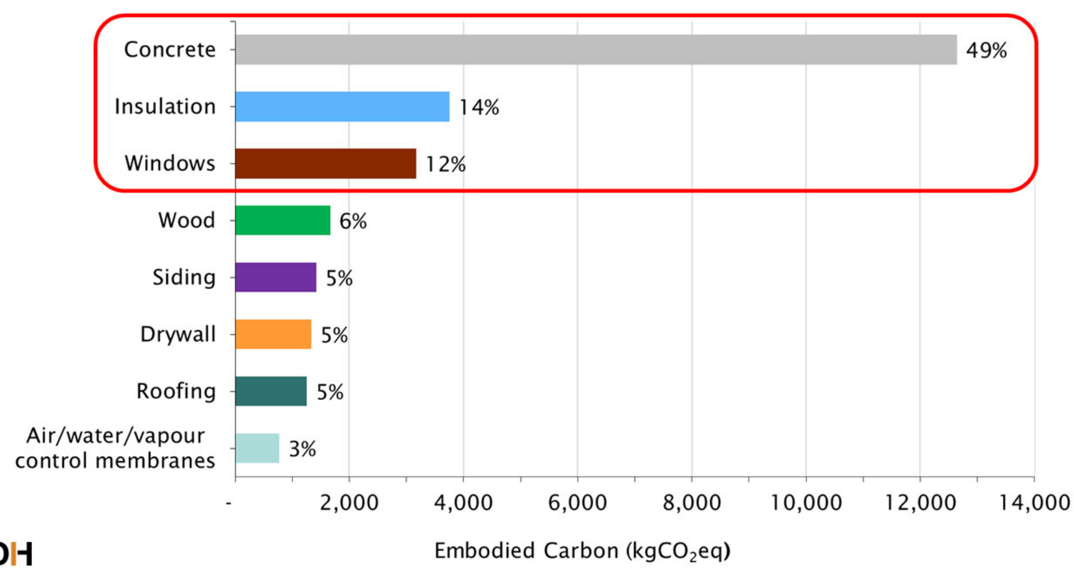
(Minimum BCBC 9.36, Step 3 performance)



46

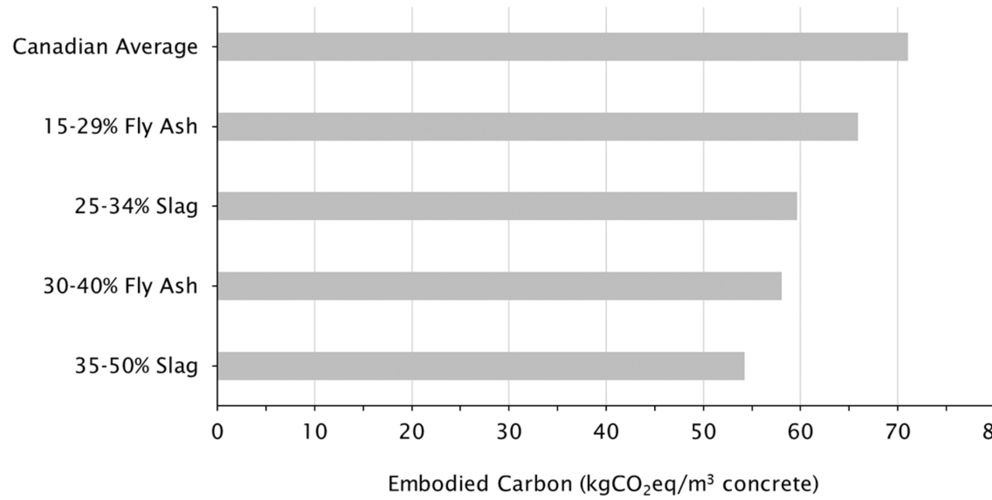
Embodied Carbon by Material Type

(Minimum BCBC 9.36, Step 3 performance)



47

What About Lower Carbon Concrete?



***The Future?:** Carbon-Neutral Concrete Prototype Architecture Prize – UK Architects Journal Oct 10, 22*

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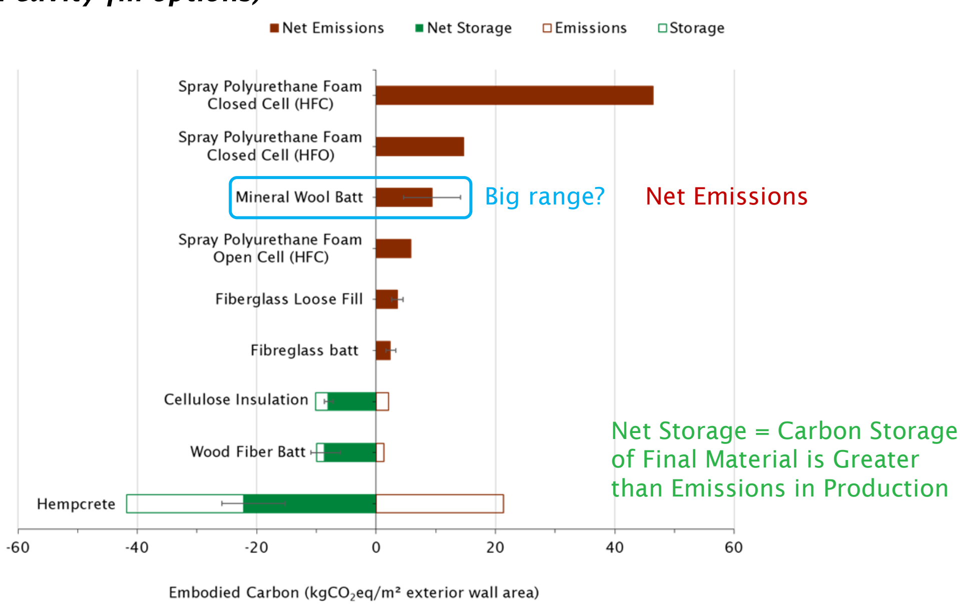
48

What about Different Insulation Types

(ex. R-20 wall cavity fill options)



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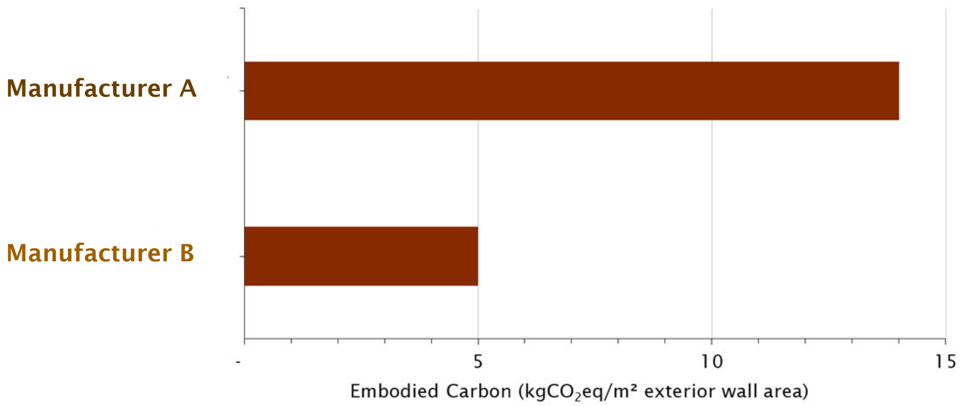
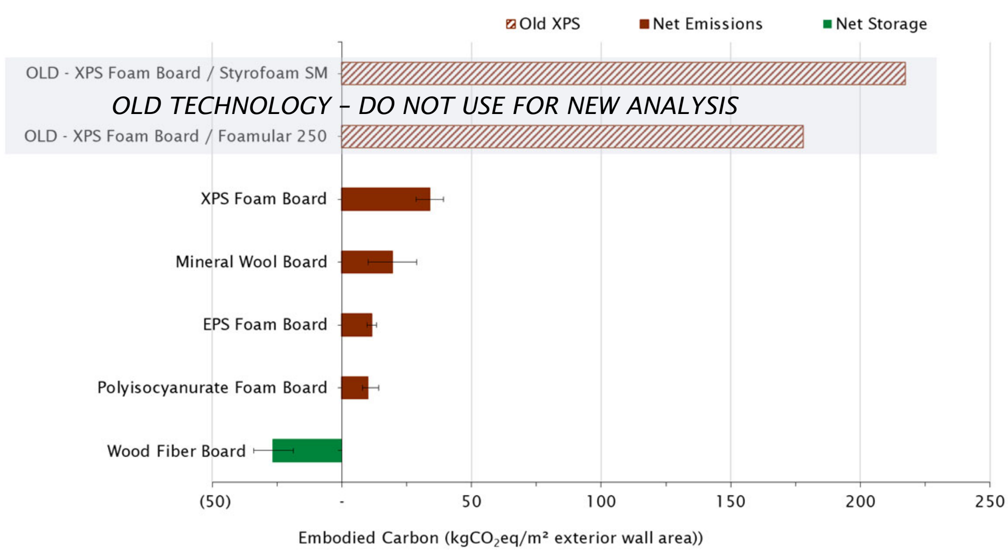
49

What about Different Insulation Manufacturers?
(ex. R-20 mineral wool batt options)



50

What about Different Insulation Types
(ex. R-20 equivalent exterior rigid board options)



51

Carbon Storing Materials

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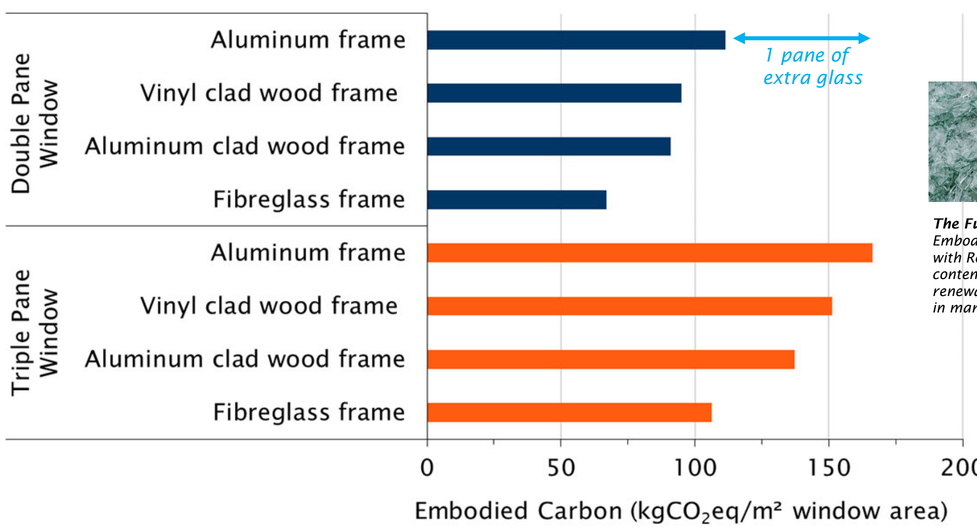
52

What about Different Window Types?



The Future?: *Lower Embodied Carbon with Recycled Glass content and renewable energy in manufacturing*

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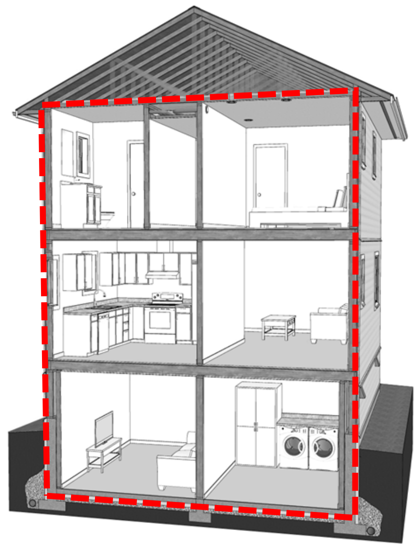
53

Building Science for Enclosure Design with a Lens on Embodied Carbon



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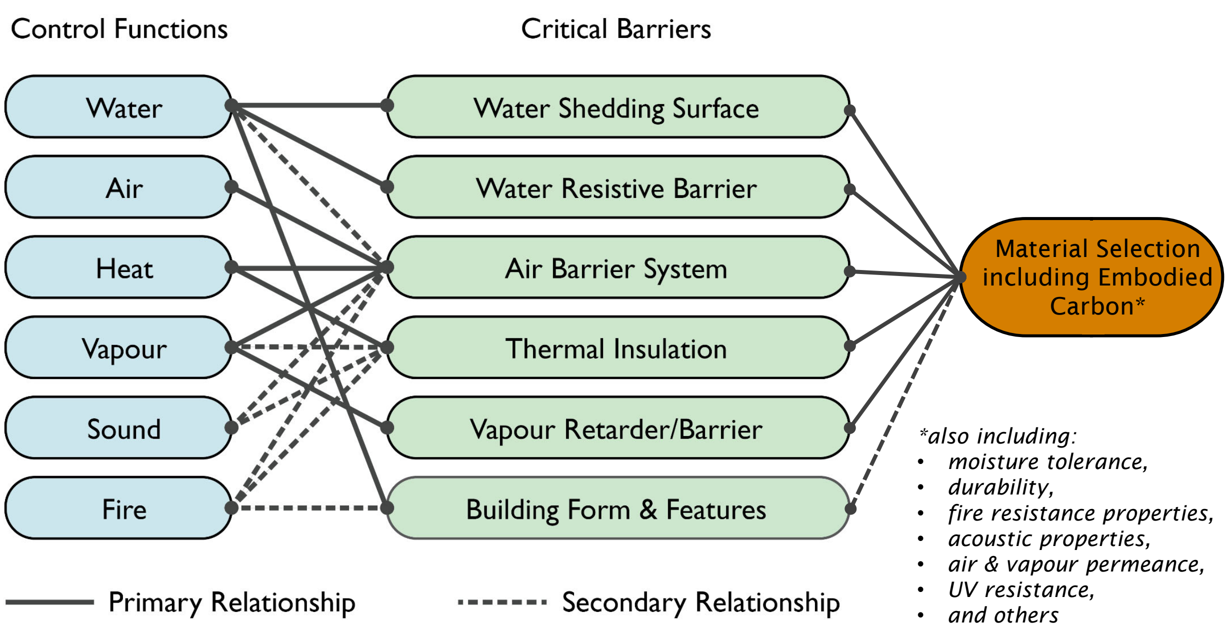
54



**also including:*
- *moisture tolerance,*
- *durability,*
- *fire resistance properties,*
- *acoustic properties,*
- *air & vapour permeance,*
- *UV resistance,*
- *and others*

55

Evaluating Alternate Design & Material Options Today & In the Future

- Cost Efficiency /
- Const
- ss)
- esilience
- E arbon in Materials & Sustainability

TIP!: We can already get to zero & even negative carbon enclosures with proven materials that are already on the market today. New and future materials may make it easier – some with lower and some with higher risks

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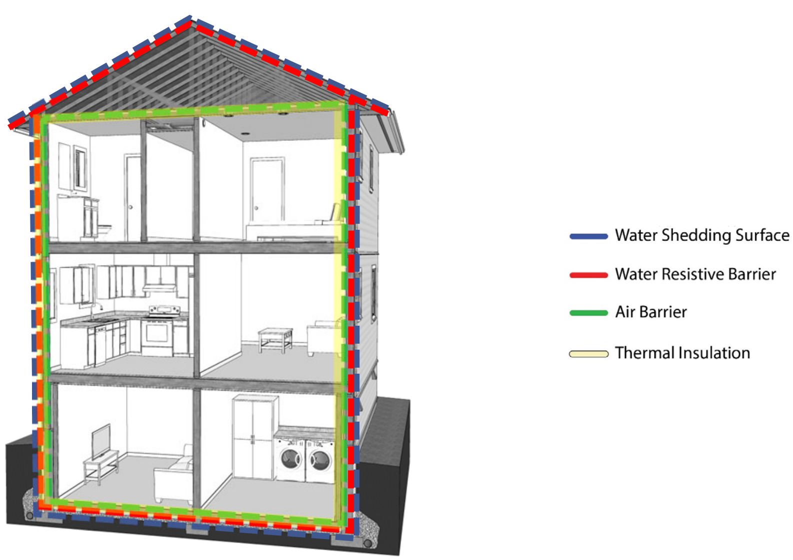
56

Control & Continuity Across the Entire Enclosure



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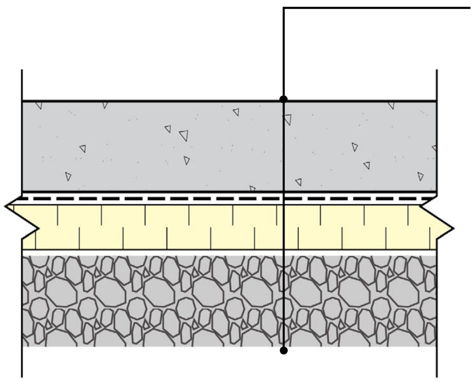
57

Rethinking Slab on Grade Designs?



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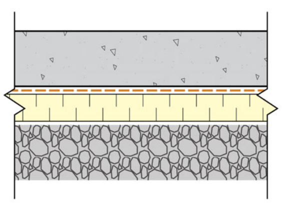
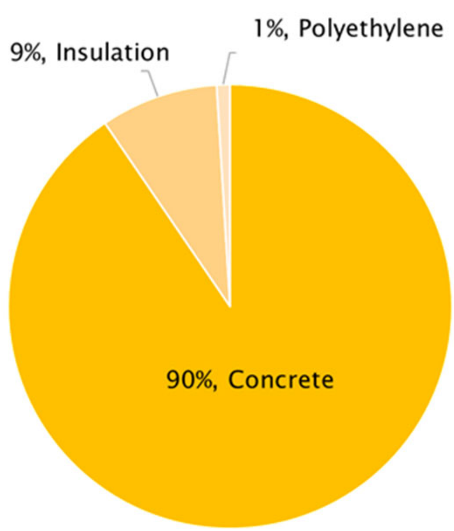
58

Slab on Grade Embodied Carbon



Floor Slab *(R-10)*
- Floor finish
- 6" concrete slab
- Polyethylene AB/VB
- 2.5" EPS insulation
- Compacted gravel fill



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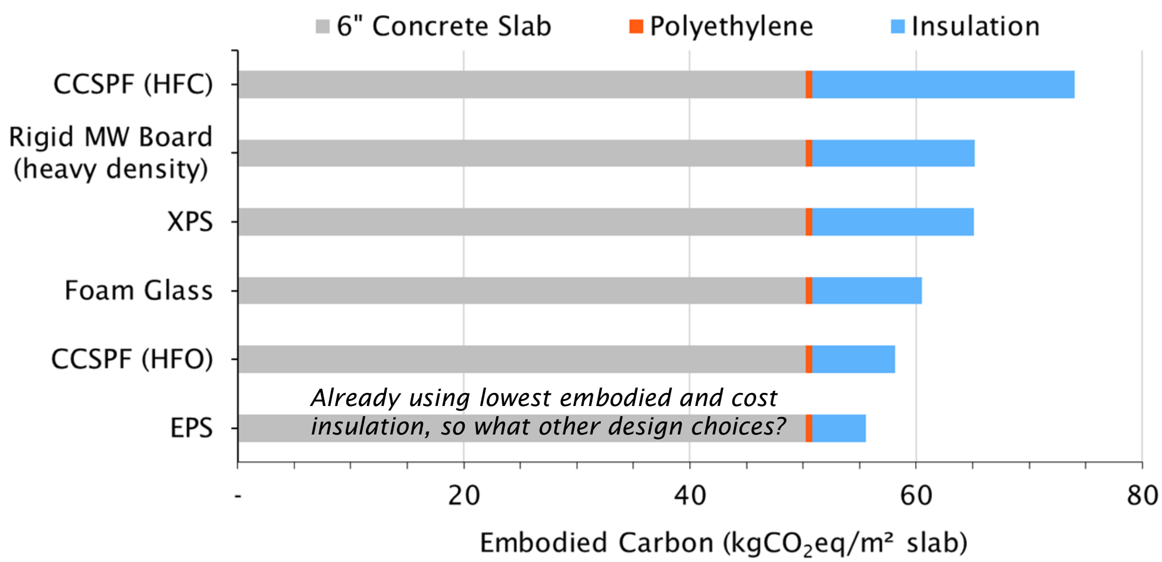
59

Slab on Grade Embodied Carbon



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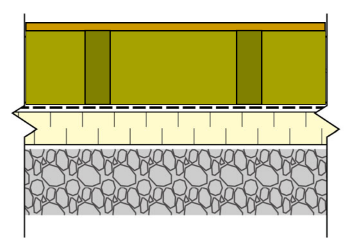
60

What about Non-Concrete Floor on Grade Permanent Wood Foundation (PWFs)?



PWF Floor on Grade *(R-10)*
- Floor finish
- ¾" treated plywood sheathing
- 2x6 treated wood framing
- Polyethylene AB/VB
- 2.5" EPS insulation
- Compacted gravel fill

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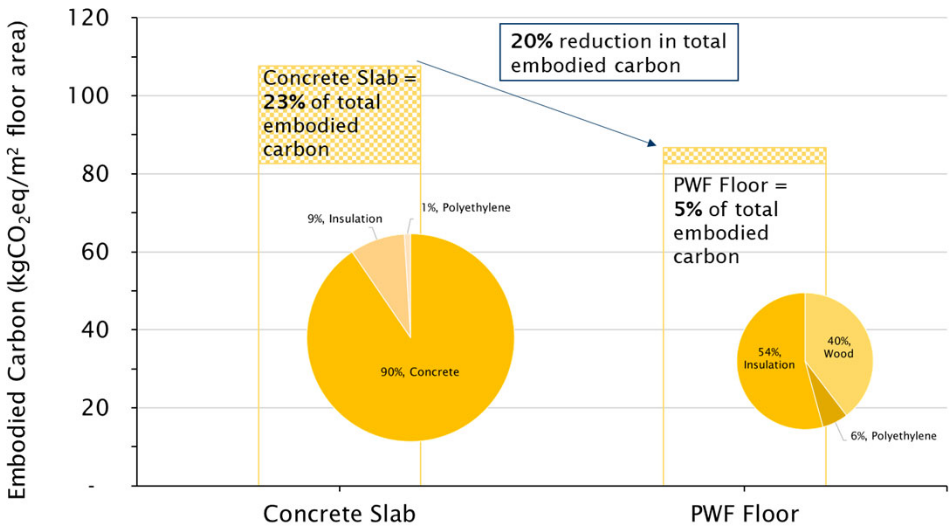
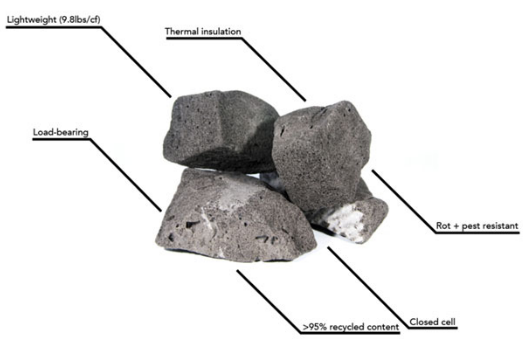
61

Concrete Slab on Grade vs PWF Floor?



62

Up & Coming Below Grade Lower-Carbon & Carbon Storing Minerals?



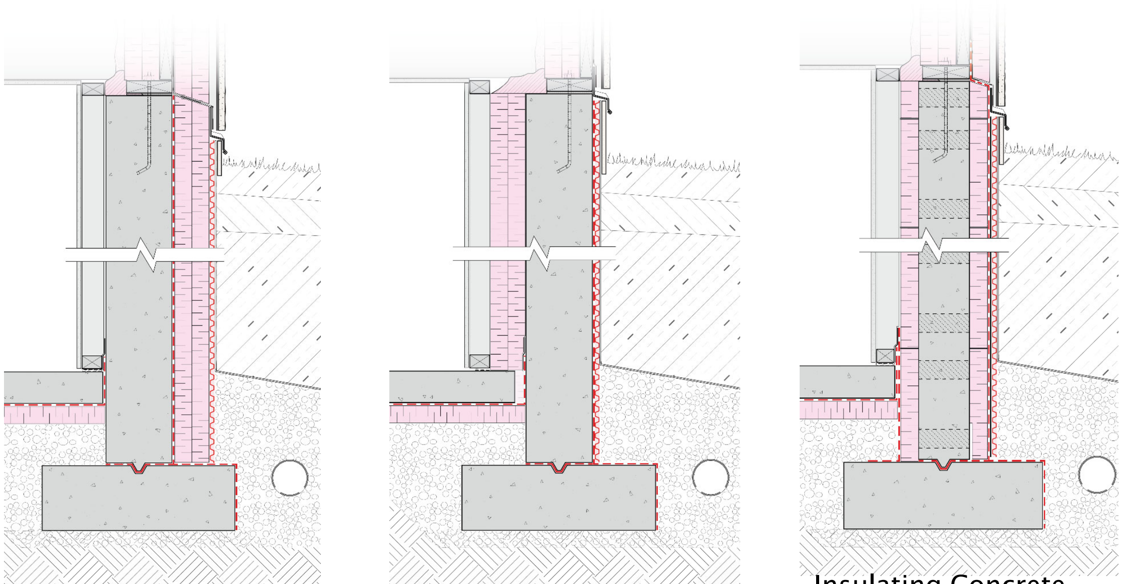
Insulating Lightweight Gravel (Upcycled Glass)
https://www.glavel.com/foam-glass-gravel/

Synthetic CaCO3 Aggregate - https://www.blueplanetsystems.com/products

Upcycled Aggregate

63

Re-thinking Below Grade Wall Designs?



Exterior Insulated

Interior Insulated

Insulating Concrete Forms (ICF)

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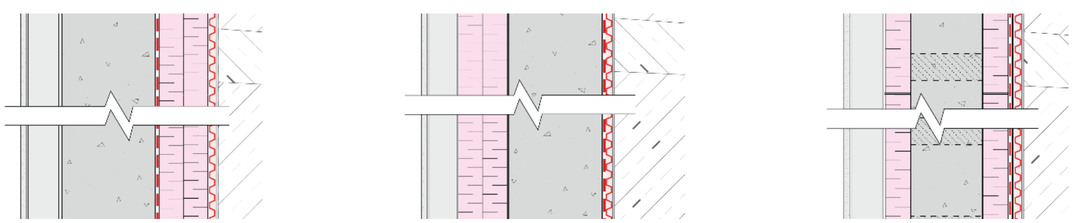
64

Re-thinking Below Grade Wall Designs?



Exterior Insulated

Interior Insulated

ICF

Below Grade Wall *(R-20)*

- Exterior/Gravel fill
- 5" EPS Insulation *(could be inside or outside or split to both sides – to carbon calculation is the same with same EPD material)*
- Waterproofing or dampproofing membrane
- 8" reinforced concrete
- 2x4 wood framing service cavity
- Gypsum board

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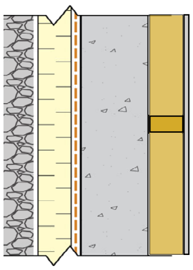
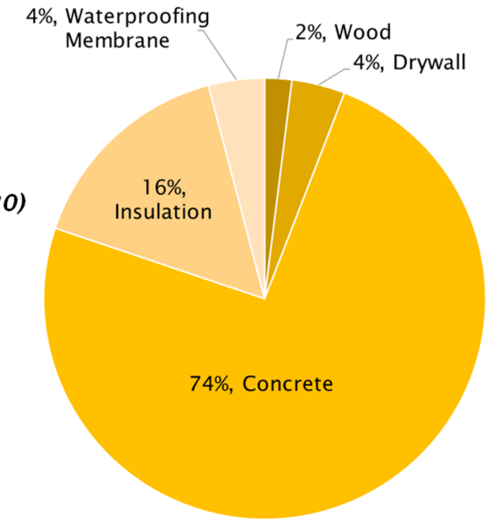
65

Below Grade Walls – Embodied Carbon



Below Grade Wall *(R-20)*

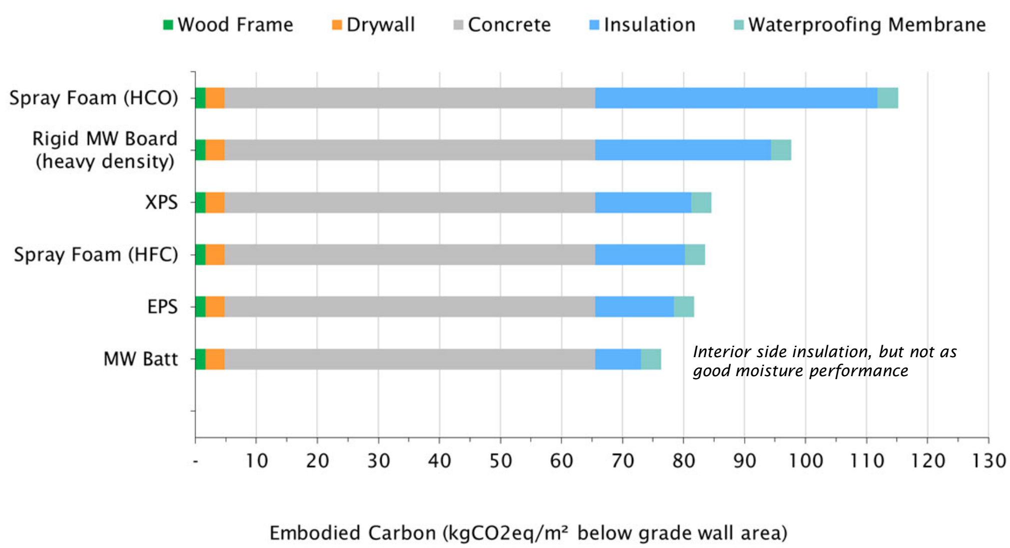
- Exterior/Gravel fill
- 5" EPS Insulation
- Waterproofing
- 8" reinforced concrete
- 2x4 wood framing
- Gypsum board



RDH

66

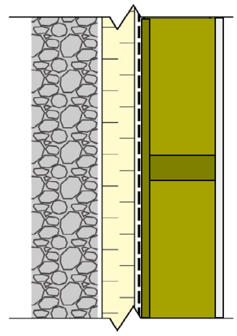
Below Grade Walls – Embodied Carbon



RDH

67

What about Non-Concrete Walls Using Permanent Wood Foundations (PWFs)?

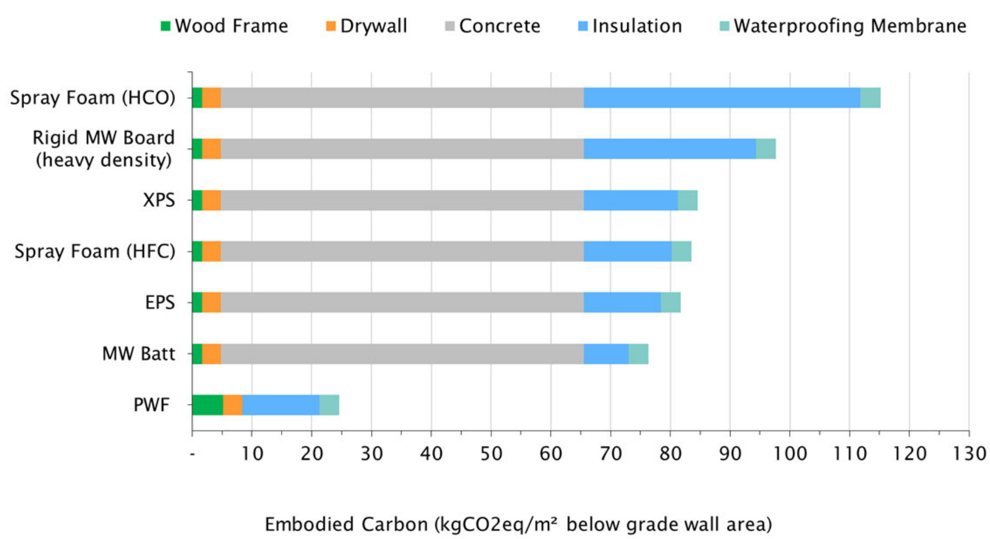


Below Grade Wall ***(R-20)***
- Exterior/Gravel fill
- 5" EPS Insulation (exterior)
- Waterproofing membrane
- ¾" treated plywood sheathing
- 2x8 treated framing (empty cavity)
- Gypsum board & Paint

RDH

68

Below Grade Walls – Embodied Carbon



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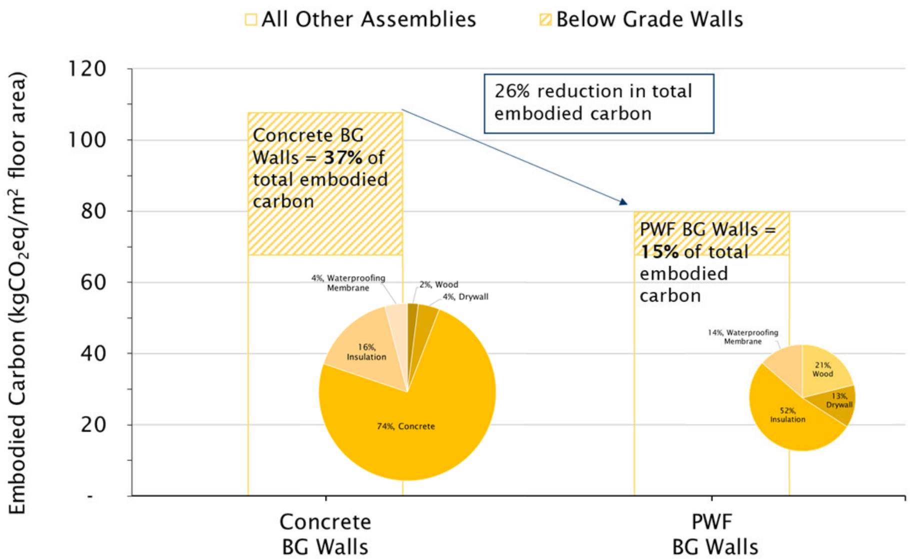
69

Carbon Reduction from PWF Below Grade Walls



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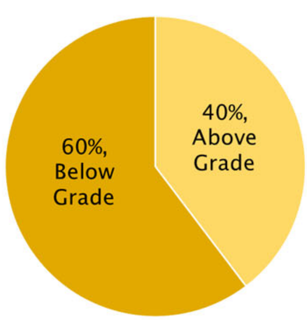
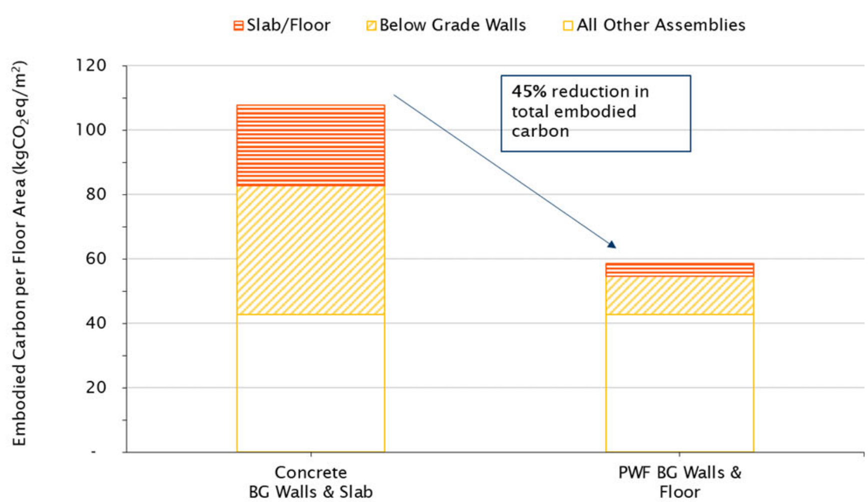
70

Final Thought – Rethinking Below Grade Completely?

Distribution of Embodied Carbon in Baseline Home with Concrete Basement





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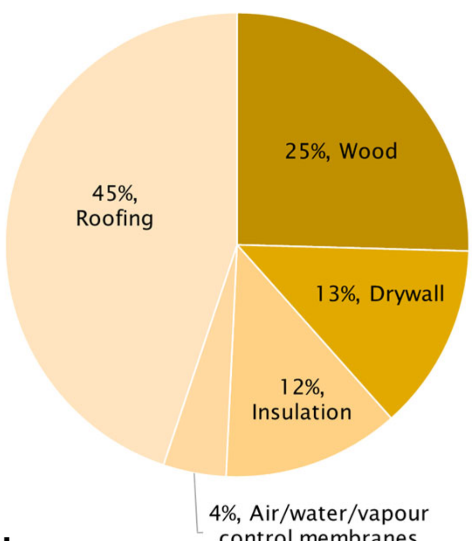
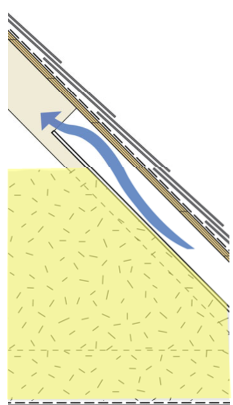
71

Elevated Homes & Non-Concrete Foundations

72

Re-Thinking Sloped Attic Roof Assemblies

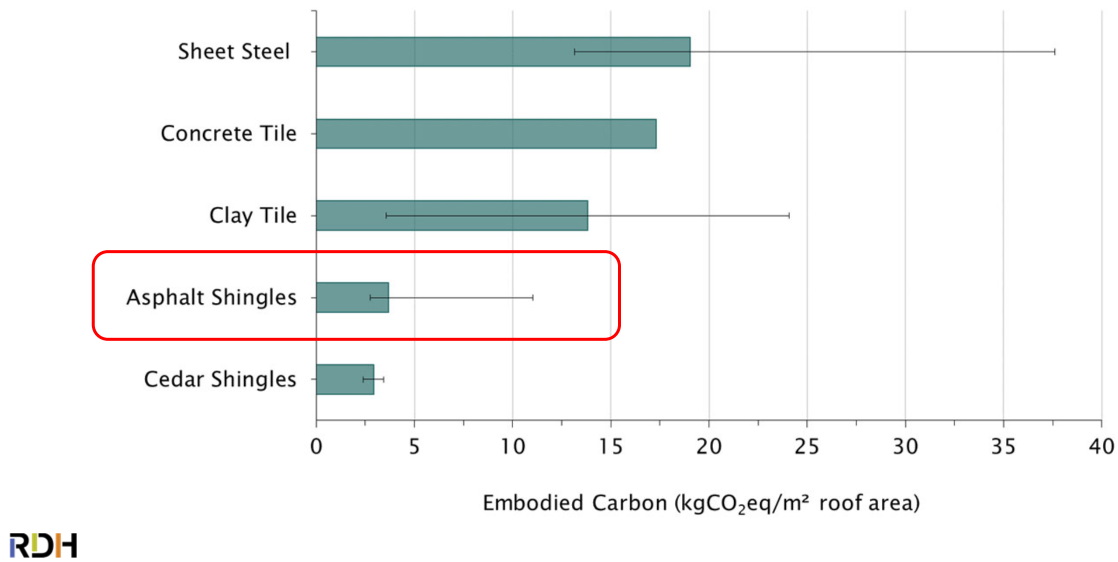




Sloped Roof (R-39 eff.)
- Asphalt shingles
- Roofing underlayment
- Plywood sheathing
- Wood trusses
- 15" blown fiberglass insulation
- Polyethylene AB/VB
- Gypsum board

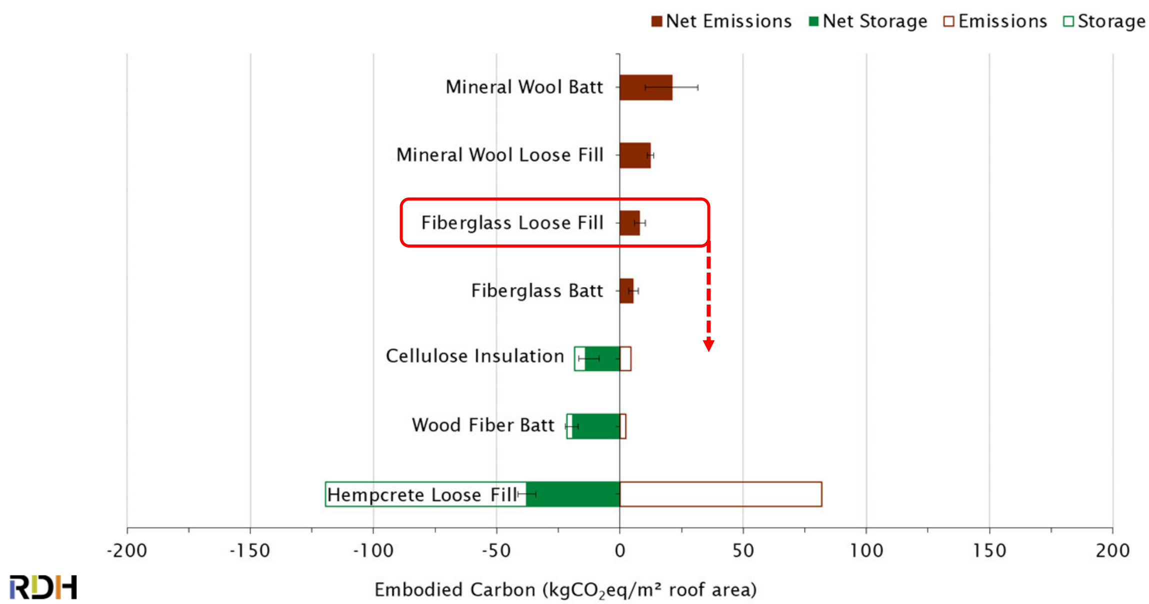
73

Common Roofing Choices and Carbon Impacts



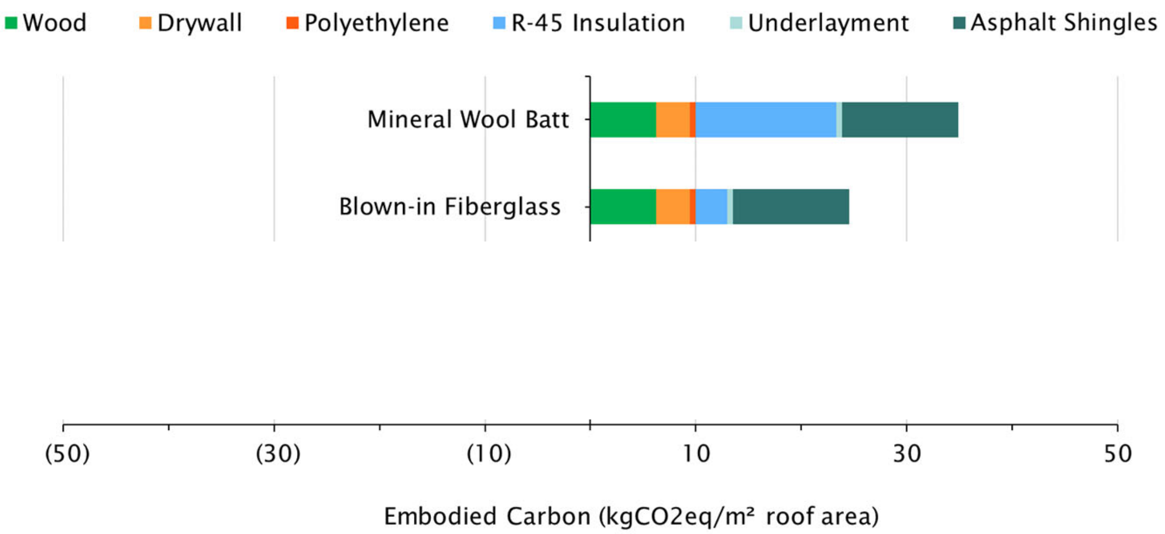
74

Attic Roof Insulation Options (R-45)



75

Roof Assembly Carbon Reductions



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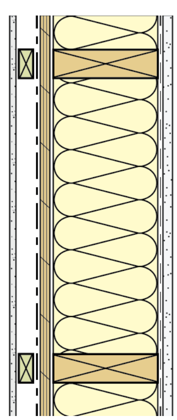
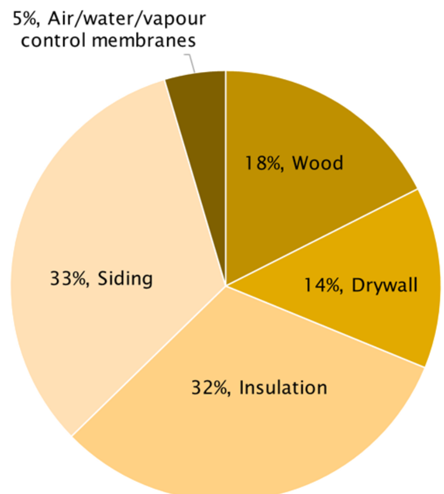
76

Re-thinking Above Grade Wall Designs

Above Grade Wall (R-17 eff.)

- Vinyl siding
- Rainscreen strapping
- House-wrap
- Plywood sheathing
- 2x6 wood framing
- Mineral wool batt
- Polyethylene AB/VB
- Gypsum board





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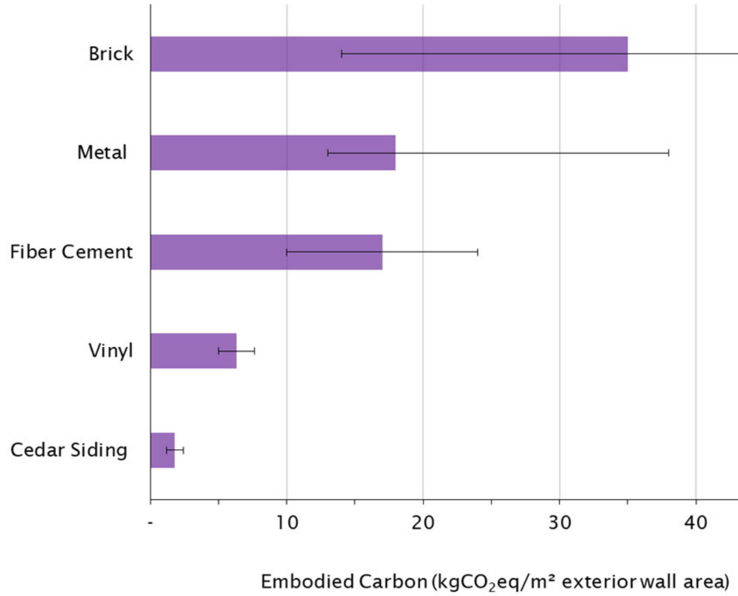
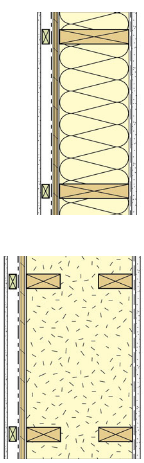
77

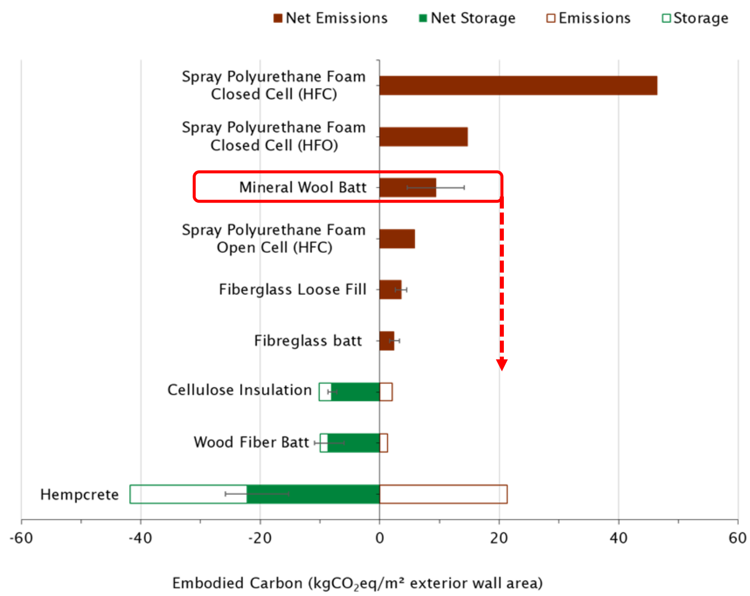
Cladding Choices & Carbon Impacts



78

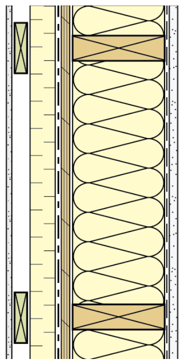
Cavity Insulation Choices

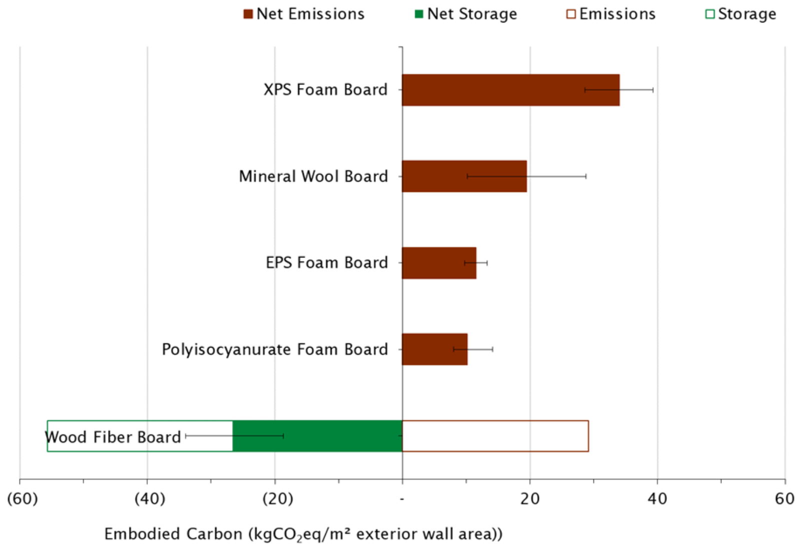




79

Adding Exterior Insulation





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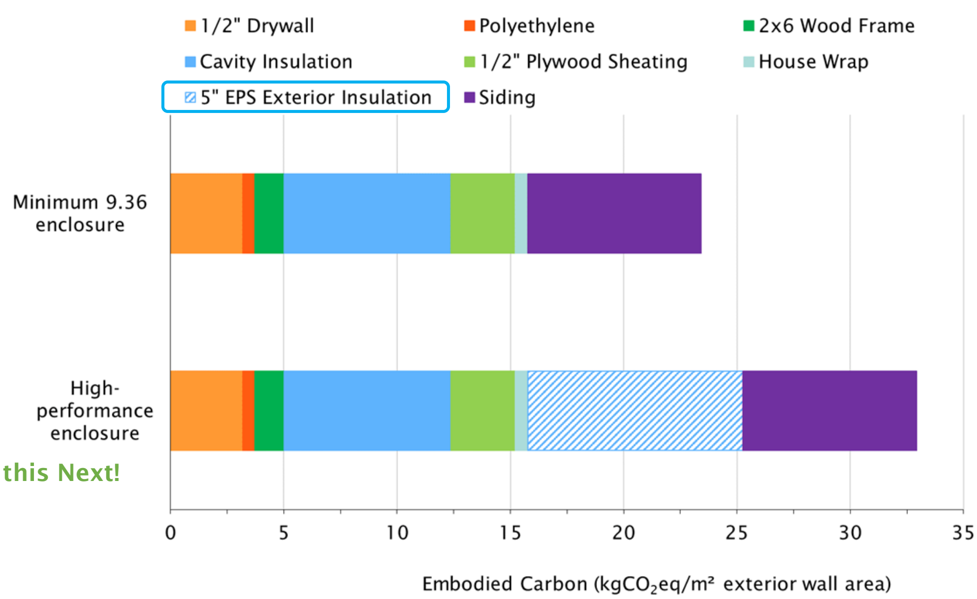
80

But… Adding Exterior Insulation adds Embodied Carbon



More on this Next!

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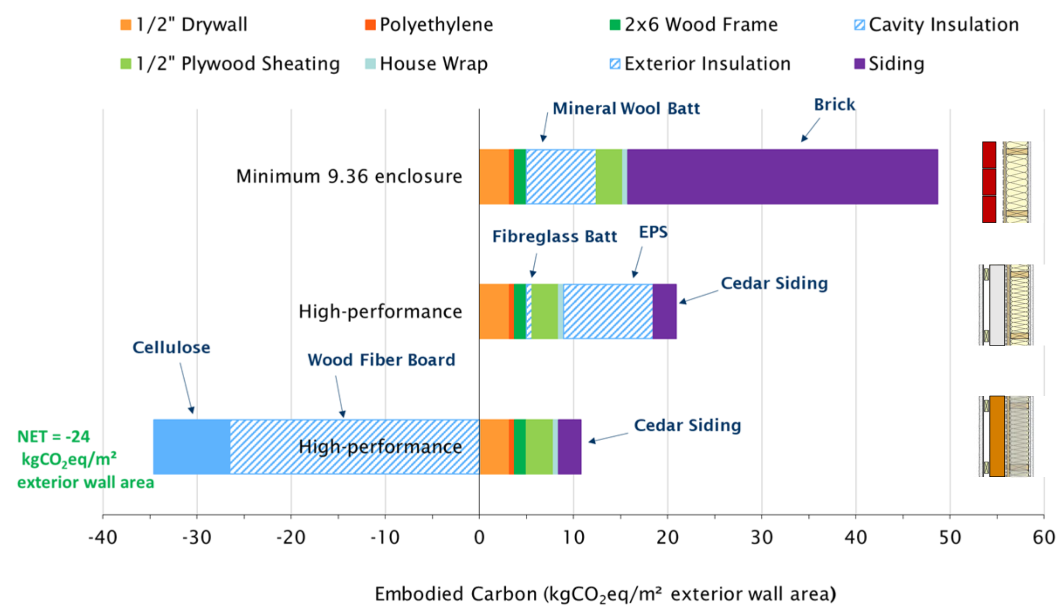
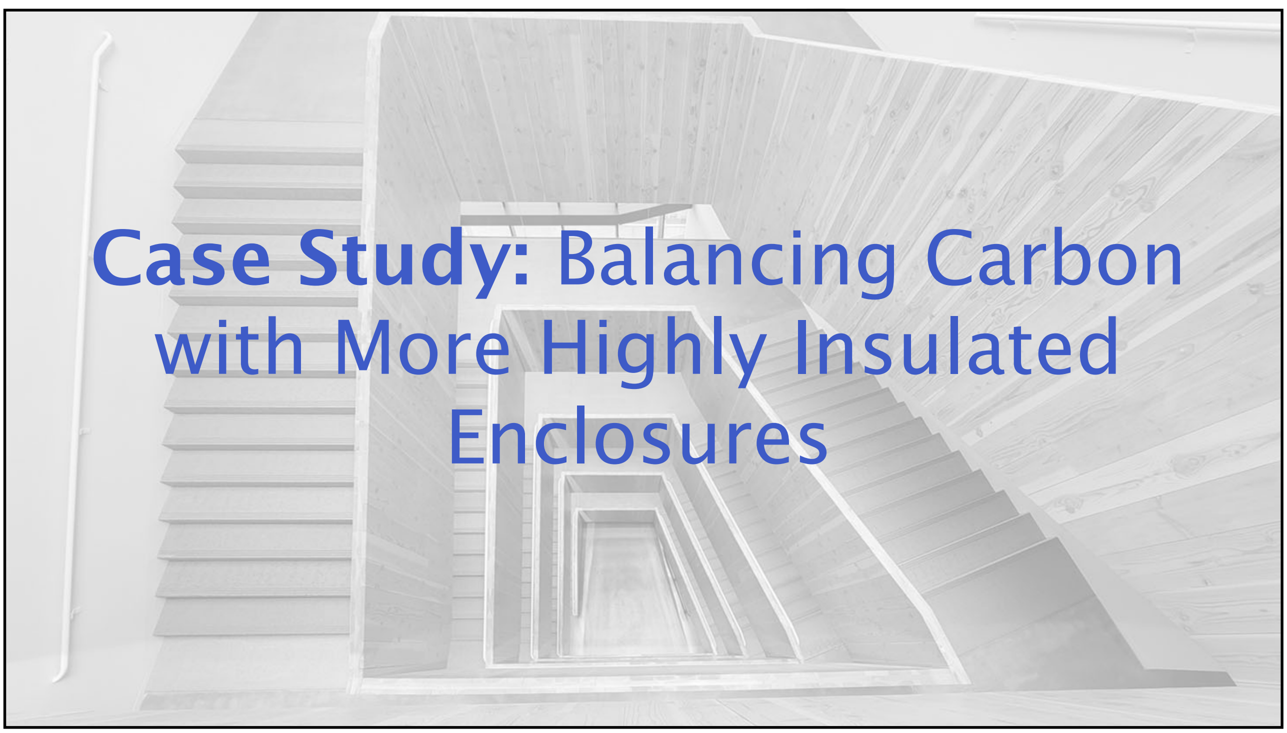
81

But Reconsider All Materials In Context & Balance



82

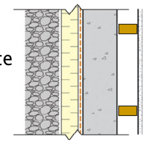


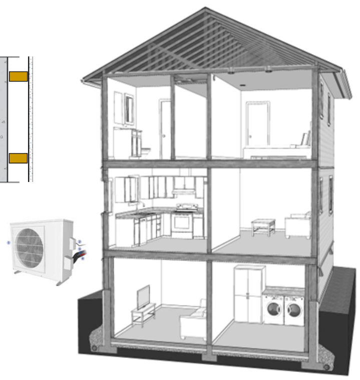
83

Higher Performance Net Zero Building Enclosure

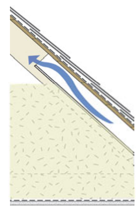
(BC Energy Code Step 5 performance)

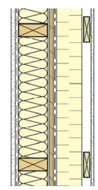
Below Grade Wall *(R-20)*
- Exterior/Gravel fill
- 5" EPS Insulation
- Waterproofing
- 8" reinforced concrete
- 2x4 wood framing
- Gypsum board



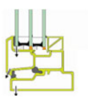


Sloped Roof (R-39 eff.)
- Asphalt shingles
- Roofing underlayment
- Plywood sheathing
- Wood trusses
- 15" blown fiberglass insulation
- Polyethylene AB/VB
- Gypsum board

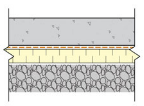




Windows *(U-0.18)*
- Triple glazing, 2x low-e, argon fill
- Fiberglass frames



Above Grade Wall (R-35 eff.)
- Vinyl siding
- Rainscreen strapping
- 5" EPS Insulation
- House-wrap
- Plywood sheathing
- 2x6 wood framing
- Mineral wool batt
- Gypsum board



Floor Slab *(R-10)*
- Floor finish
- 6" concrete slab
- Polyethylene AB/VB
- 2.5" EPS insulation
- Compacted gravel fill

ASHP heatpump for heating and cooling
Airtightness = 1.0 ACH @ 50 Pa

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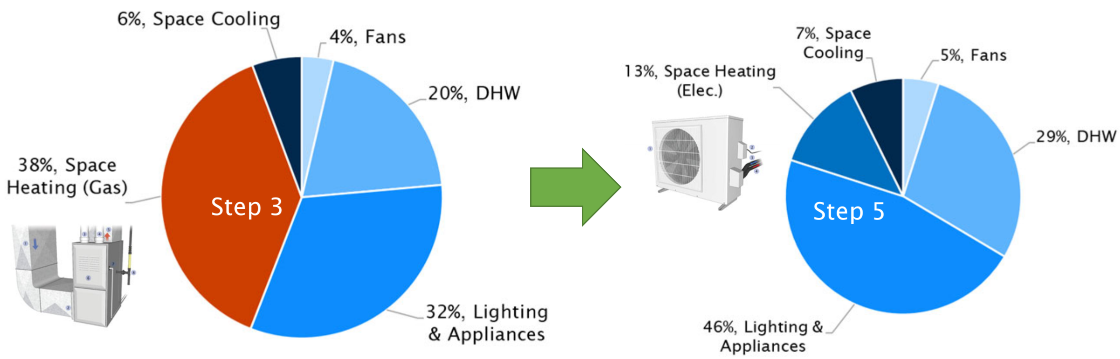
84

Energy Use and Carbon in Operations: Case Study House from Step 3 to Step 5 (NZ Ready)

Total Energy per Floor Area = **91** kWh/m²/yr

Total Energy per Floor Area = **63** kWh/m²/yr



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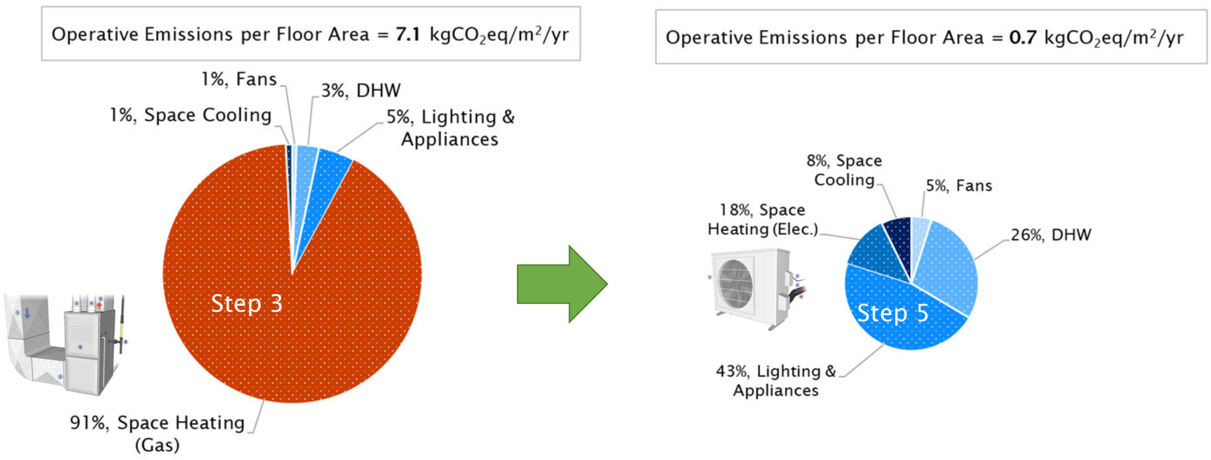
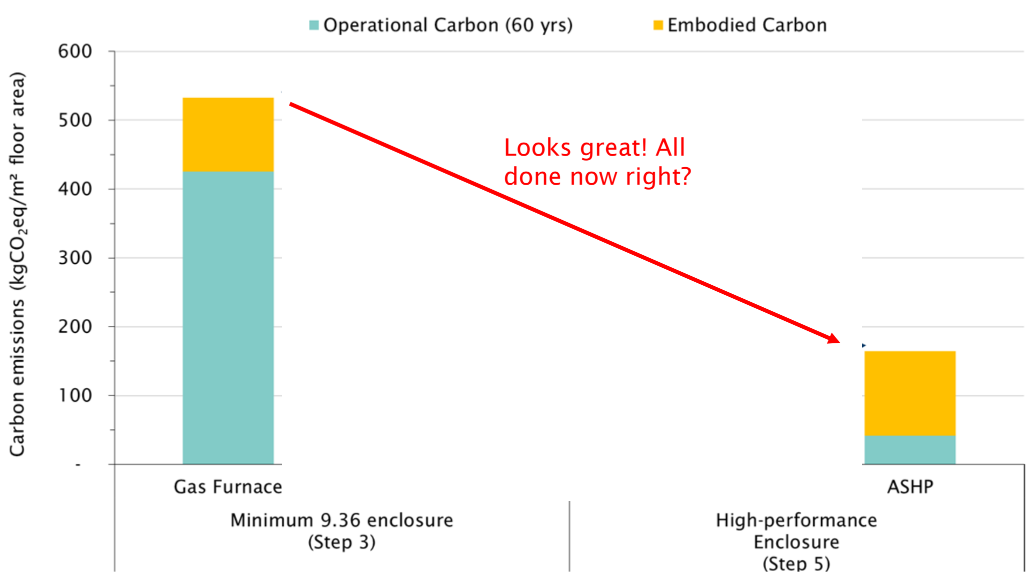
85

Energy Use and Carbon in Operations: Case Study House from Step 3 to Step 5 (NZ Ready)



86

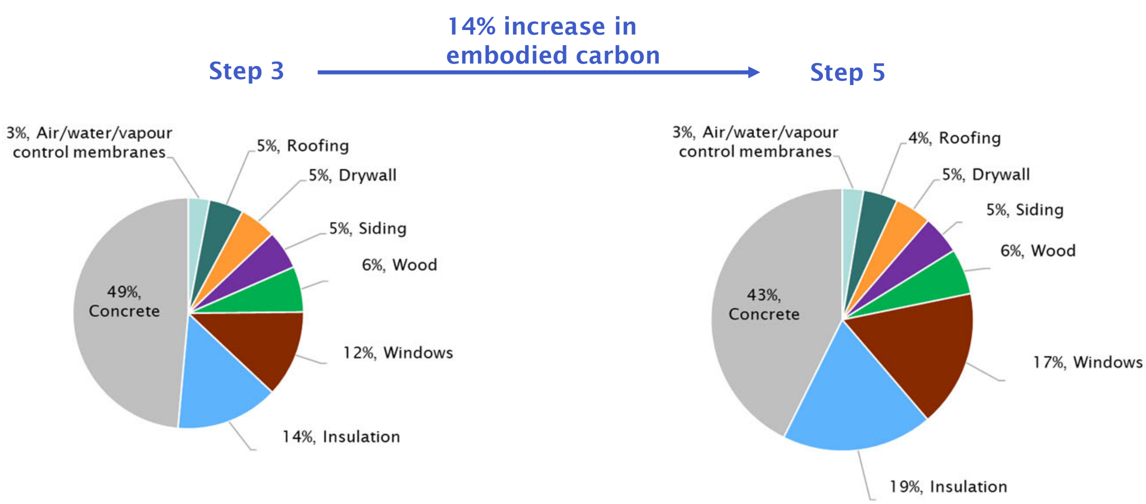
Higher Performance Enclosure to Reduce Total Carbon?



87

Adding Higher Performance Can Add Carbon

(Recall Double to Triple Glazing & 5" Exterior EPS to walls)



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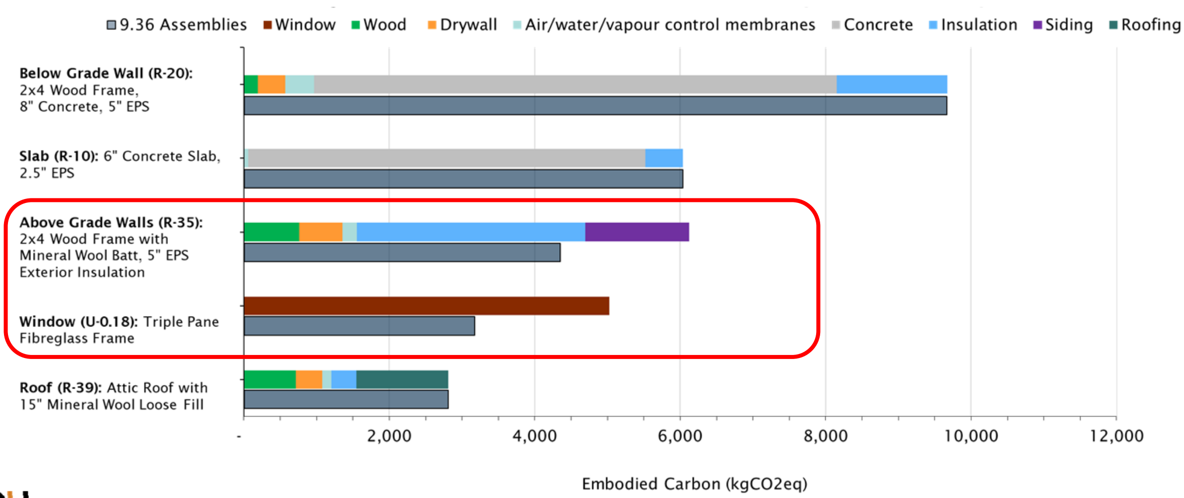
88

Oops?!

What Went Wrong?

89

High Performance Enclosure – Embodied Carbon by Assembly & Material Breakdown



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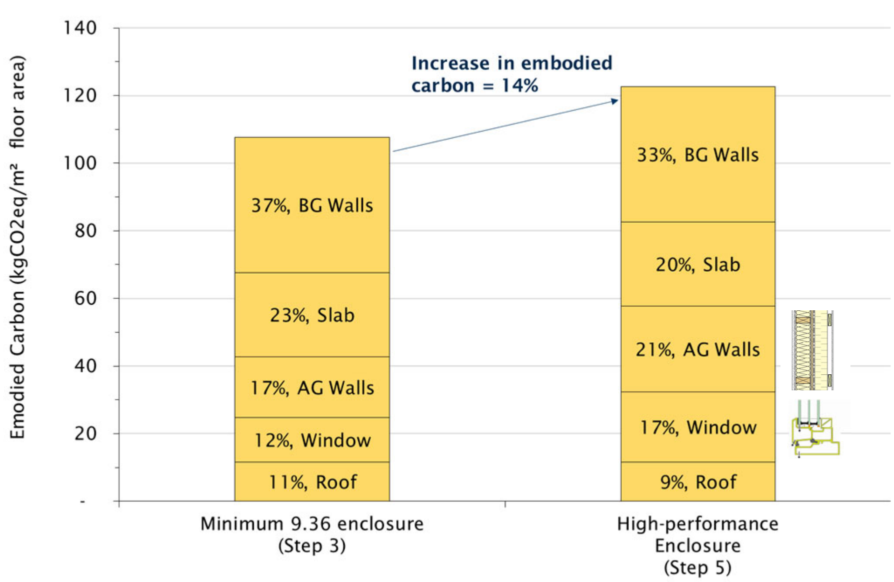
90

Adding Higher Performance Can Add Carbon



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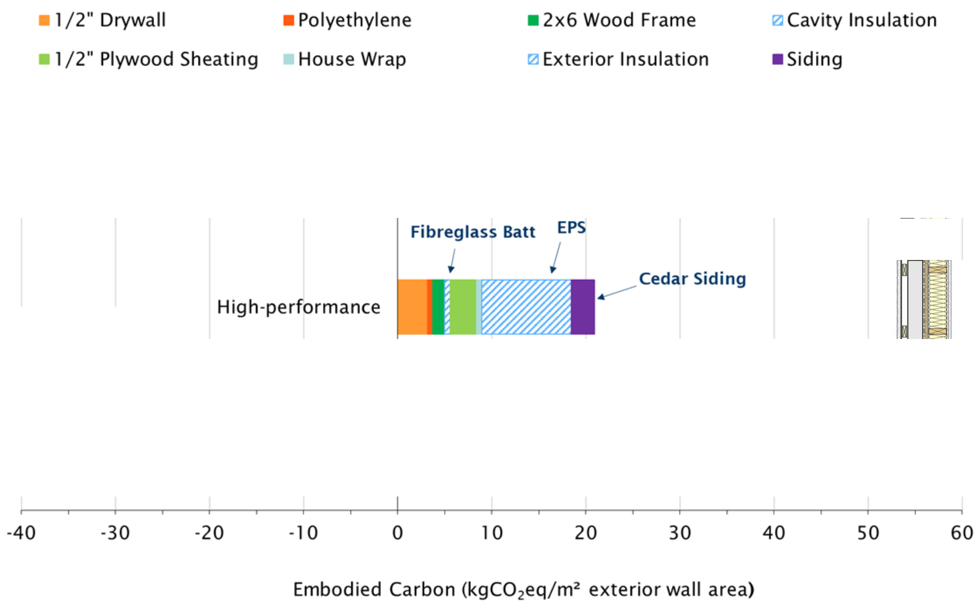
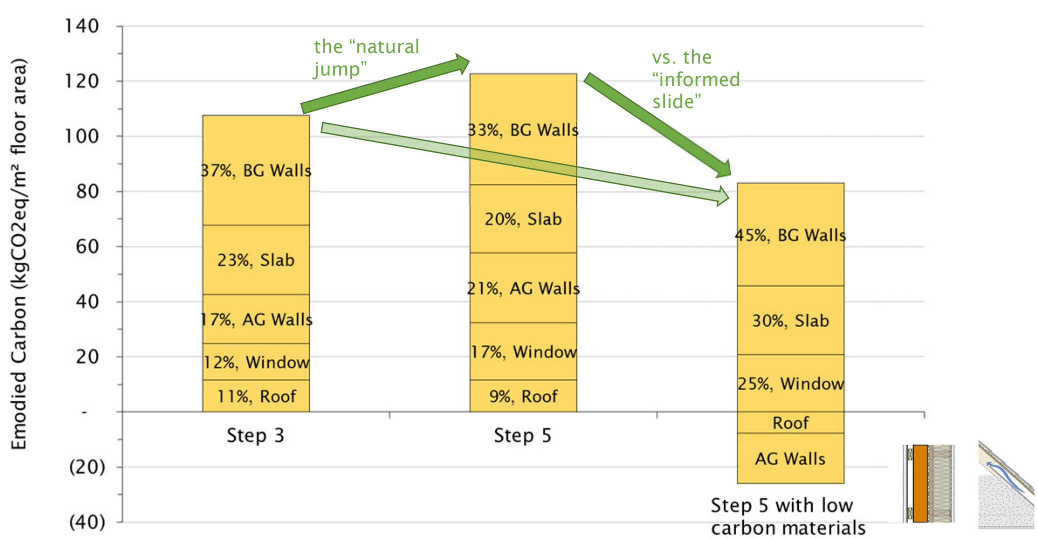
91

..Or We Could Reduce Carbon with Alternate Insulation



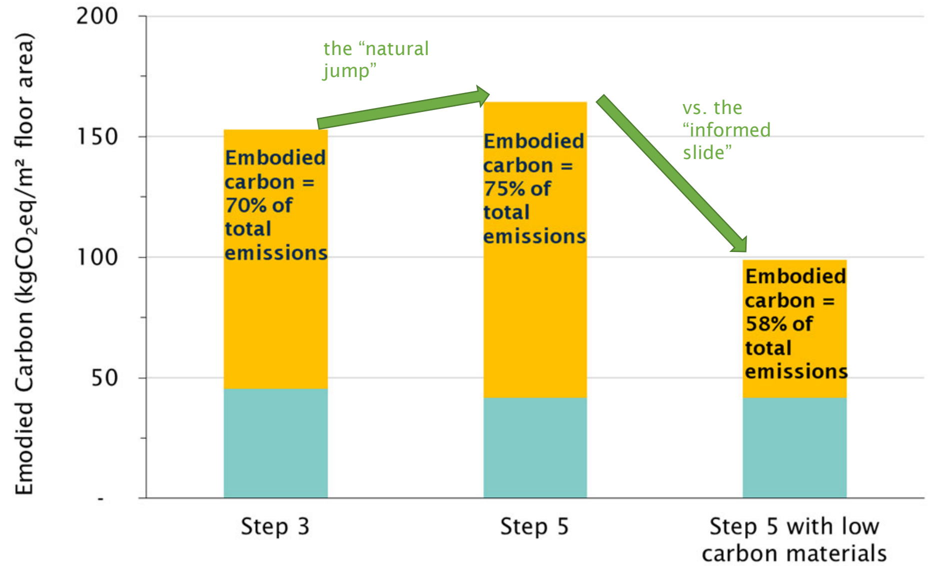
92

Understanding Carbon Can Make Different Choices



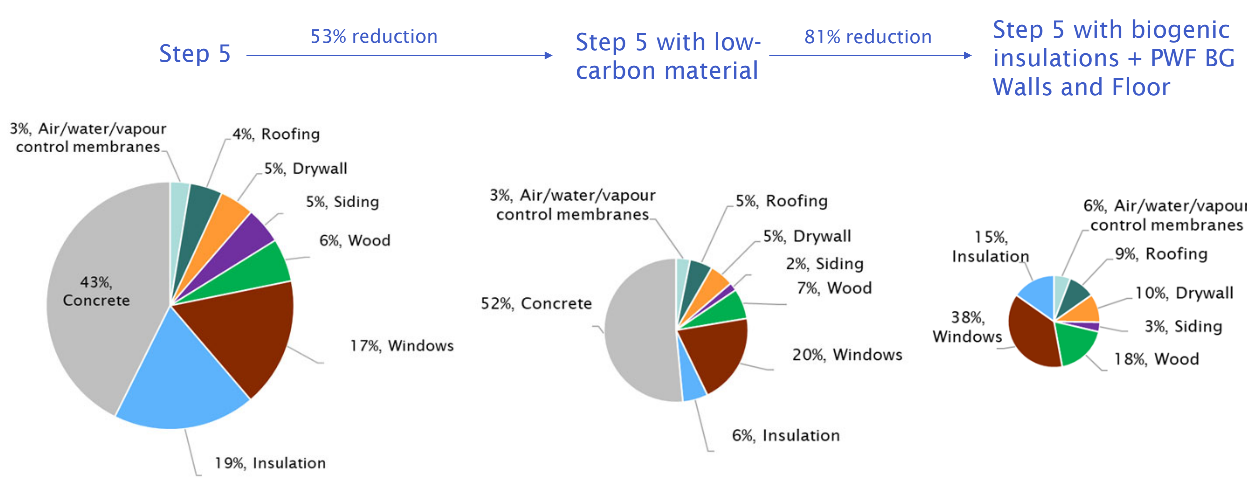
93

Understanding Carbon Can Make Different Choices



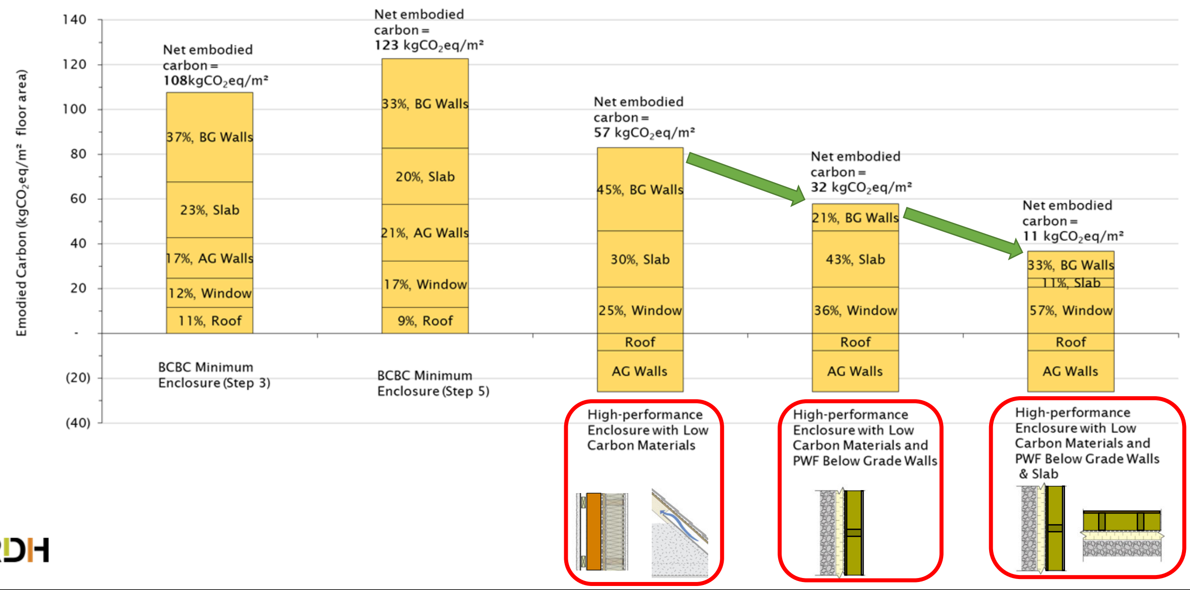
94

Possibilities when Considering Alternate Approaches



95

How Low Can we Go? - Embodied Carbon



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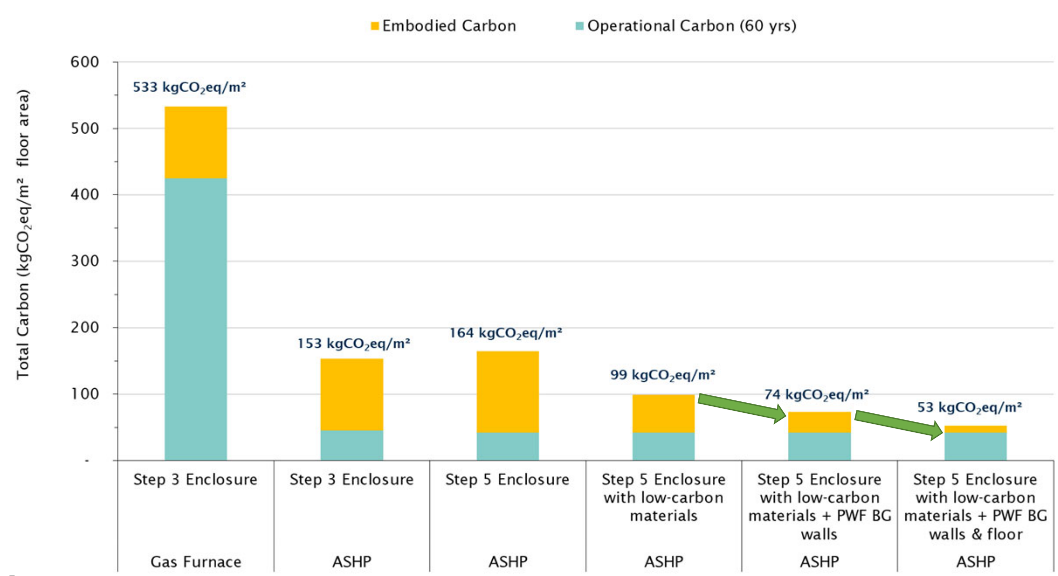
How Low Can We Go? - Total Carbon



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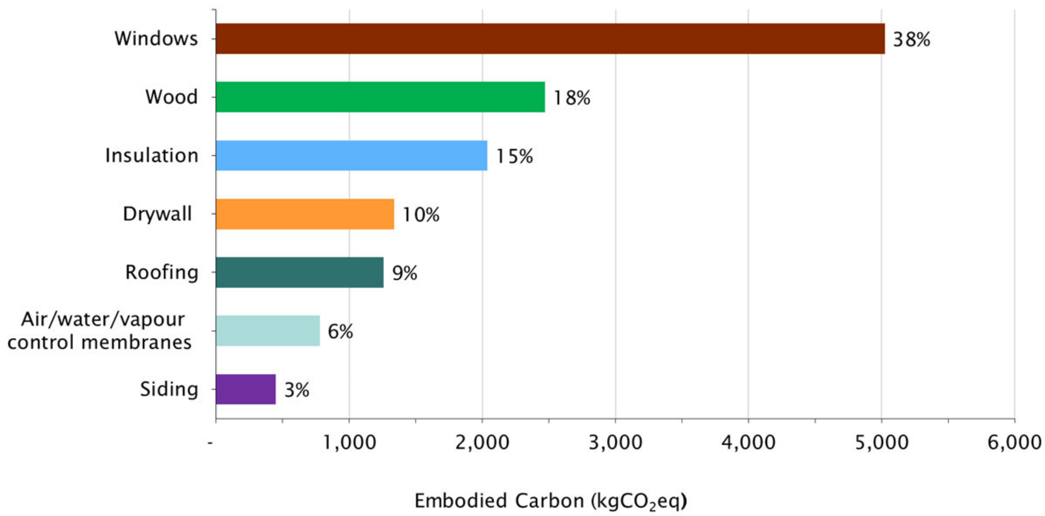
What's Left?

(High performance enclosure with non-concrete foundation (PWF BG Walls & Slab), use of carbon sequestering insulation)



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99

A Windowless Future?! I hope not!

BUT…
R&D underway to reduce GHG emissions from float glass production as well as window frame materials

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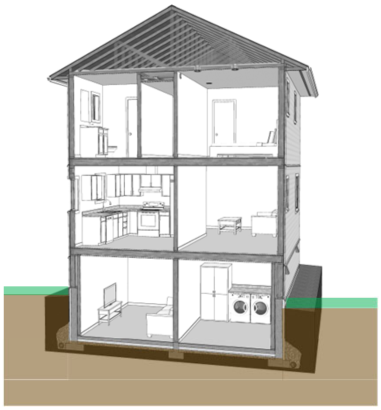
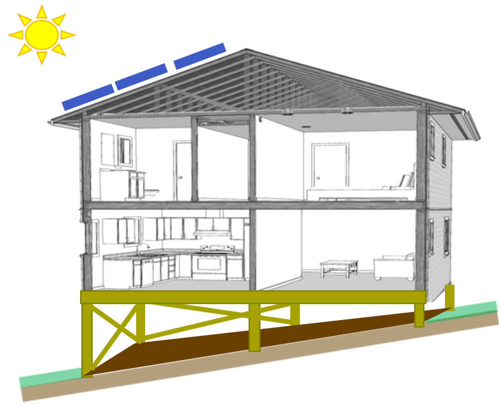
Simple Design Approaches to Zero Carbon



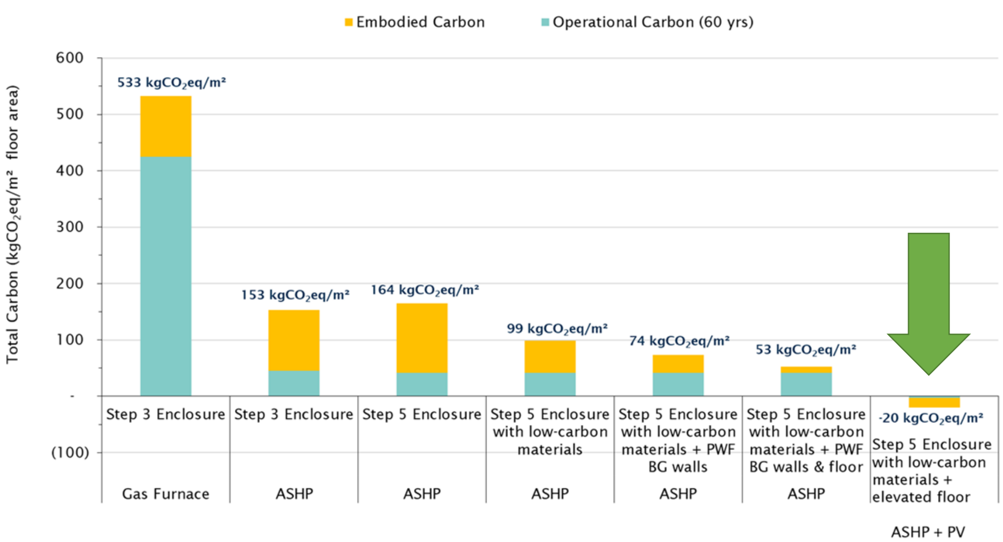


- Elevated house on wood or steel foundation system, no basement or slab on grade *(bonus flood resilience)*
- Same total floor area, all wood-frame assemblies and floor trusses. Use of biogenic, carbon storing insulation fill for suspended floor *(low risk use)*
- Added PV on roof relative to size of house needs
- Used current grid emissions factor to calculate offset

101

Possibility of Net Zero Carbon Buildings

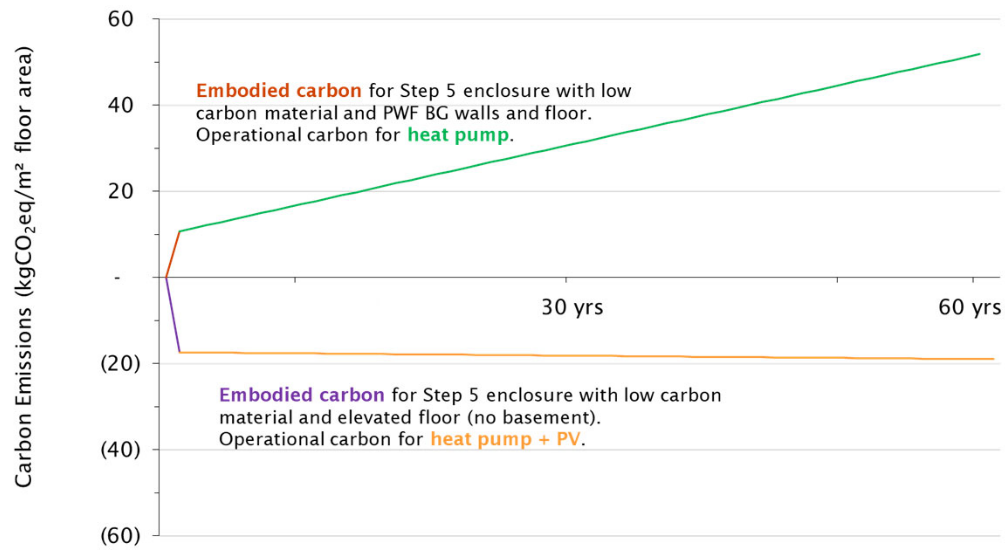
Design to Minimize High Carbon Materials, Electrification, PV Offset



102

True Possibility of Net Zero Carbon Buildings

Design to Minimize High Carbon Materials, Electrification, PV Offset



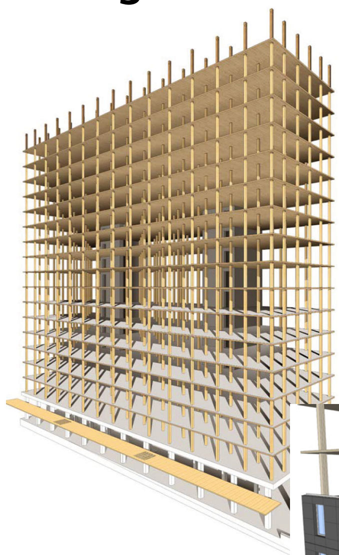
103

Key Points

- **Operating Carbon Opportunities <u>Continue</u>**
  - Energy efficiency – airtight, well insulated enclosure, optimal window selection, efficient mechanicals
  - Electrification w/ consideration for the grid
- **Embodied Carbon Opportunities <u>Arise</u>**
  - Material of lower GWP potential materials
  - Biogenic materials (Wood & wood fiber, straw, hemp etc.) have impactful sequestration benefits and could offset portion to all of rest of house materials
  - Watch placement and durability of bio-based materials
  - New opportunities will continue to develop

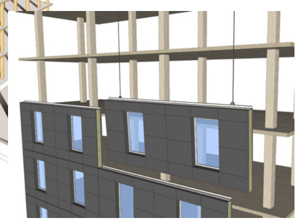
104

Larger Scale New and Existing Building Opportunities



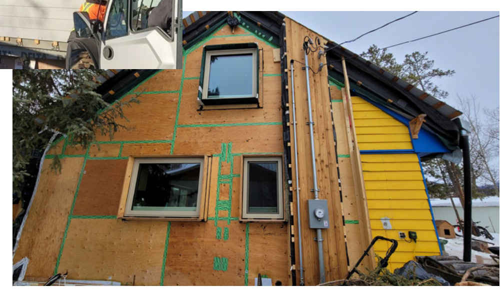
Larger buildings = different opportunities and practicalities

Unique carbon considerations for façade elements



Deep Energy Retrofits for All Existing Building Types

Watch embodied and operational carbon interplay



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105

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109

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RDH BUILDING SCIENCE

Net-Zero Energy and Carbon Building Design: Feasibility in Northern Canada and Alaska

Presenter: Robin Urqhart
Date: November 16, 2022
Time: 1-2pm ET / 10-11am PT
Cost: Free!

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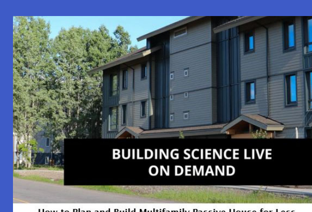

110