Achieving Net Zero Carbon Designation for Builders

NET ZERO CARBON
BUILDING PROFESSIONAL

EEBA

In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

"This educational offering is recognized by the Minnesota Department of Labor and Industry as satisfying **1.5 code/energy hours** of credit toward **Building Officials and Residential Contractors** continuing education requirements."

For additional continuing education approvals, please see the continuing education credit section in the conference agenda booklet.

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Agenda

- The compelling trend beyond an energy focus to a zero carbon imperative
- Introduction to Operational and Embodied Carbon
  - A case study contrasting an energy rating versus carbon accounting
- Carbon Accounting Metrics and Tools
- Design and Material Selection Opportunities to Optimize Carbon Reductions
- Next Steps for designers and builders

Who's here and What would you like to talk about??

The Energy Focus

Since the 1970's

Reduce the reliance on foreign energy

Reduce waste

- Research
- Voluntary programs such as ENERGY STAR
- Manufacturer innovations
- Code and Standards improvements

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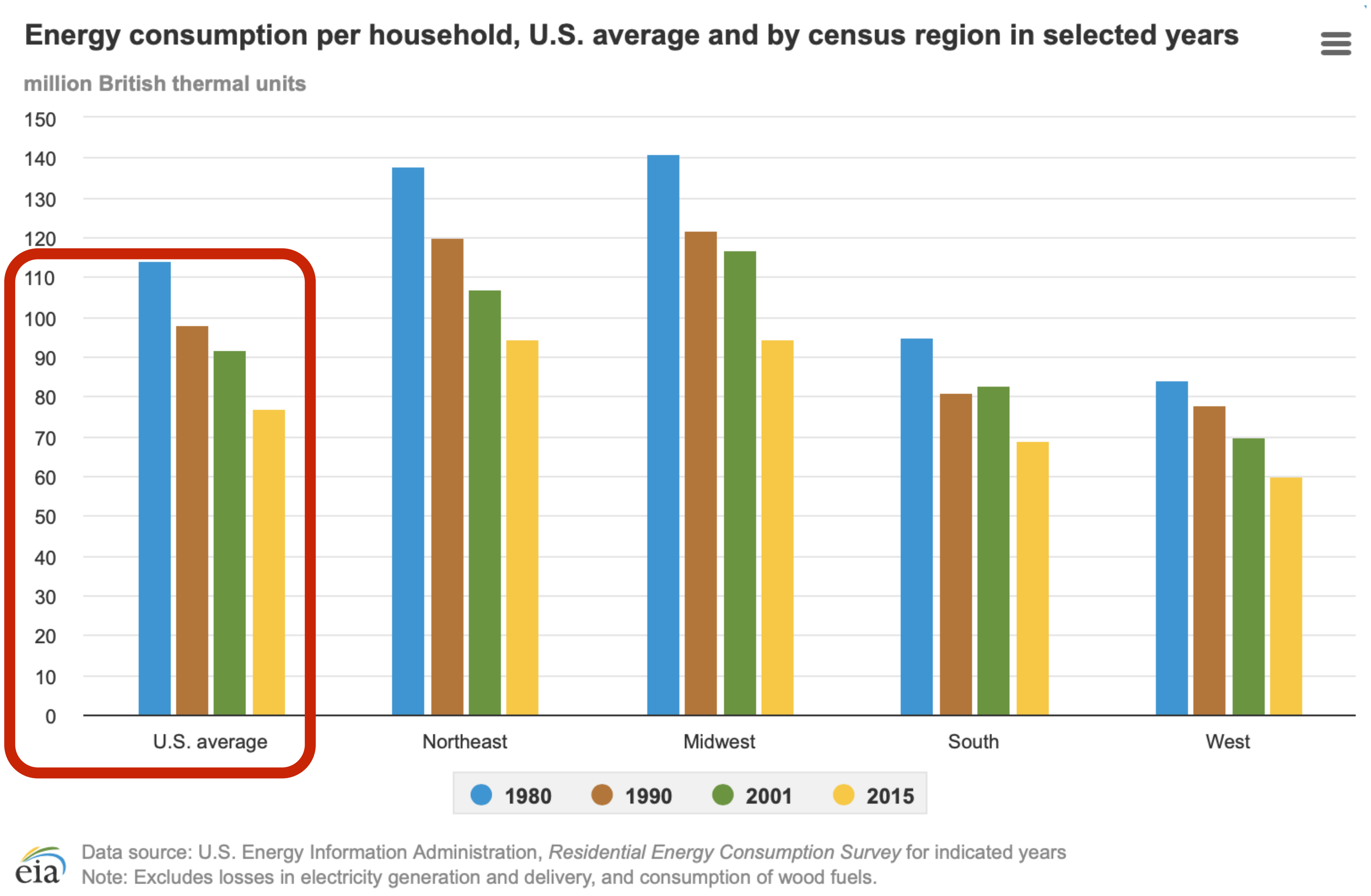
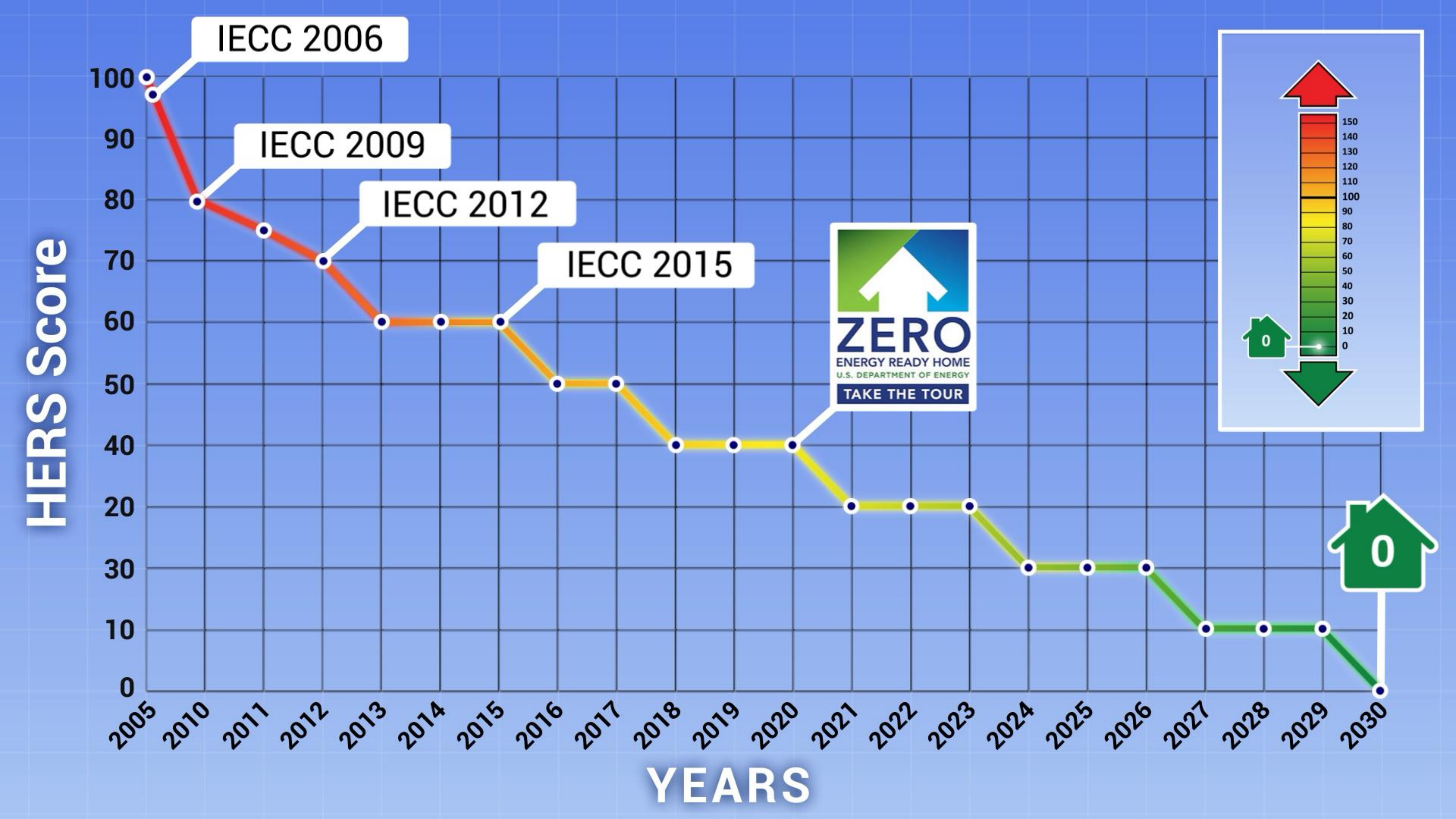
The Energy Focus



Since 1980

A 34% reduction per household

Despite houses getting bigger



IECC 2006
IECC 2009
IECC 2012
IECC 2015
ZERO
ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY
TAKE THE TOUR
HERS Score
100
90
80
70
60
50
40
20
30
10
0
2005
2010
2011
2012
2013
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YEARS
0
150
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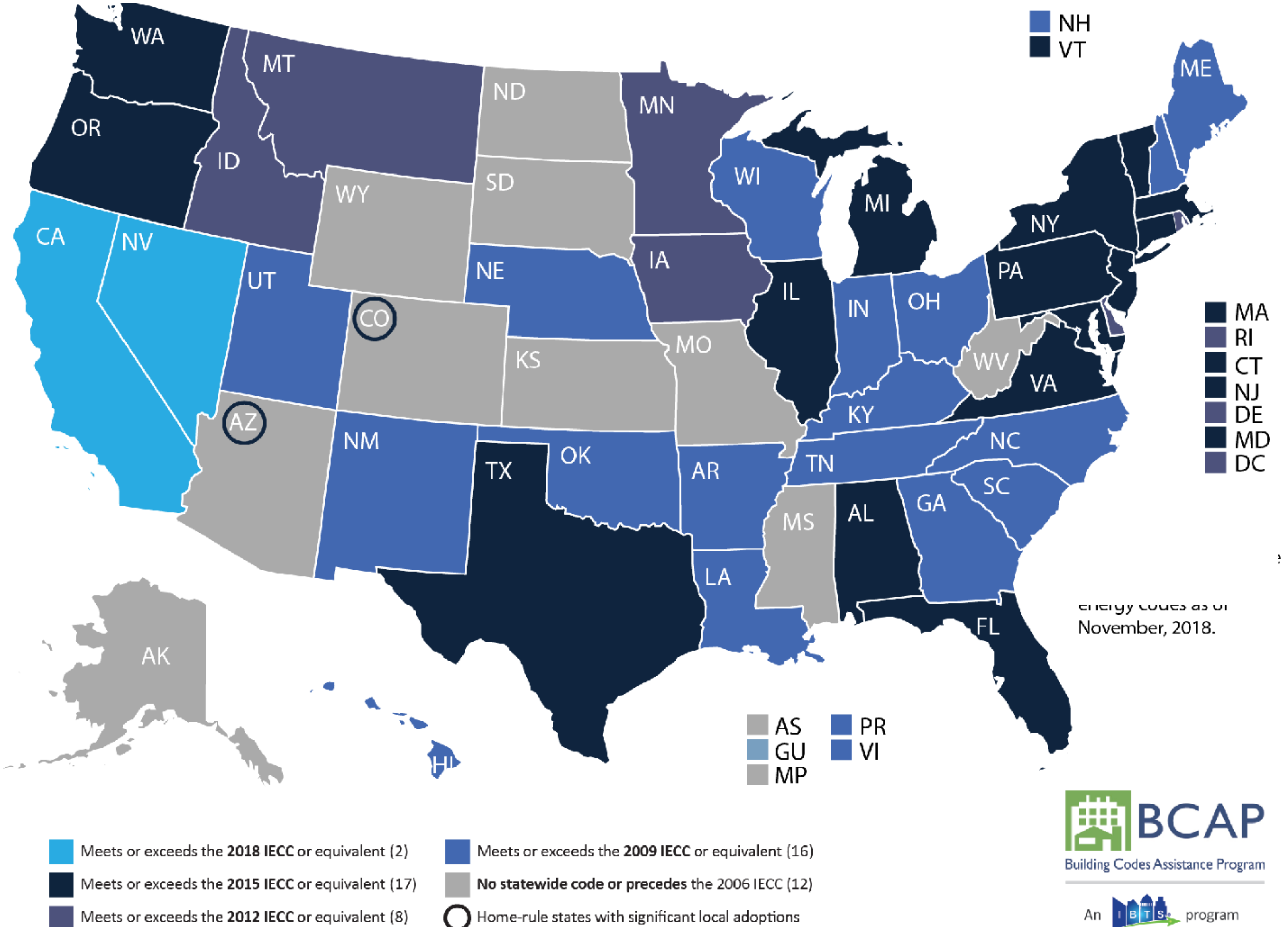
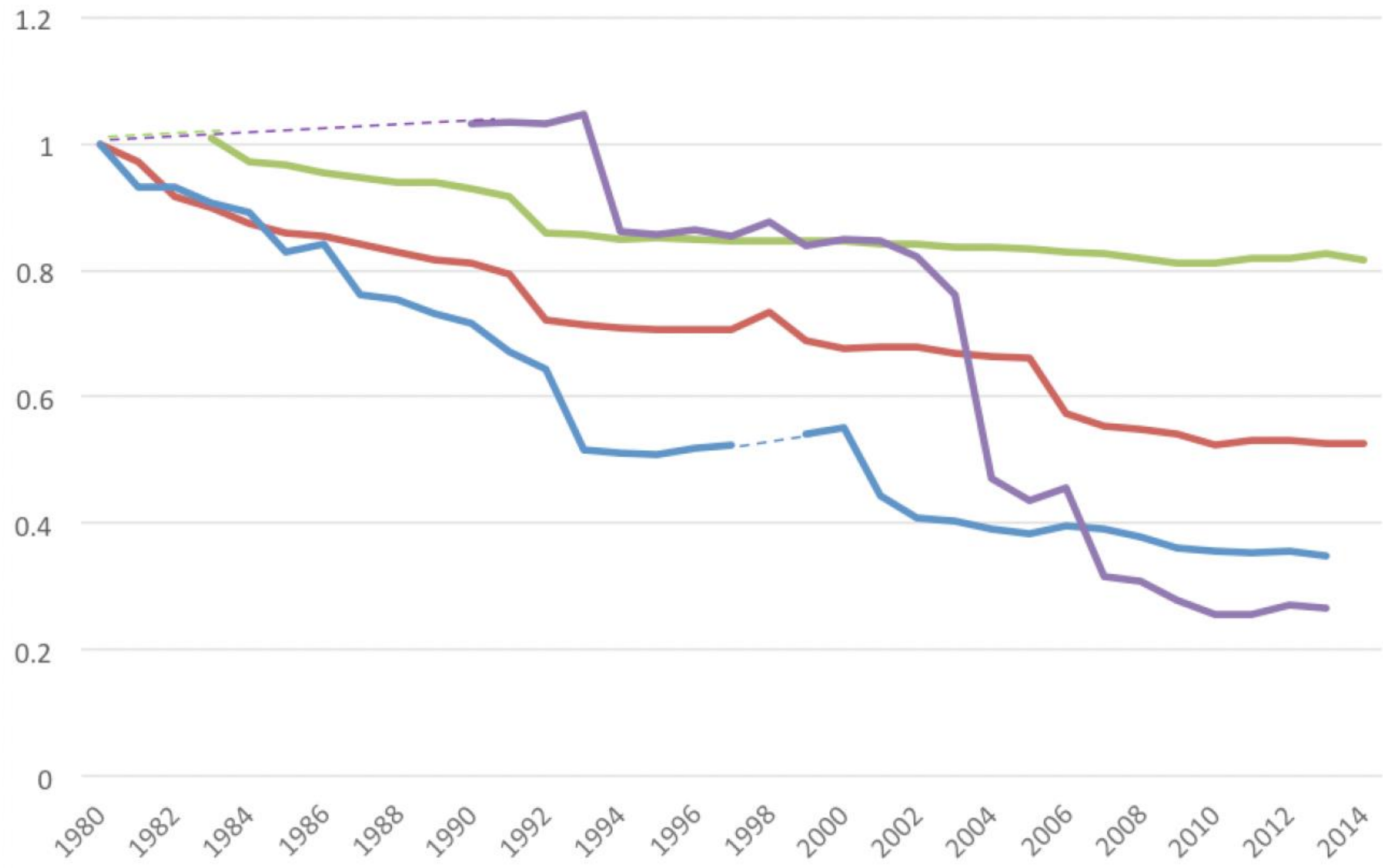
0

Residential Code Adoption
as of March 2022



The Energy Focus - Appliances improved



Gas furnaces - 20%

AC & HPs - 50%

Refrigerators - 65%
Clothes washers - 75%

Figure 5. Relative average energy consumption of new appliances sold over the 1980–2014 period (2014 r data not yet available). ***Source:*** **ACEEE analysis of data from Air-Conditioning and Refrigeration Institute, As Manufacturers, Lawrence Berkeley National Laboratory, and confidential industry sources.**

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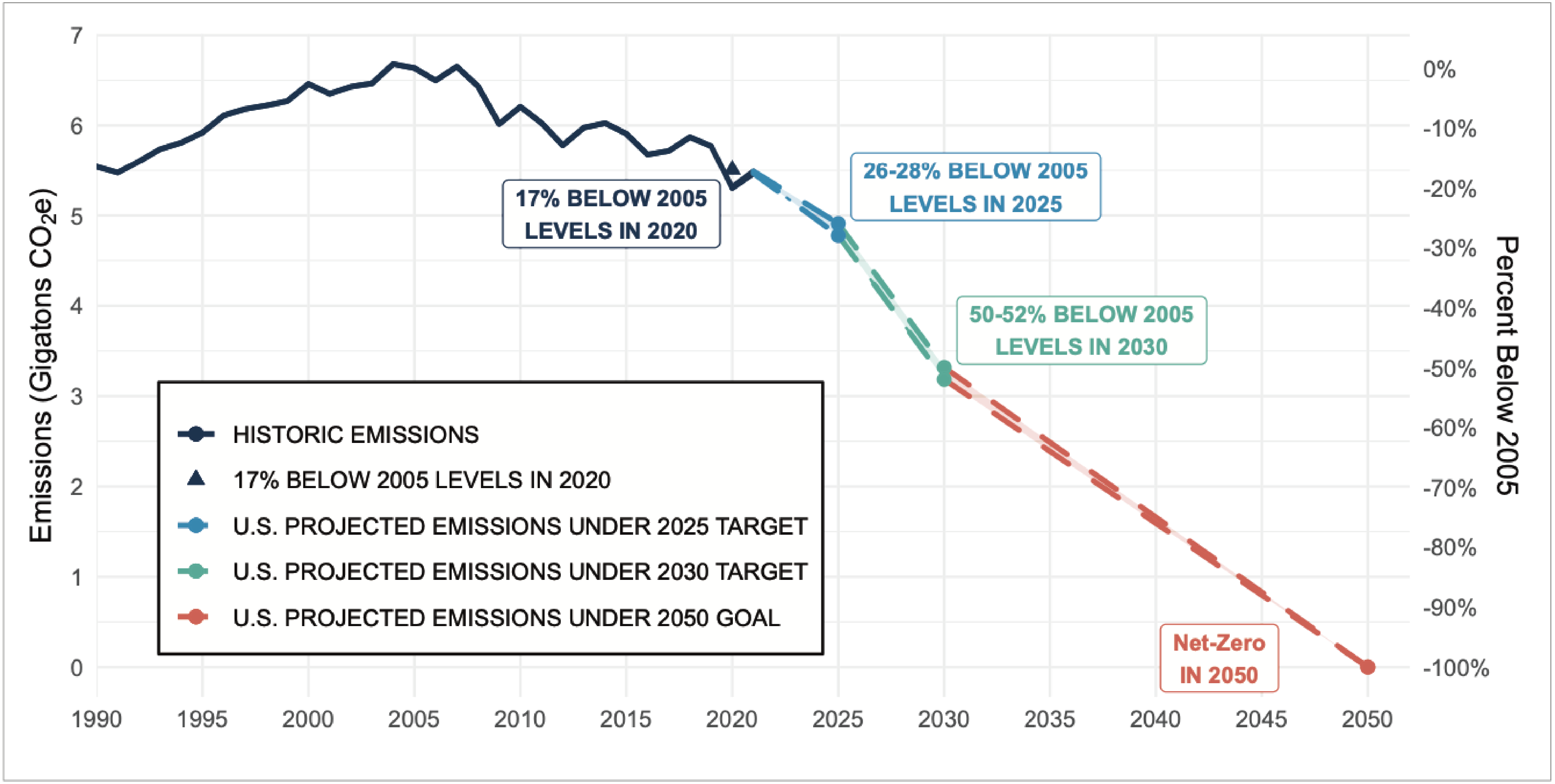
The New Imperative - Greenhouse Gas Emissions



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Zero by 2050

The Challenge - There is still an affordable housing crisis

WHY IS IT IMPORTANT?

The built environment is growing at a record pace in the United States. In just one sector, it is estimated that 2.5 million new housing units are needed to make up for the nation's housing shortage.[10] To reduce the GHG emissions associated with that construction, communities need to act now to create embodied carbon strategies that reduce environment impacts from buildings we'll use well into the future.

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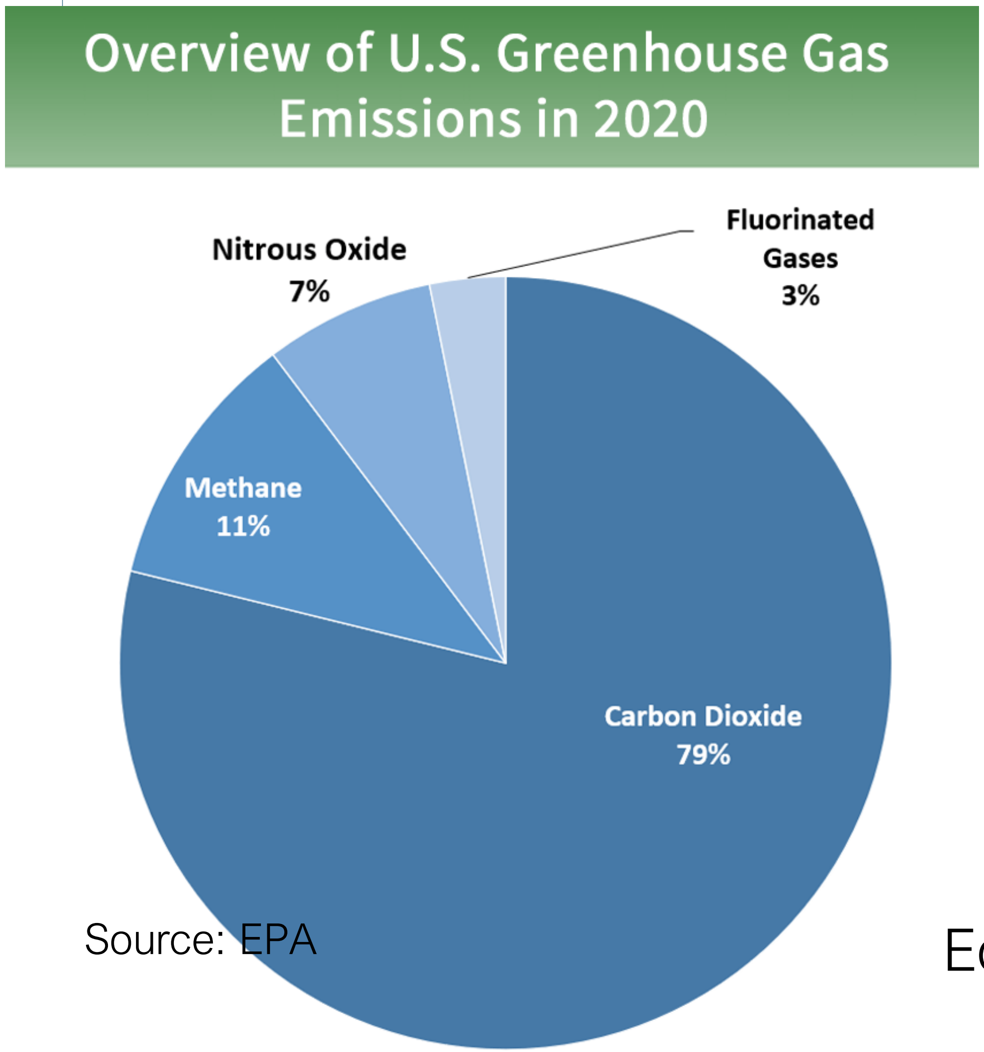
Greenhouse Gas Fundamentals



Source: EPA

U.S. Environmental Protection Agency (2022). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020

- Gases that “trap” heat in the upper atmosphere.
- Producing, processing and burning of fossil fuels is most significant
- Chemical and agricultural processes are a significant source
- Carbon dioxide can be absorbed and sequestered.
  - Forests and bio-based building products for example
- Each gas has a Global Warming Potential (GWP)
- GWP is often expressed as a comparison to 1 ton of CO_2.

In this workshop we will use Carbon Dioxide Equivalents (CO_2e) in all calculations and exercises Kg and Tonnes

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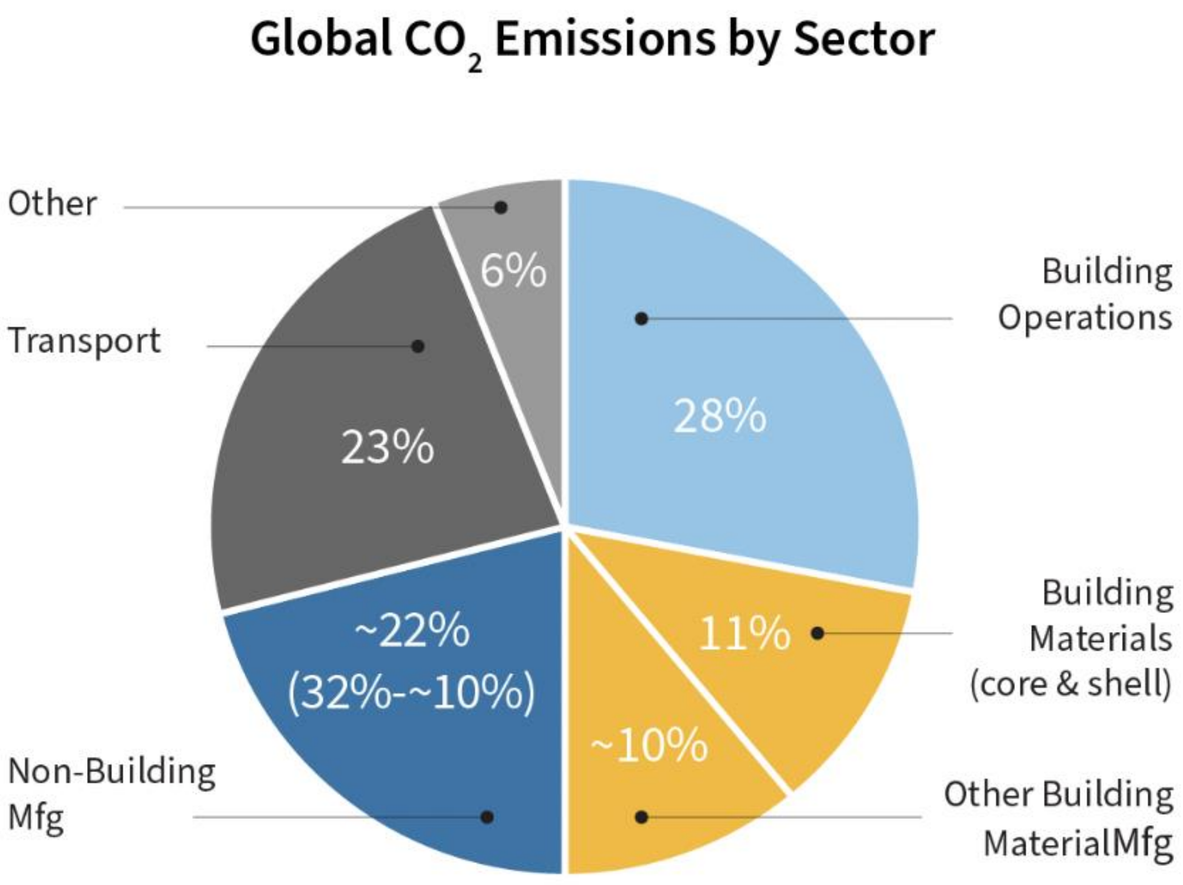
The New Imperative - Greenhouse Gas Emissions

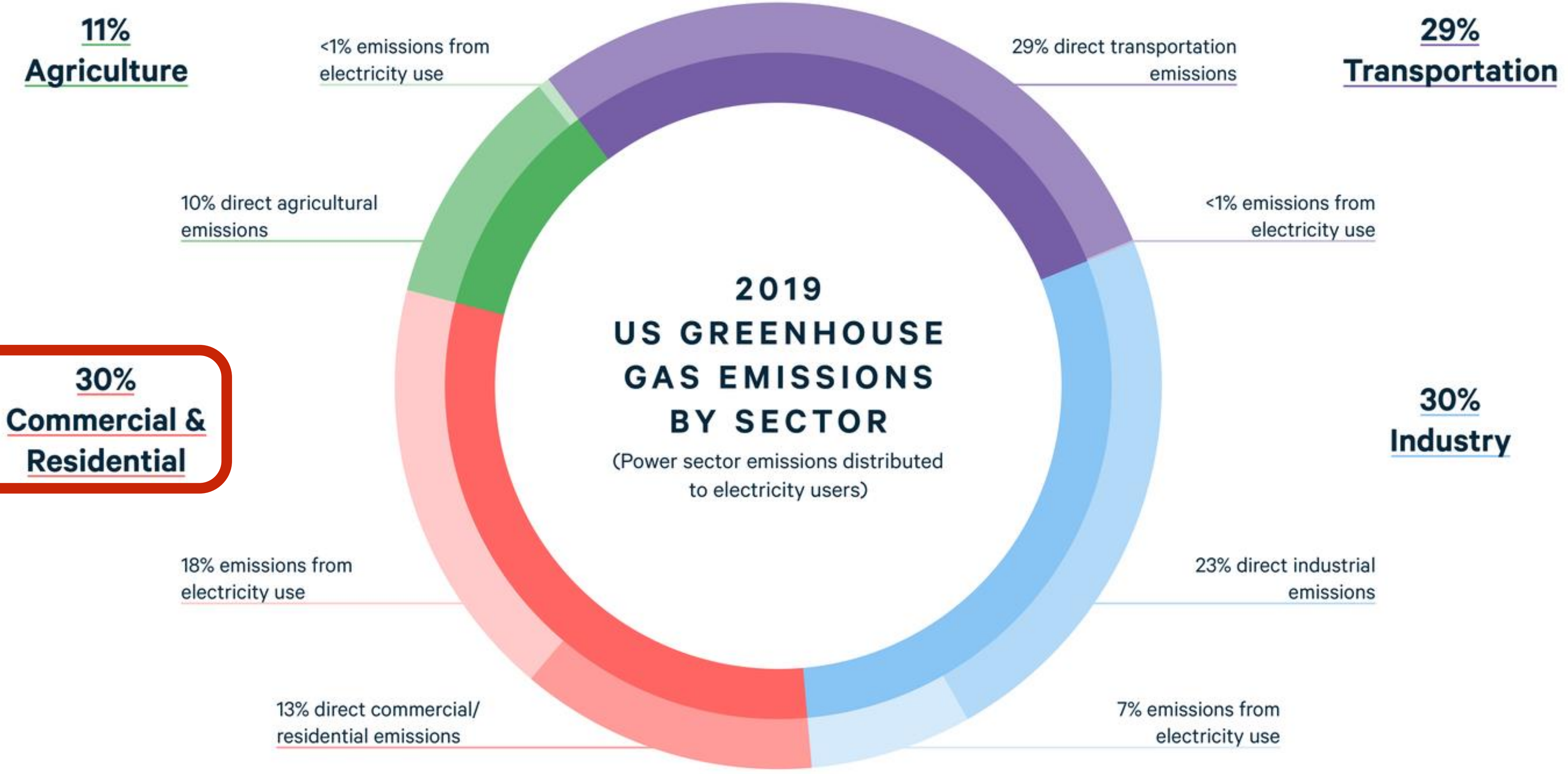


Adapted from 2019 Global Status Report, Global Alliance for Building and Construction (GABC) and Architecture 2030.

Buildings are a significant opportunity for meeting global targets

Operations + Construction

The New Imperative - U.S. Greenhouse Gas Emissions



Source: EPA Greenhouse Gas Inventory 2019

RFF

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Builder & Developer

Environmental Social Governance **ESG** Reporting

Finance Applications & Development Approvals

“No Longer Just a One-Off Trend
To be sure, Meritage is hardly alone as an ESG-focused home builder anymore. Visit the websites of industry stalwarts such as Beazer Homes, Century Communities, D.R. Horton, K. Hovnanian, KB Home, LGI Homes, Taylor Morrison, Toll Brothers, and Tri Pointe Homes, and you’ll see a section on ESG highlighted either directly from the homepage or on the investor relations page “
Builder Mag April 2022

Of the largest Homebuilders in the US, 8 of 10 are now producing ESG or Carbon Benchmarking Reports

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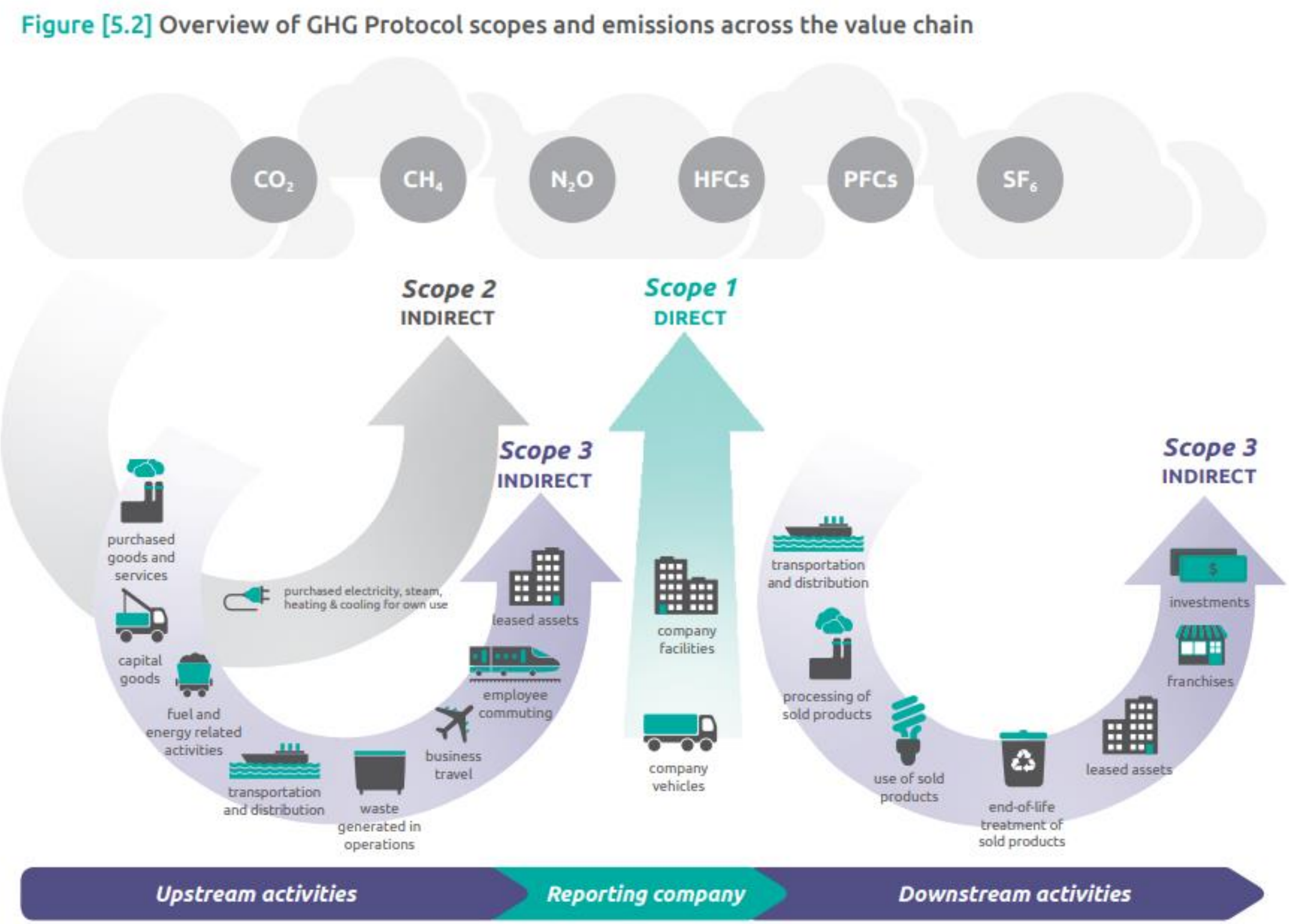
Emissions Scope 1,2,3 – What does this mean for Homebuilding

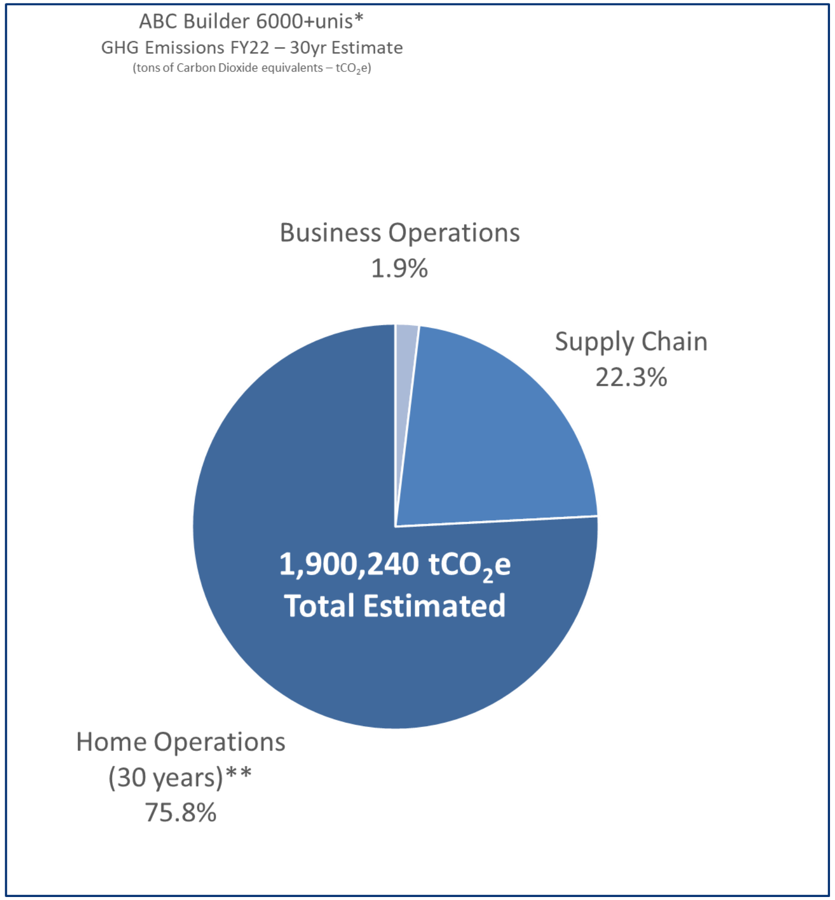


2021 World economic Forum

Emissions Scope 1,2,3 – What does this mean for Homebuilding

	Business Operations	
Scope 1 - Direct Control	Scope 1	Natural Gas
		Fleet Fuel
Scope 2 - Indirect Control	Scope 2	Electricity
		Steam (66 Wellington ONLY)
Scope 3 - All Other Emissions	Scope 3a	Air Travel
		Hotels
		Car Rentals
		Employee Commute
	Supply Chain	
	Scope 3b	Purchased Goods & Services
		Energy Related Activities
		Transportation & Distribution
		Waste & Recycling
	Home Operations	
	Scope 3c	Natural Gas – Heating
		Electricity – Heating/ Cooling/ Plug Loads

Estimate for FY22 based on FY20 results and estimates for Supply Chain and Home Operations



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Carbon Emissions

‘Upfront’ Embodied Carbon

Manufacturing, transportation, and installation of construction materials

Operational Carbon

Building energy consumption

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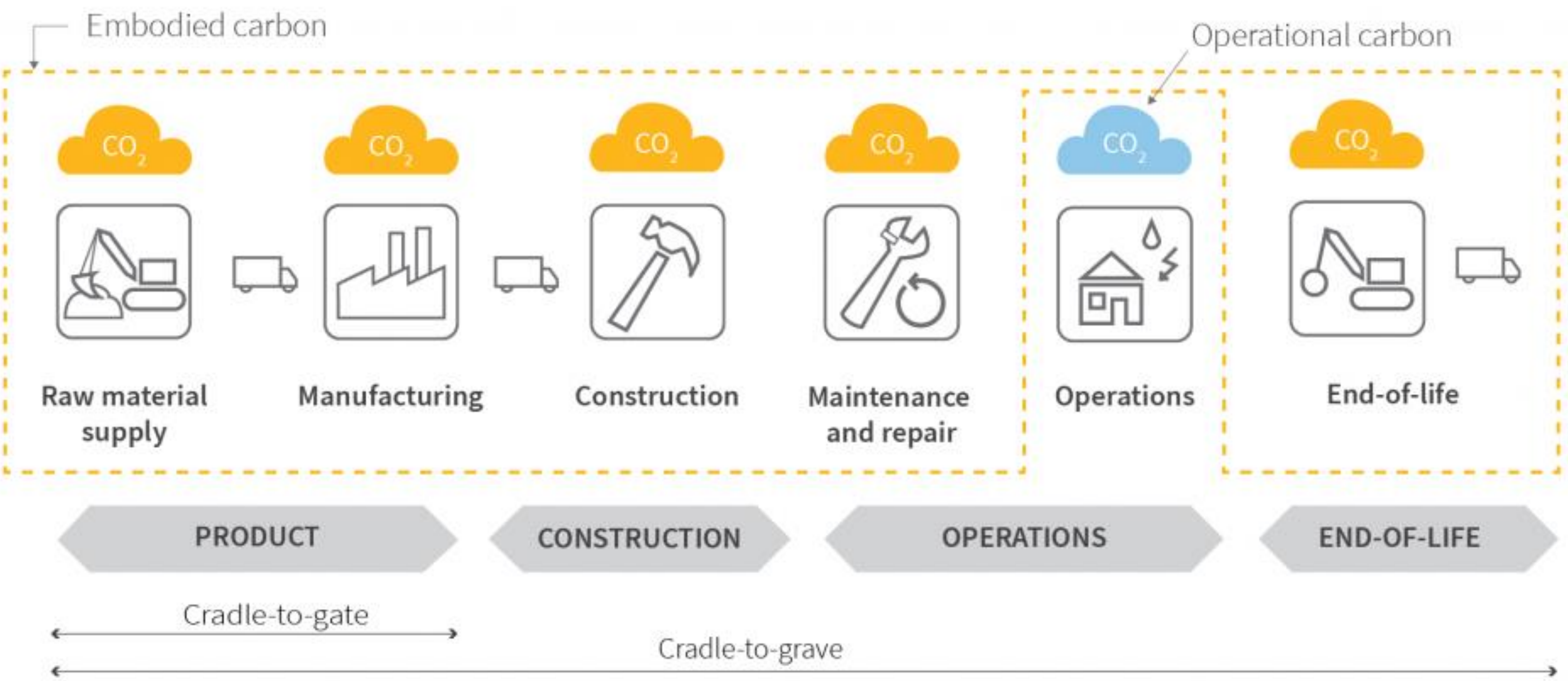
Building Lifecycle



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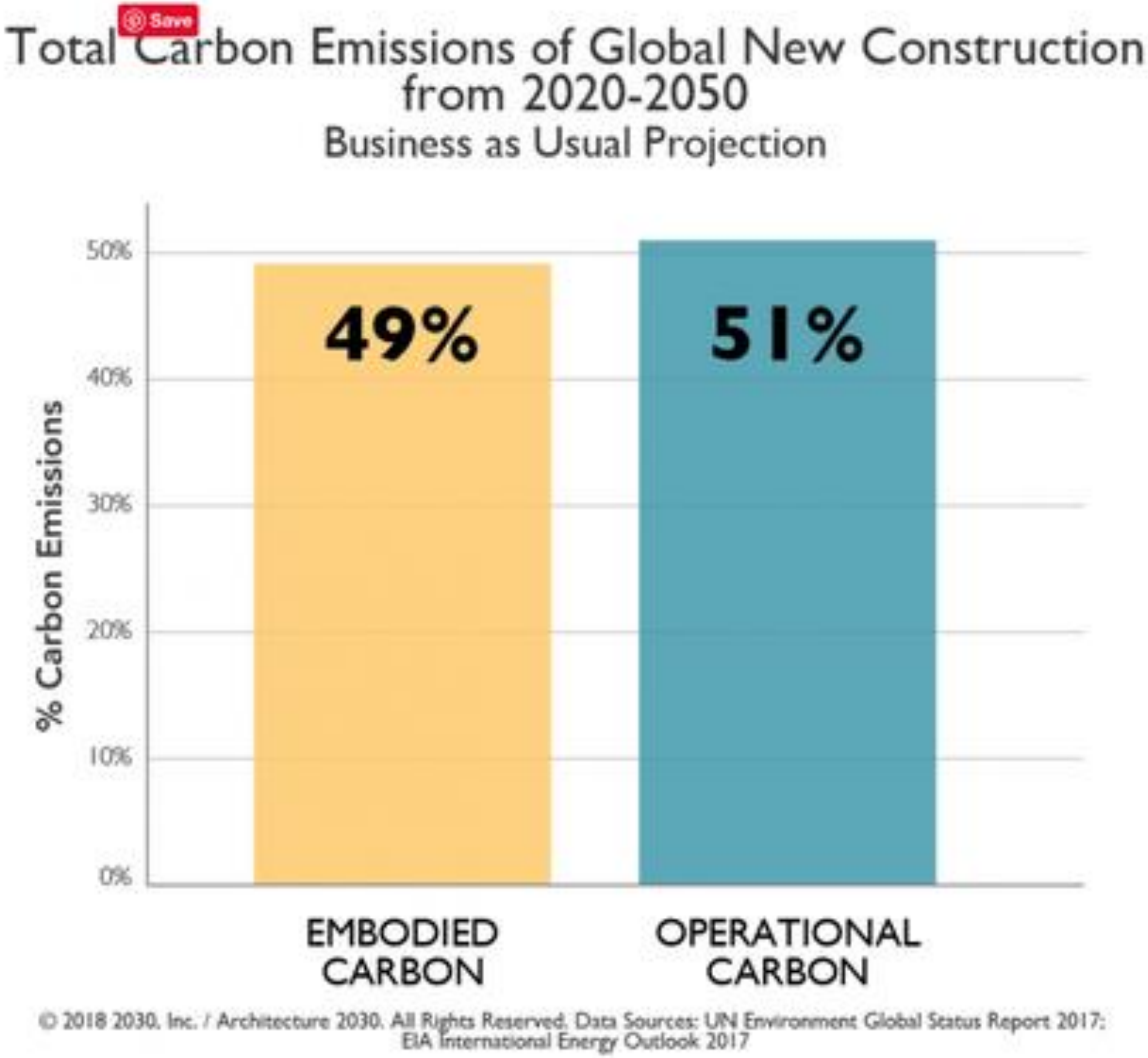
Embodied Carbon vs Operational Carbon



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Energy vs Carbon : The choices are complex

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Embodied Carbon

- Passive Homes/ Net Zero Energy homes(Lots of insulation material), may need to operate for **100+ years to offset embodied energy of materials(concrete, insulation,etc)**
- Organic Cotton bag may need to be **used 20,000 times** to be an improvement over a plastic, single use bag
- Stainless steel water bottles embodied carbon is **14x greater than single use plastic bottle**

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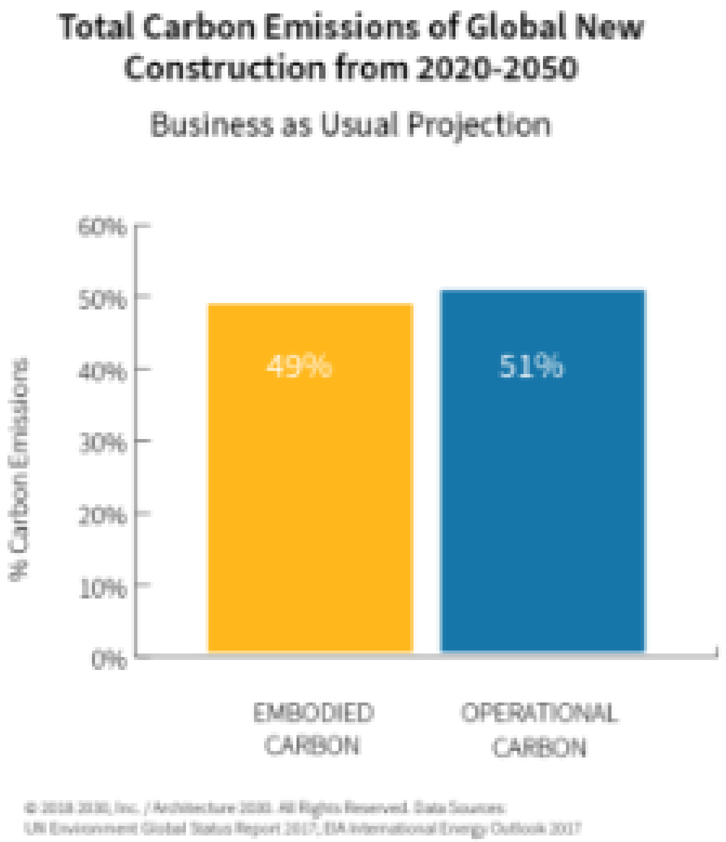
Why Embodied Carbon is focused in Construction:



The world's building stock is expected to double by 2060 — that's equivalent to adding an entire New York City to the planet every month for the next 40 years.

This is good news for home builders. However, without some changes in how we produce buildings, it's bad news for climate change and carbon emissions.

Cement — a key ingredient that gives concrete its strength — is also one of the largest emitters of CO2 in the built environment.

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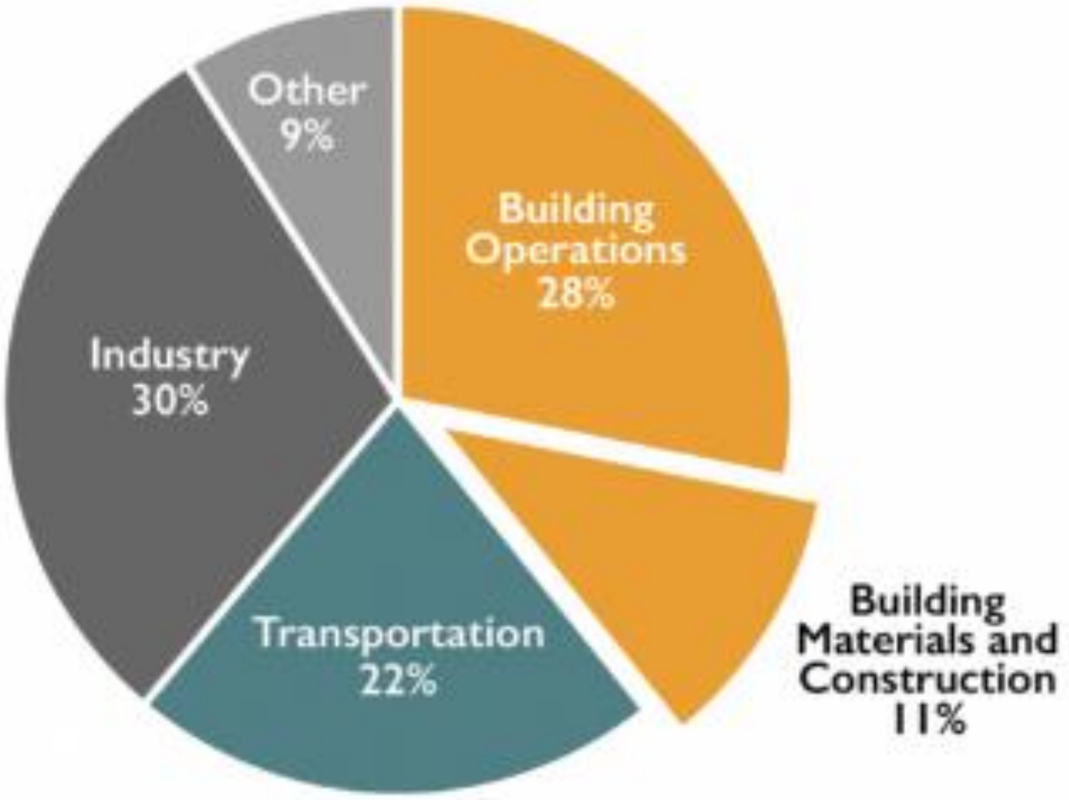
Embodied carbon is expected to account for nearly 50% of the overall carbon footprint of new construction between now and 2050.

Annually, embodied carbon is responsible 11% of global GHG emissions and 28% of global building sector emissions.

The embodied carbon emissions of building products and construction represent a significant portion global emissions: concrete, iron, and steel alone produce ~9% of annual global GHG emissions; embodied carbon emissions from the building sector produce *11% of annual global GHG emissions.*

Global CO_2 Emissions by Sector



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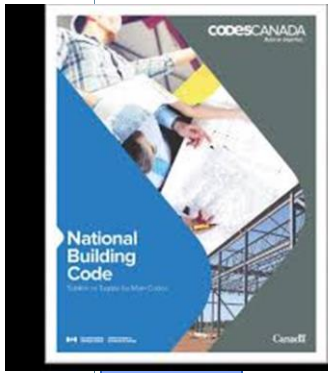
Proposed NBC CANADA 2020 Tiered Energy Code Part 9.36

netzero readyhome
The ultimate in comfort and efficiency



2015 NBC 9.36 improvement

Tier 1 -0% improvement

Tier 2 -10% improvement

Tier 3 -20%

Tier 4 -40% improvement

Tier 5 -70% improvement

What is the impact of a tiered ENERGY codes on EMBODIED CARBON?

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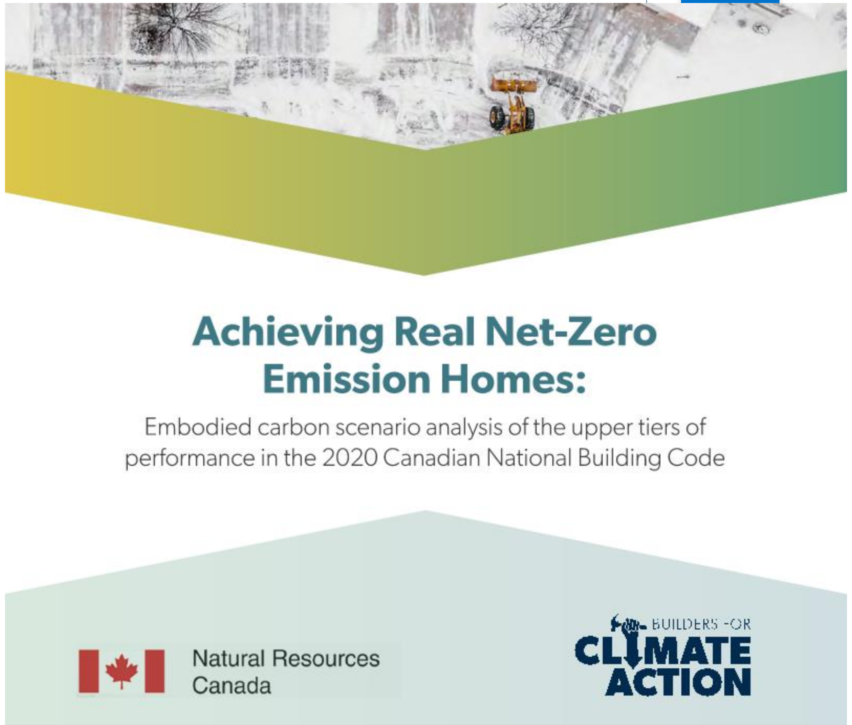
Energy vs Carbon : The choices are complex

The increase of 93 kg CO_2e/m^2 in MCE between Tier 3 to Tier 5 for the high carbon material selection (HCM) model presents a cautionary warning that the pursuit of energy efficiency without consideration of material emissions can cause dramatic increases in overall emissions.



https://www.buildersforclimateaction.org/report---embarc-report.html

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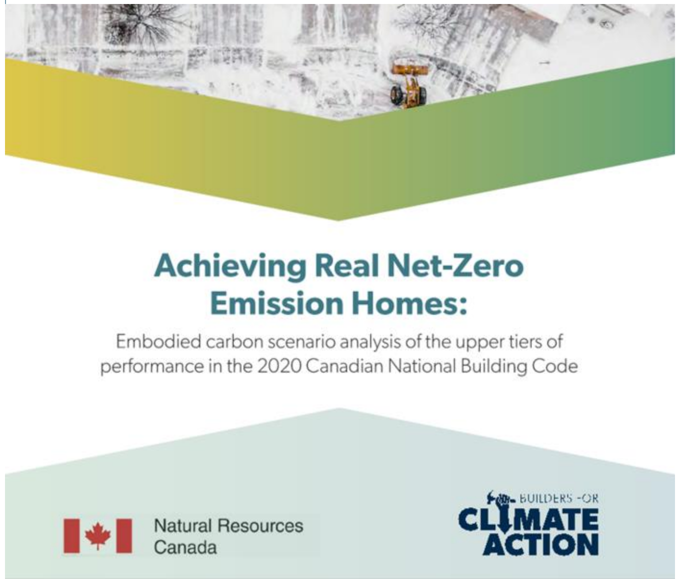
Energy vs Carbon : The choices are complex



"In 2021, Natural Resources Canada (NRCan) released the report "Achieving Real Net Zero Emission Homes " establishing that **material carbon emissions (MCE) for new homes will outweigh operational carbon emissions (OCE) for electrified homes using relatively clean electrical grids such as that in the Greater Toronto and Hamilton Area (GTHA) for almost 120 years.**

At the highest levels of energy efficiency proposed by codes, this imbalance extends to 166 years of OCE to equal MCE"

https://www.buildersforclimateaction.org/report---embarc-report.html

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A house is a 30 year product with emissions

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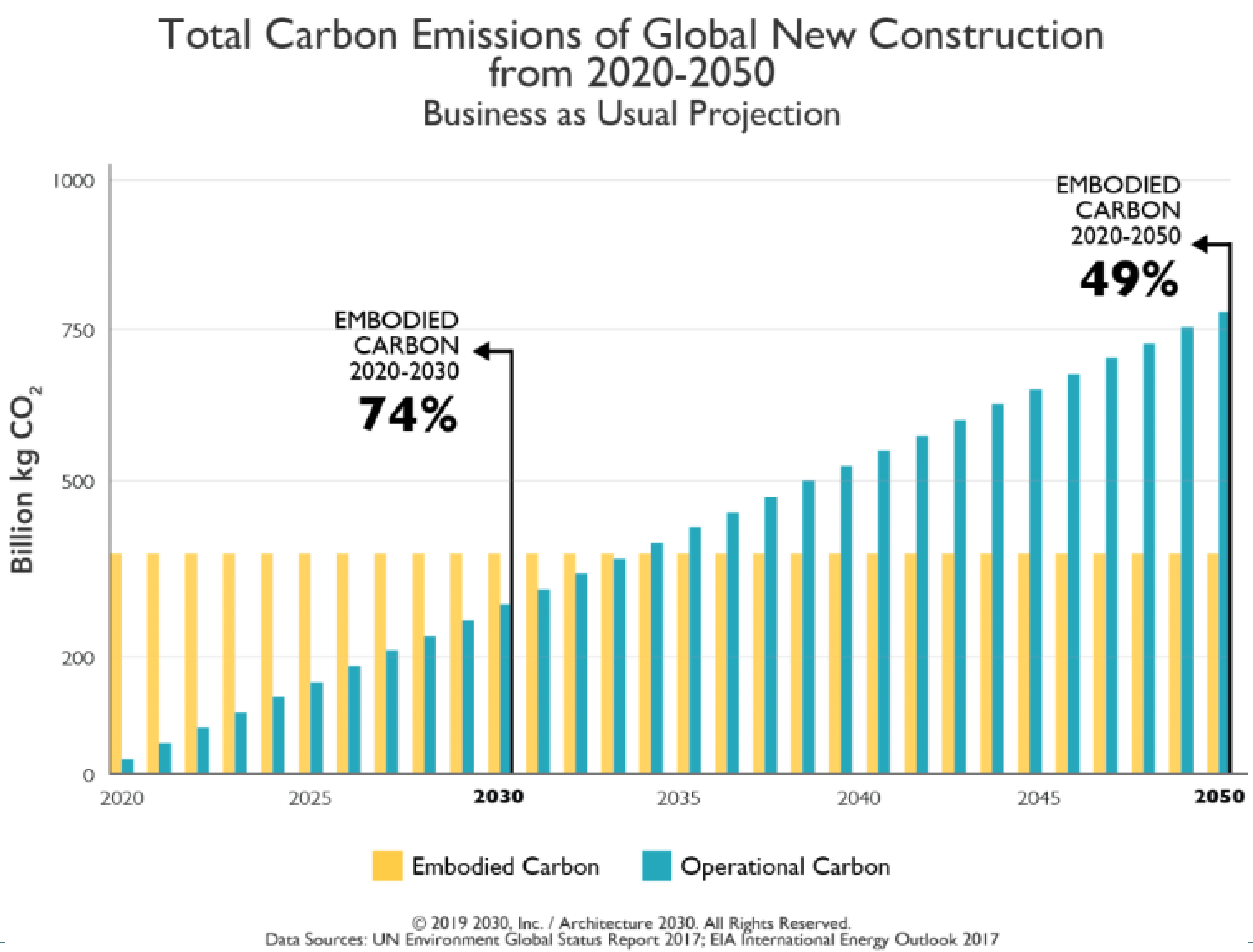
Embodied Carbon vs Operational Carbon



WHY Embodied Carbon BECOMES MORE IMPORTANT WITH TIME

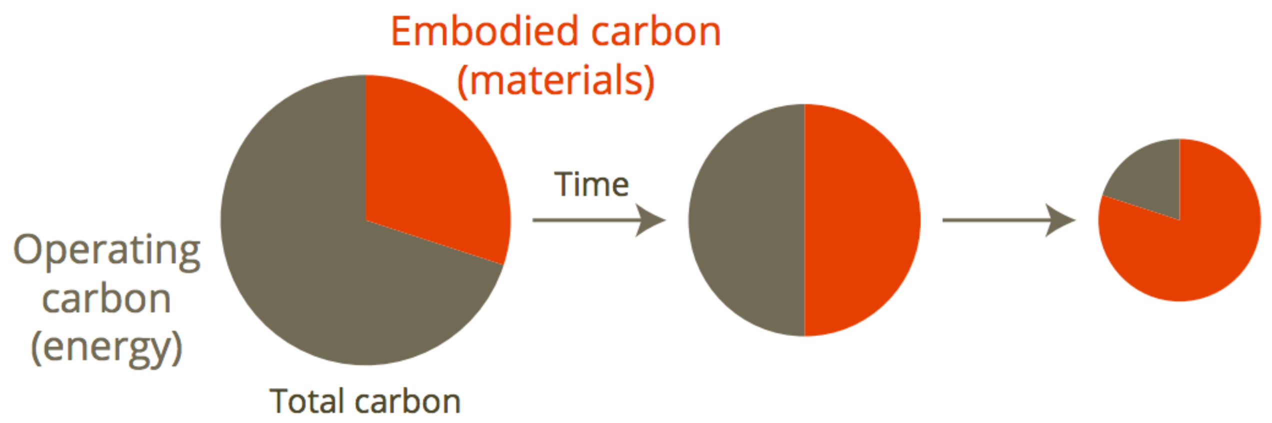
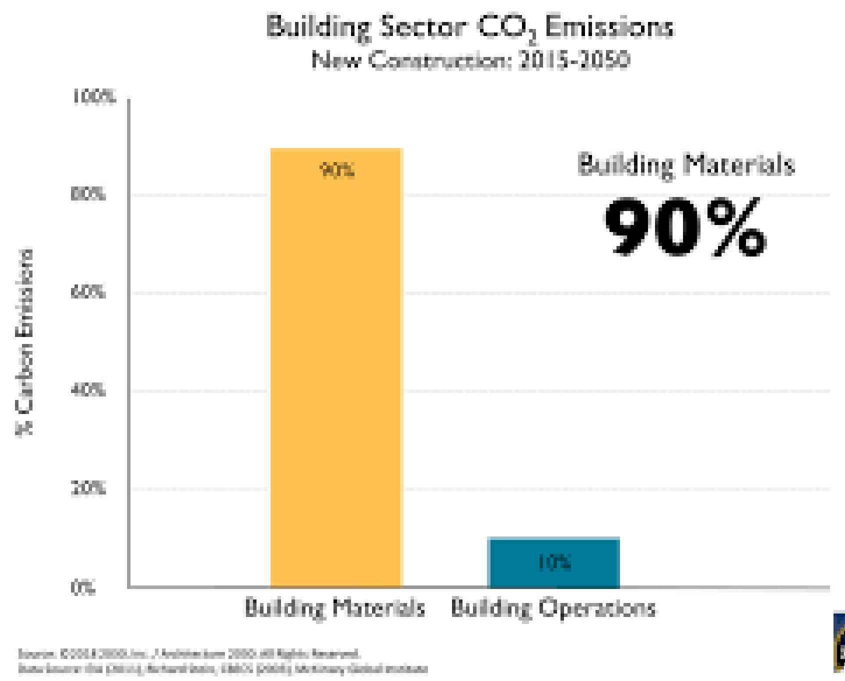


Figure 1. Growing importance of embodied carbon as building operational energy decarbonizes



Scenario assumes decarbonization of grid-energy…..But we need to know what THAT(decarbonisation of grid) means for our future.

Carbon is coming to building codes

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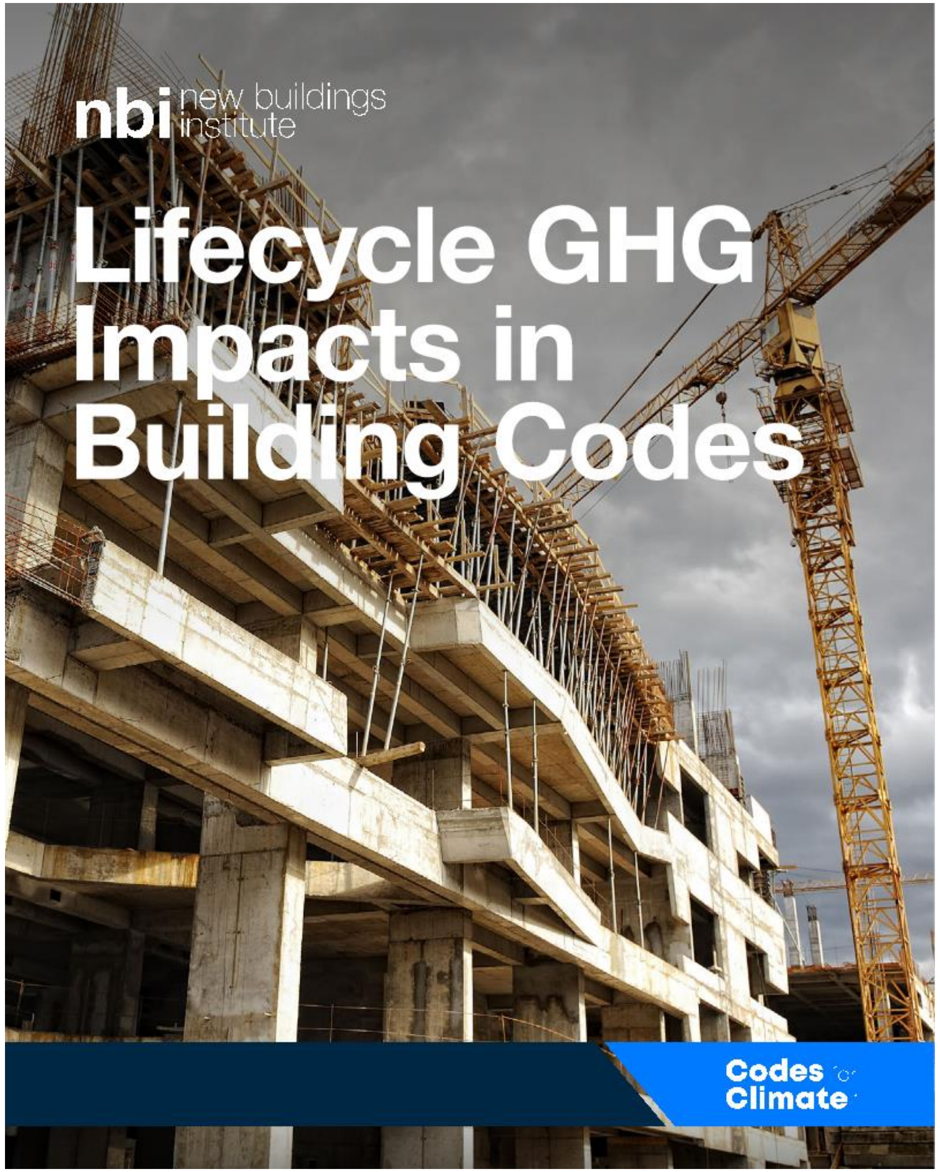

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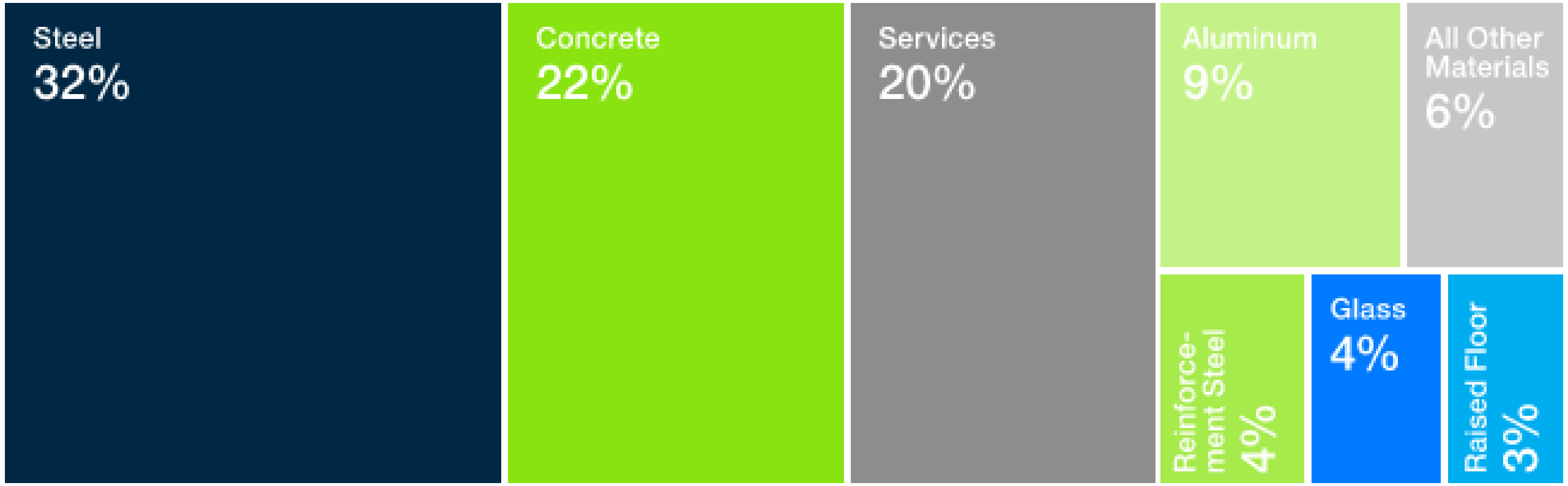
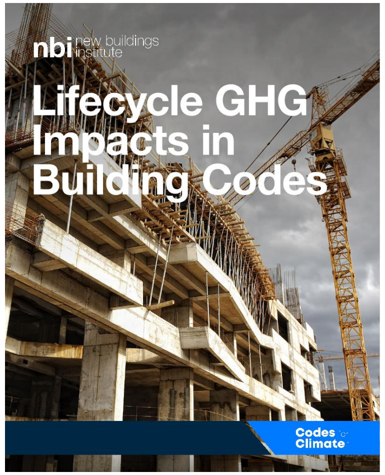
Carbon is coming to building codes

Carbon Emission Benchmarking is first step.

Carbon Emission Reduction is step 2 .





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Carbon is coming to building codes

For Low Rise Residential the picture is a little different …

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

Prepared for
Meeri Durand, Manager of Planning, Development & Sustainability, City of Castlegar
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Prepared by
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Natalie Douglas, Embodied Carbon Pilot Coordinator, City of Nelson

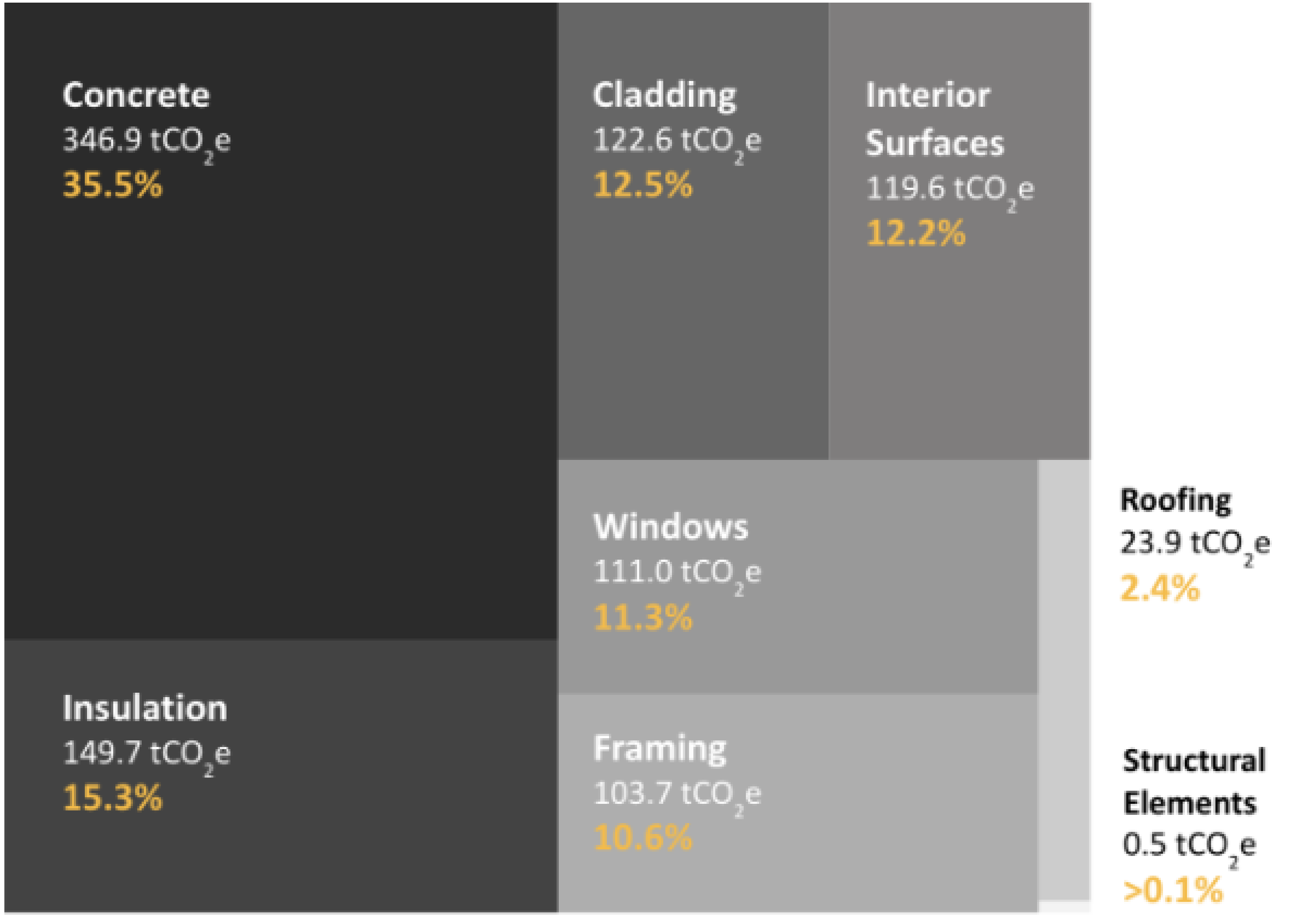

Figure 5. *This tree chart illustrates which materials contributed the most amount of overall emissions across all 34 case study homes.*

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Carbon is coming to building codes

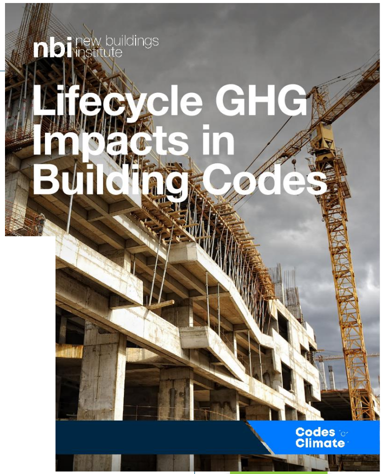

TABLE B: MATERIAL MAPPING OF BUILDING CODES

	Building Code	Residential Code	Mechanical Code	Plumbing Code	Electrical Code	Green Code	Energy Code
Primary Systems							
	Structural, envelope	All	Air supply, distribution, conditioning	Water supply, disposal, hot water	Electrical service, wiring, and systems	Site, Materials, Energy, IAQ,	
Materials Covered							
Concrete	X	X	X	X		X	
Steel	X	X	X	X			
Glass	X	X					
Aluminum	X		X				
Wood	X	X					
Copper			X	X	X		
Plastic	X	X	X	X			
Insulation	X	X	X				
Refrigerants			X			X	

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Carbon is coming to building codes AND to Home Performance Ratings

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Carbon is coming to building codes AND to Home Performance Ratings

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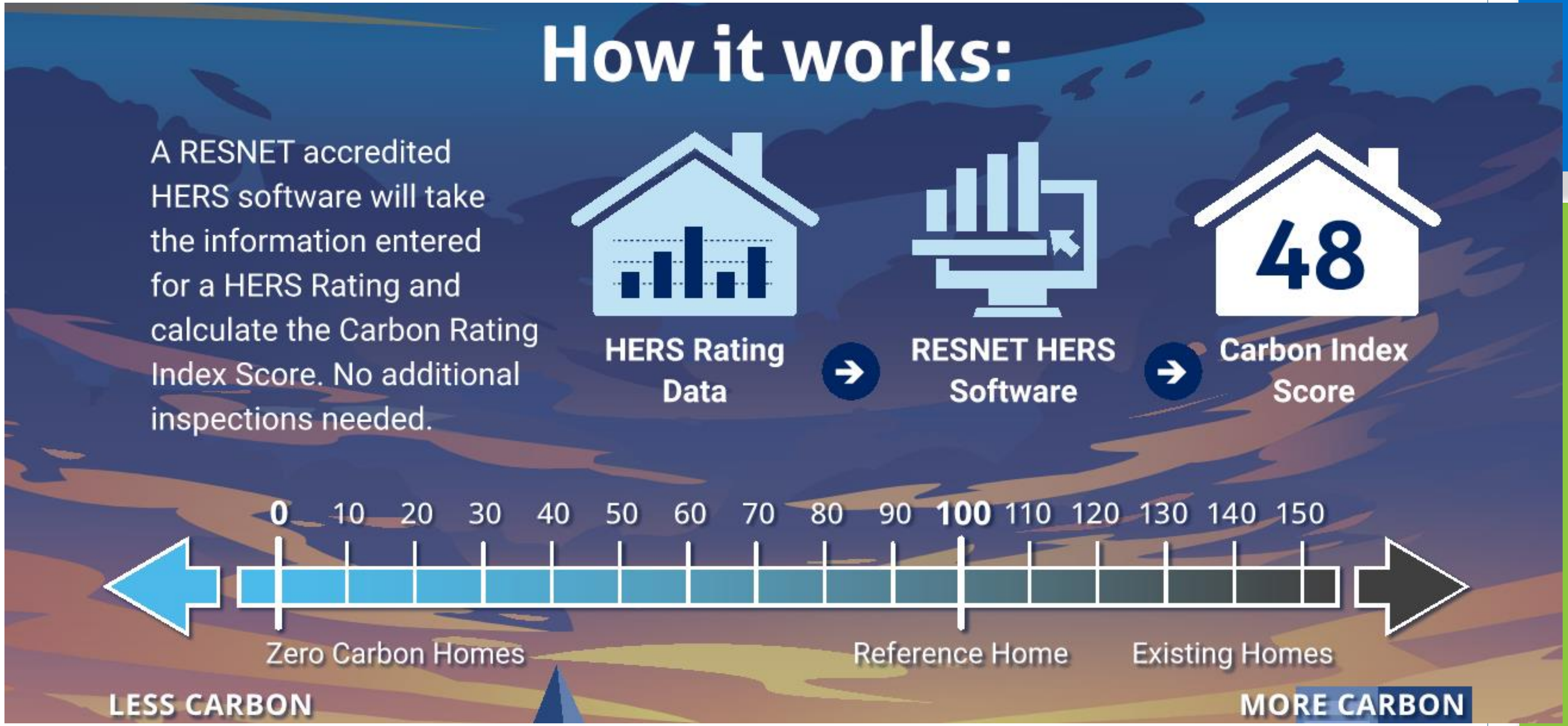
Carbon is coming to building codes AND to Home Performance Ratings



For more information, visit
resnet.us/co2eindex

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Carbon is coming to building codes AND to Home Performance Ratings

Are we ready for this ?

What can we do to prepare ?

GWP Global Warming Potential
Carbon “equivalency”

Global Warming Potential (GWP) Factors

GWP factors depend on

- How much heat is trapped by 1 kg of the GHG (or some other unit of mass)
- How long the GHG persists in the atmosphere
- Time horizon over which the heat trapping is being considered (usually 100 years → GWP100)

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Greenhouse Gases Important for Buildings

There are thousands of GHGs; a few are **very important in buildings**:

- **Carbon dioxide (CO_2)**
- **Methane (CH_4)**
- **Nitrous oxide (N_2O)**
- **Fluorinated gases**, such as hydrochlorofluorocarbons (HCFCs) – used as propellants (spraying) and refrigerants (for cooling systems)

  E.g., R-134a (HFC-134a) - CF_3CH_2F - used in cooling

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Global Warming Potential (GWP) Factors

Some greenhouse gases (GHGs) trap more heat than others

- If 1 kg of methane (CH_4) is emitted, how much heat will be trapped compared to CO_2 over a 100-year timeframe?

This is the global warming potential (GWP100) of CH_4

- 1 kg of CH_4 is equivalent to 25 kg CO_2 over a 100-year time horizon*
  - For CH_4, GWP100 = 25 kgCO2e

- Sometimes called "characterization" or "emission" factors

GHG	GWP100* (kgCO2e/kg GHG)
CO_2	1
CH_4	25
N_2O	298
HCFC-22	1810
SF_6	22800

* from TRACI 2.1, 2014

* Based on GWP100 from TRACI v2.1, 2014, USEPA

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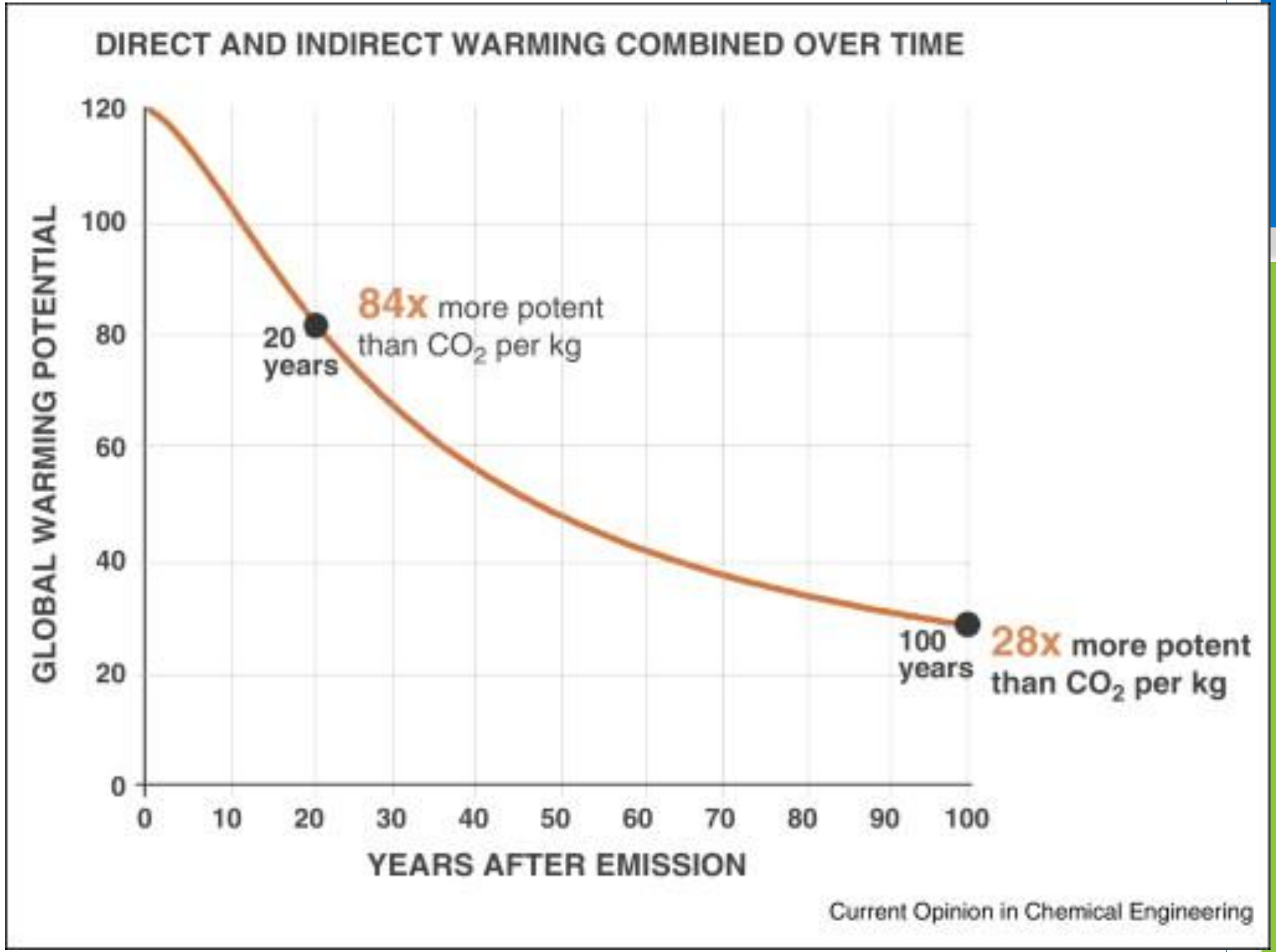
GWP Changes Over Time

- Usually, shorter-term effects are greatest
- Most reports use 100 years (GWP100)
- GWP100 can vary from source to source depending on factors used in calculation and sometimes are updated with new findings



From Allen, D.T. 2014. Methane emissions from natural gas production and use: reconciling bottom-up and top-down measurements. *Cur Op Chem Eng* 5:78-83. Link

GWP Factors are Used to Calculate CO_2 Equivalents

E.g., Kilograms of carbon dioxide equivalents (kgCO2e)

E.g., **Tonnes of CO_2** equivalents (tCO2e)

- Can be calculated for any product or service
  - E.g., **tCO2e of embodied carbon for construction of a residential home**
  - E.g., kgCO2e for production of 1 kWh of electricity in a gas-fired power plant

TEST YOUR KNOWLEDGE

What is the GWP100 factor (Global Warming Potential -100 years) of CO2 ?

1. 25
2. 298
3. 1
4. 0

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Achieving Net Zero Carbon Designation for Builders

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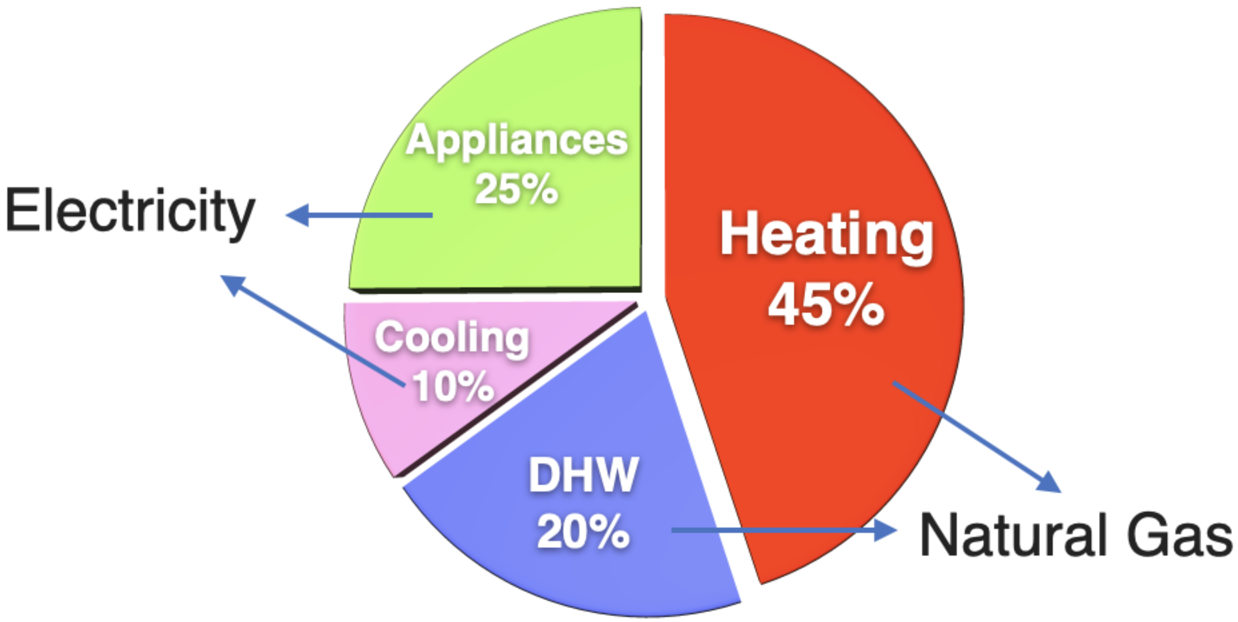
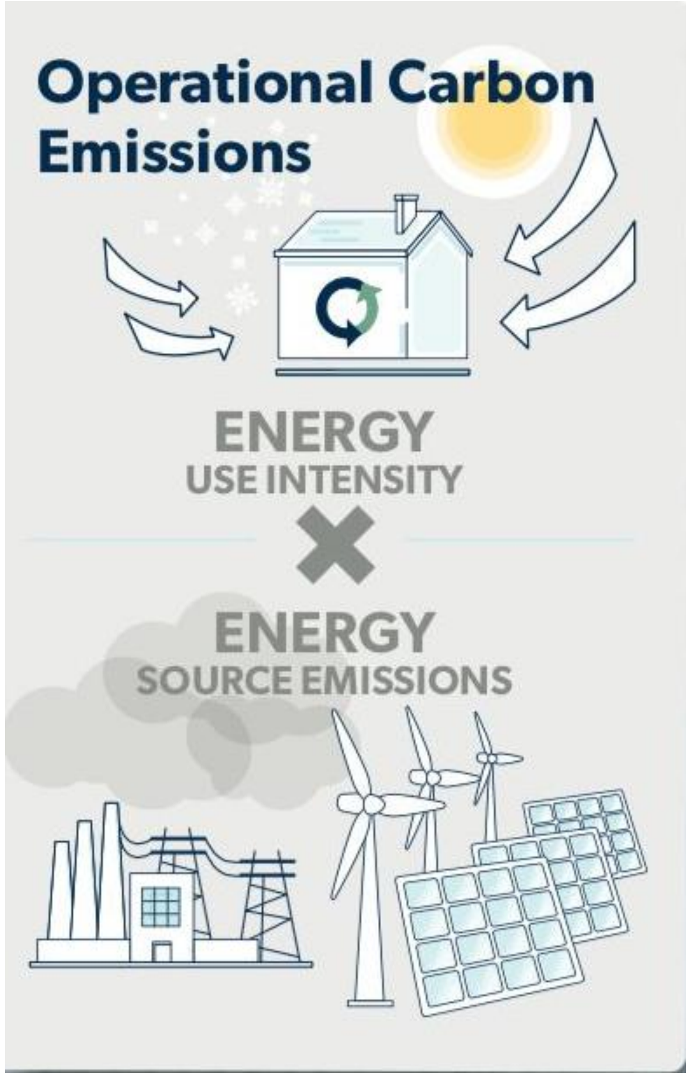
Operational Carbon

Operational Carbon

A function of energy use:

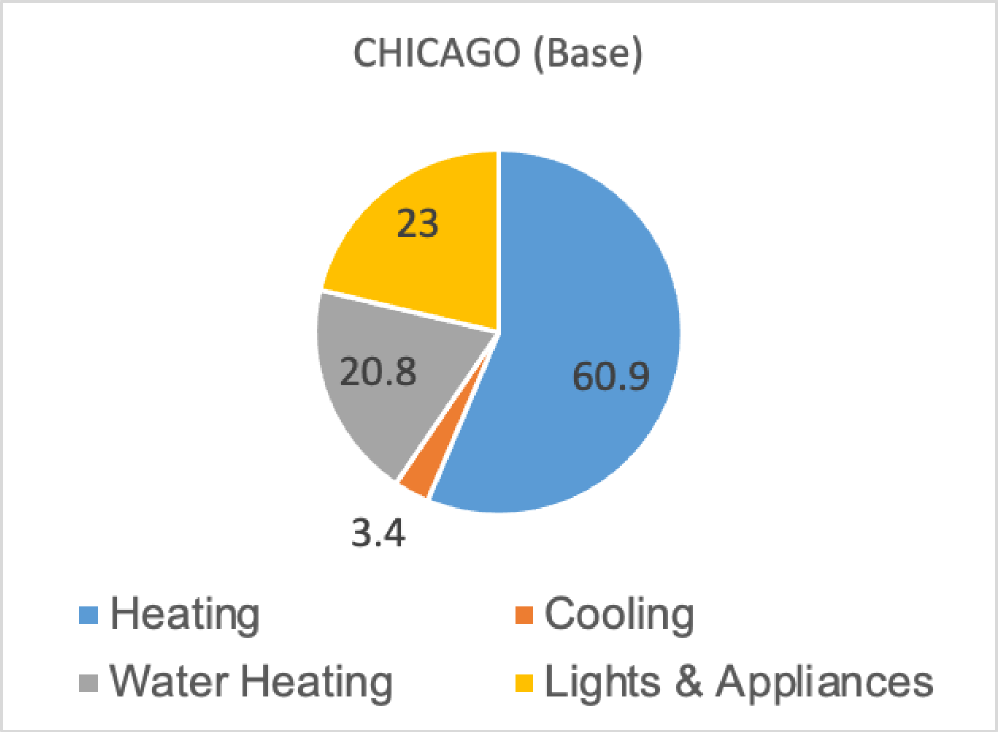
- Annual energy consumption
- Fuel / energy choice
- Emissions in generating the energy





Energy Use in Homes - EEBA Carbon House - Chicago

Energy Use from Your Energy Rater

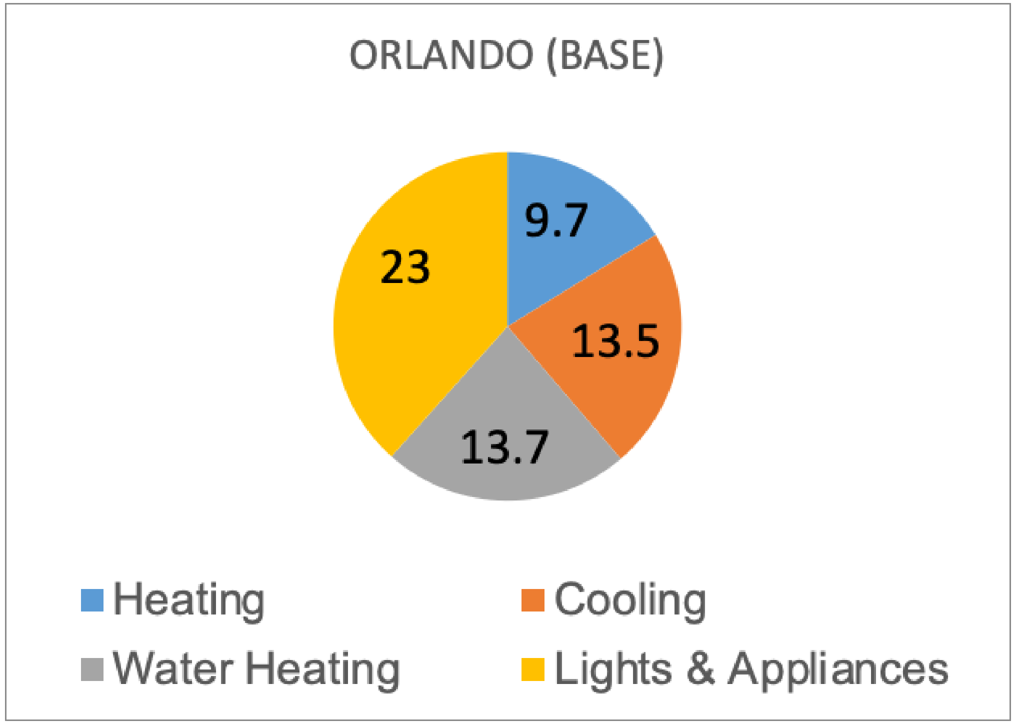


Gas: 81.7 MMBTU/yr
Electric: 26.4 MMBTU/yr
Total: 108.1 MMBTU/yr

This is converted to Tonnes of Carbon based on fuel use x the energy source emissions

Energy Use in Homes - EEBA Carbon House - Orlando

Energy Use from Your Energy Rater

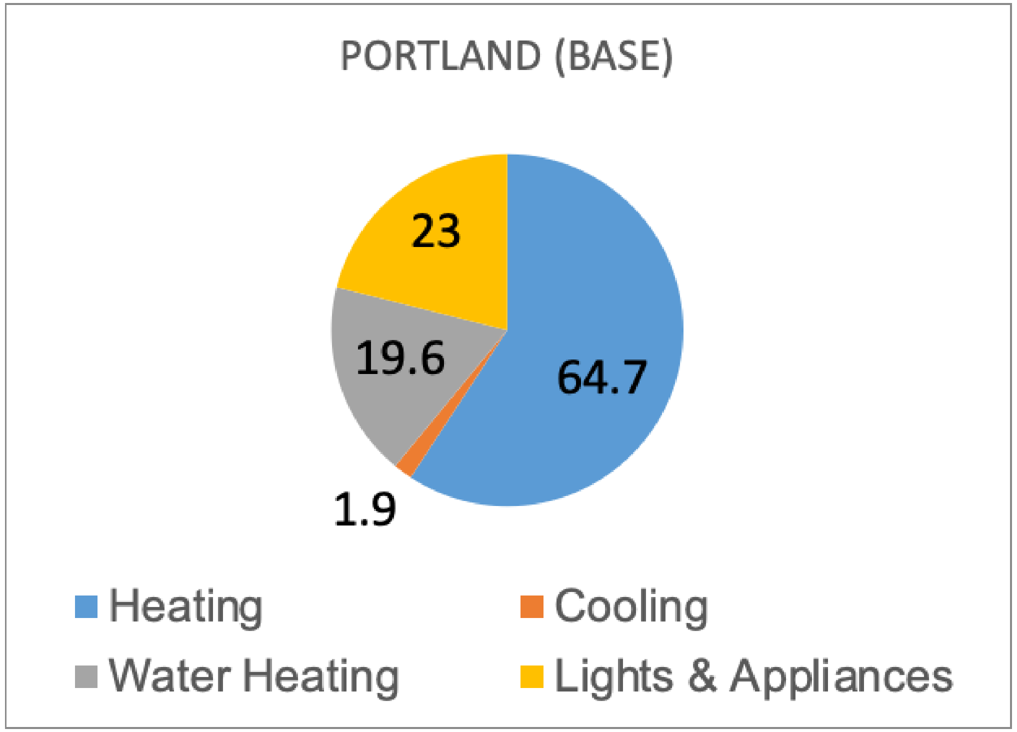


Gas: 23.4 MMBTU/yr
Electric: 36.4 MMBTU/yr
Total: 59.8 MMBTU/yr

This is converted to Tonnes of Carbon based on fuel use x the energy source emissions

Energy Use in Homes - EEBA Carbon House - Portland

Energy Use from Your Energy Rater

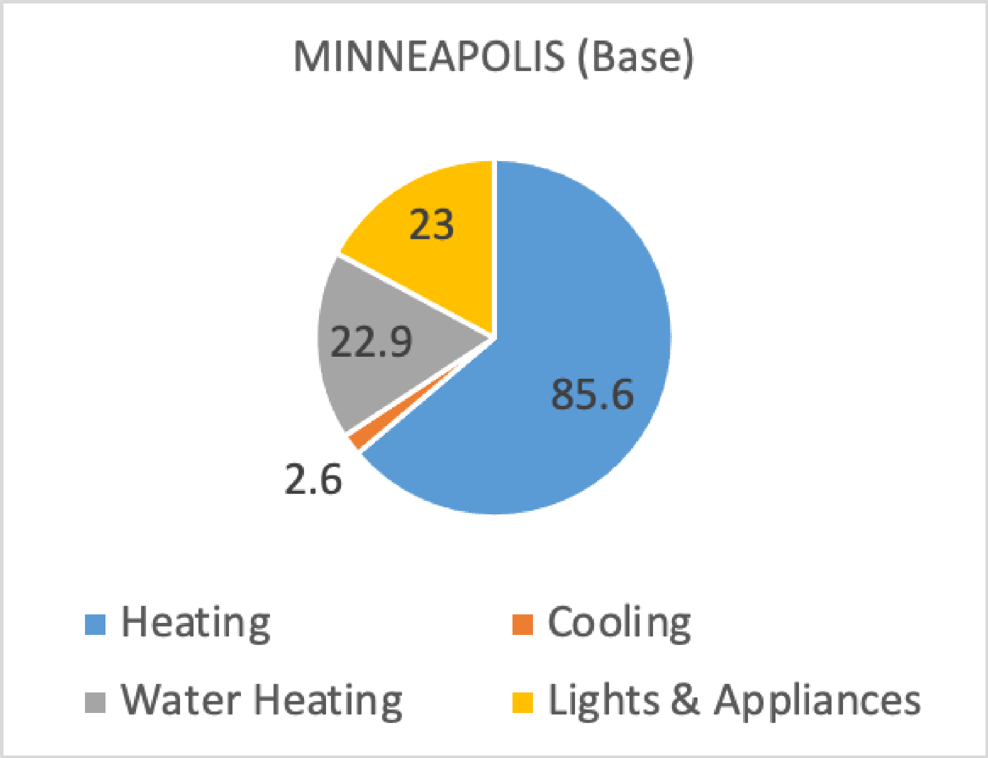


Gas: 84.3 MMBTU/yr
Electric: 24.9 MMBTU/yr
Total: 109.2 MMBTU/yr

This is converted to Tonnes of Carbon based on fuel use x the energy source emissions

Energy Use in Homes - EEBA Carbon House - Minneapolis

Energy Use from Your Energy Rater



Gas: 108.5 MMBTU/yr
Electric: 25.6 MMBTU/yr
Total: 134.1 MMBTU/yr

This is converted to Tonnes of Carbon based on fuel use x the energy source emissions

Emissions from electrical generation

They vary significantly:

Coal

Diesel

Natural gas

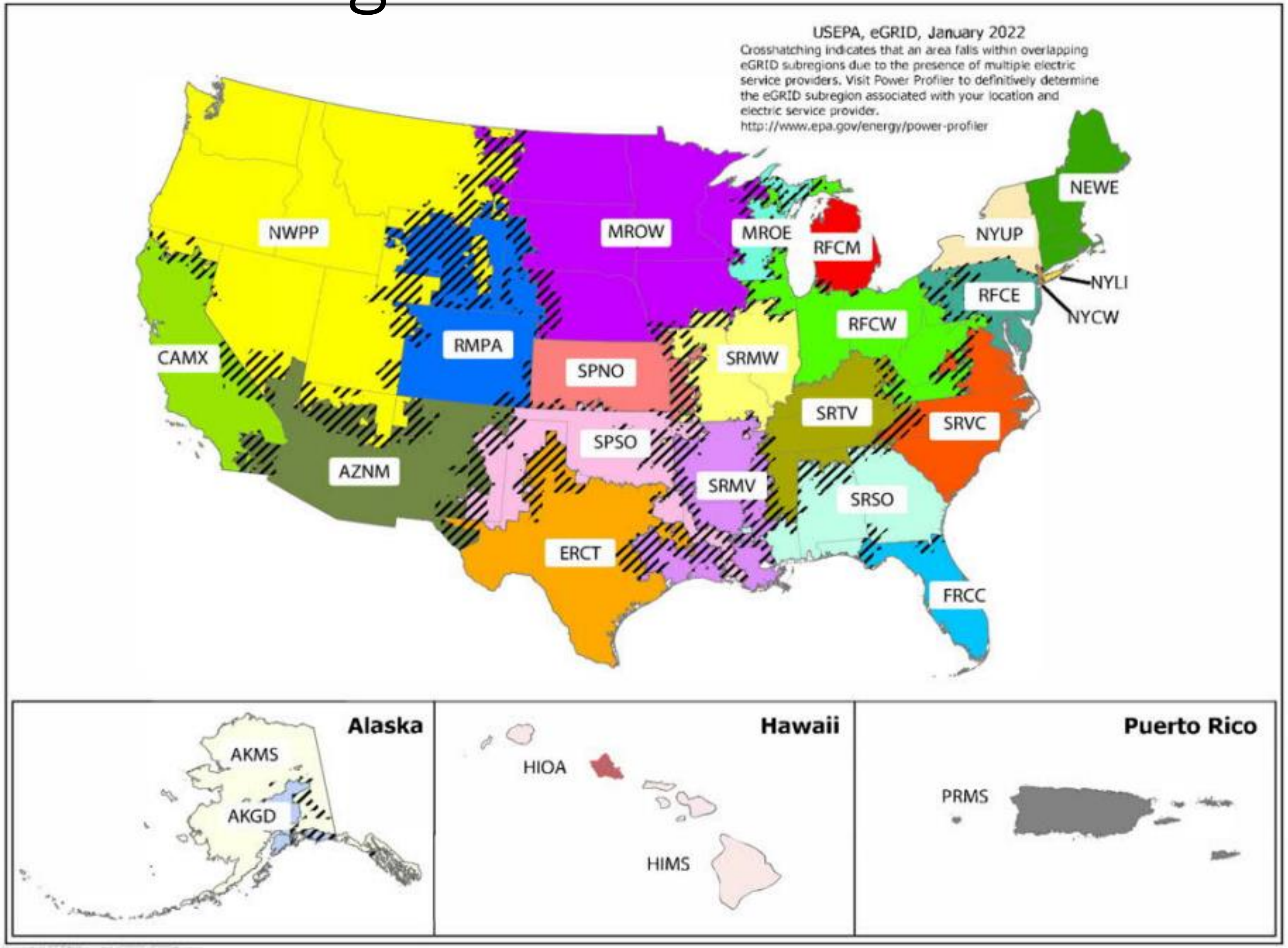
Nuclear

Hydro-electric

Wind

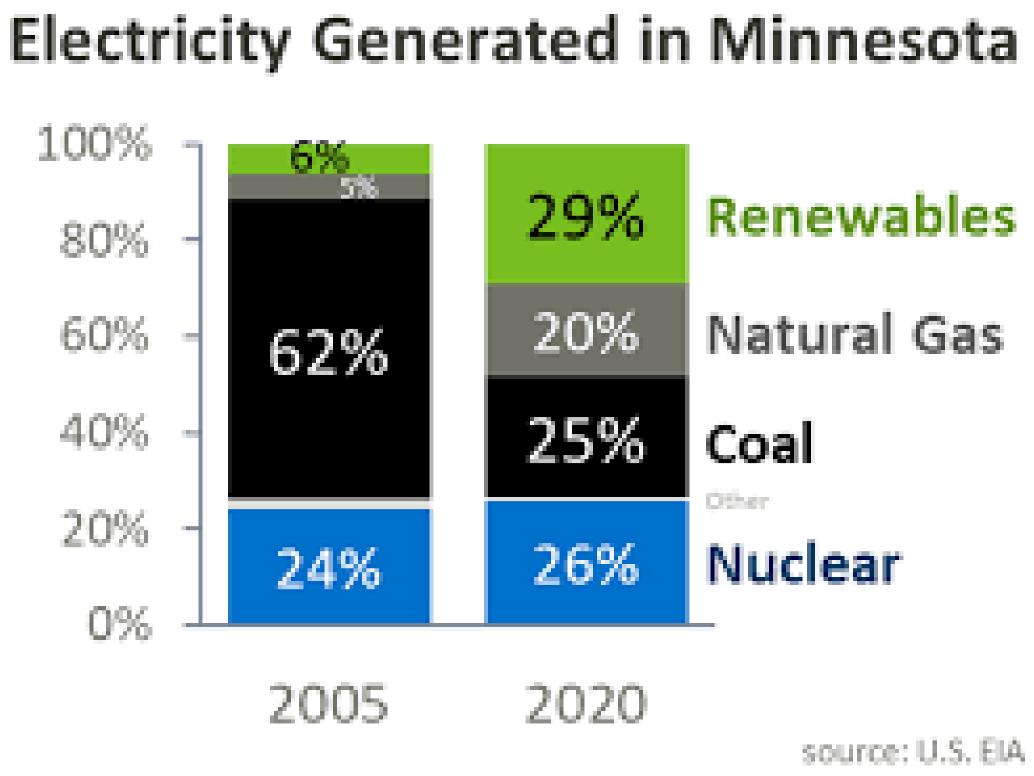
Solar

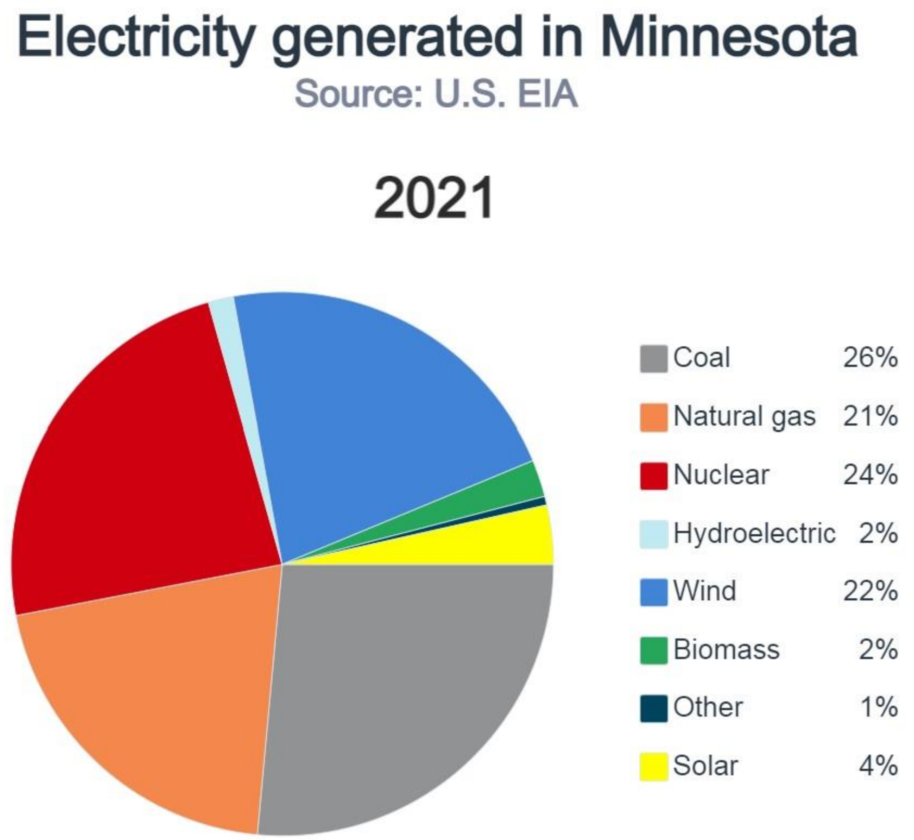
Every utility has different emission factors



https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

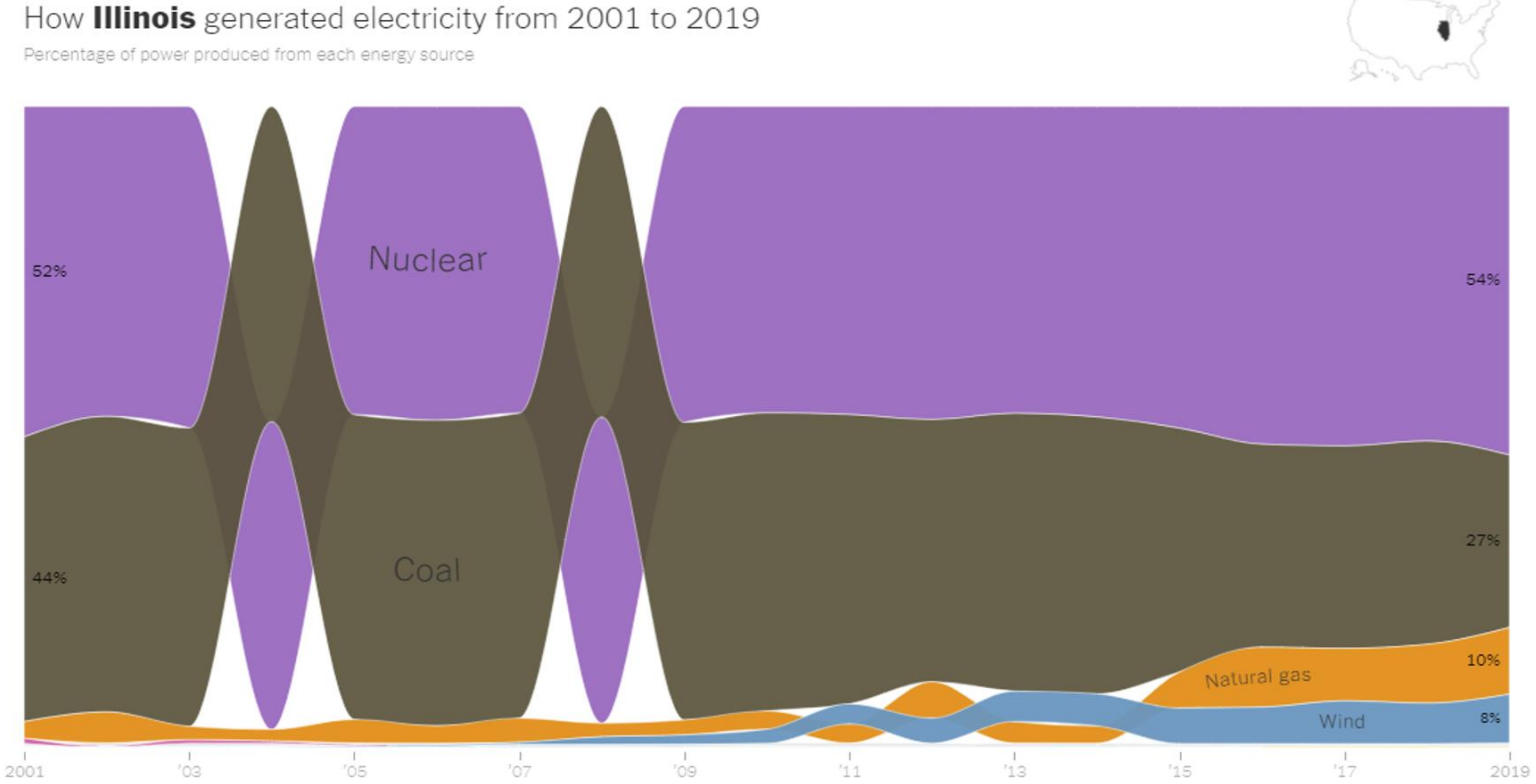
Emissions from electrical generation





https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

Every utility has different emission factors



https://www.nytimes.com/interactive/2020/10/28/climate/how-electricity-generation-changed-in-your-state-election.html

Every utility has different emission factors

Electricity

eGRID Subregion	Total Output Emission Factors		
	CO_2 Factor (lb / MWh)	CH_4 Factor (lb / MWh)	N_2O Factor (lb / MWh)
AKGD (ASCC Alaska Grid)	1,097.6	0.100	0.014
AKMS (ASCC Miscellaneous)	534.1	0.027	0.005
AZNM (WECC Southwest)	846.6	0.054	0.007
CAMX (WECC California)	513.5	0.032	0.004
ERCT (ERCOT All)	818.6	0.052	0.007
FRCC (FRCC All)	835.1	0.049	0.006
HIMS (HICC Miscellaneous)	1,143.2	0.110	0.017
HIOA (HICC Oahu)	1,653.0	0.178	0.027
MROE (MRO East)	1,526.4	0.139	0.020
MROW (MRO West)	979.5	0.104	0.015
NEWE (NPCC New England)	528.2	0.074	0.010
NWPP (WECC Northwest)	600.0	0.056	0.008
NYCW (NPCC NYC/Westchester)	634.6	0.022	0.003
NYLI (NPCC Long Island)	1,203.9	0.138	0.018
NYUP (NPCC Upstate NY)	233.5	0.016	0.002
PRMS (Puerto Rico Miscellaneous)	1,602.2	0.085	0.014
RFCE (RFC East)	652.5	0.045	0.006
RFCM (RFC Michigan)	1,153.1	0.101	0.014
RFCW (RFC West)	985.0	0.086	0.012
RMPA (WECC Rockies)	1,144.8	0.101	0.014
SPNO (SPP North)	954.0	0.100	0.014
SPSO (SPP South)	931.8	0.060	0.009
SRMV (SERC Mississippi Valley)	740.4	0.032	0.004
SRMW (SERC Midwest)	1,480.7	0.156	0.023
SRSO (SERC South)	860.2	0.060	0.009
SRTV (SERC Tennessee Valley)	834.2	0.075	0.011
SRVC (SERC Virginia/Carolina)	623.1	0.050	0.007
US Average	818.3	0.065	0.009

Source: EPA eGRID2020, February 2022

Kgs of CO_2 per MegaWatt Hour of electricity generated

U.S. Average	**370**	
Orlando	379	
Atlanta	392	
Portland	274	
Chicago	449	
Minneapolis	448	
Upstate NY	233	"Lowest"
Oahu	750	"Highest"

https://www.epa.gov/system/files/documents/2022-04/ghg_emission_factors_hub.pdf

Converting Energy Use to Operational Carbon Equivalents

Fuel source x energy source emissions

Natural Gas = 53.06 kg CO_2 per mmBtu

Electricity (Chicago) = 449 kg CO_2 / MW

Gas: 81.7 MMBTU/yr
Electric: 26.4 MMBTU/yr
Total: 108.1 MMBTU/yr

Operational Carbon for EEBA House - Chicago

7.82 Tonnes CO_2e / yr

30yr equivalent : 234 tCO2e

Converting Energy Use to Operational Carbon Equivalents

Fuel source x energy source emissions

Natural Gas = 53.06 kg CO_2 per mmBtu

Electricity (Orlando) = 380 kg CO_2 / MW

Gas: 23.4 MMBTU/yr
Electric: 36.4 MMBTU/yr
Total: 59.8 MMBTU/yr

Operational Carbon for EEBA House - Orlando

5.31 Tonnes CO_2e / yr

30yr equivalent : 159 tCO2e

Converting Energy Use to Operational Carbon Equivalents

Fuel source x energy source emissions

Natural Gas = 53.06 kg CO_2 per mmBtu

Electricity (Portland) = 274 kg CO_2 / MW

Gas: 84.3 MMBTU/yr
Electric: 24.9 MMBTU/yr
Total: 109.2 MMBTU/yr

Operational Carbon for EEBA House - Portland

6.48 Tonnes CO_2e / yr

30yr equivalent : 194 tCO2e

Converting Energy Use to Operational Carbon Equivalents

Fuel source x energy source emissions

Natural Gas = 53.06 kg CO_2 per mmBtu

Electricity (Minneapolis) = 448 kg CO_2 / MW

Gas: 108.5 MMBTU/yr
Electric: 25.6 MMBTU/yr
Total: 134.1 MMBTU/yr

Operational Carbon for EEBA House - Minneapolis

9.12 Tonnes CO_2e / yr

30yr equivalent : 273 tCO2e

Converting Energy Use to Operational Carbon Equivalents

Greenhouse Gases may come from your Energy Rater

ekotrope

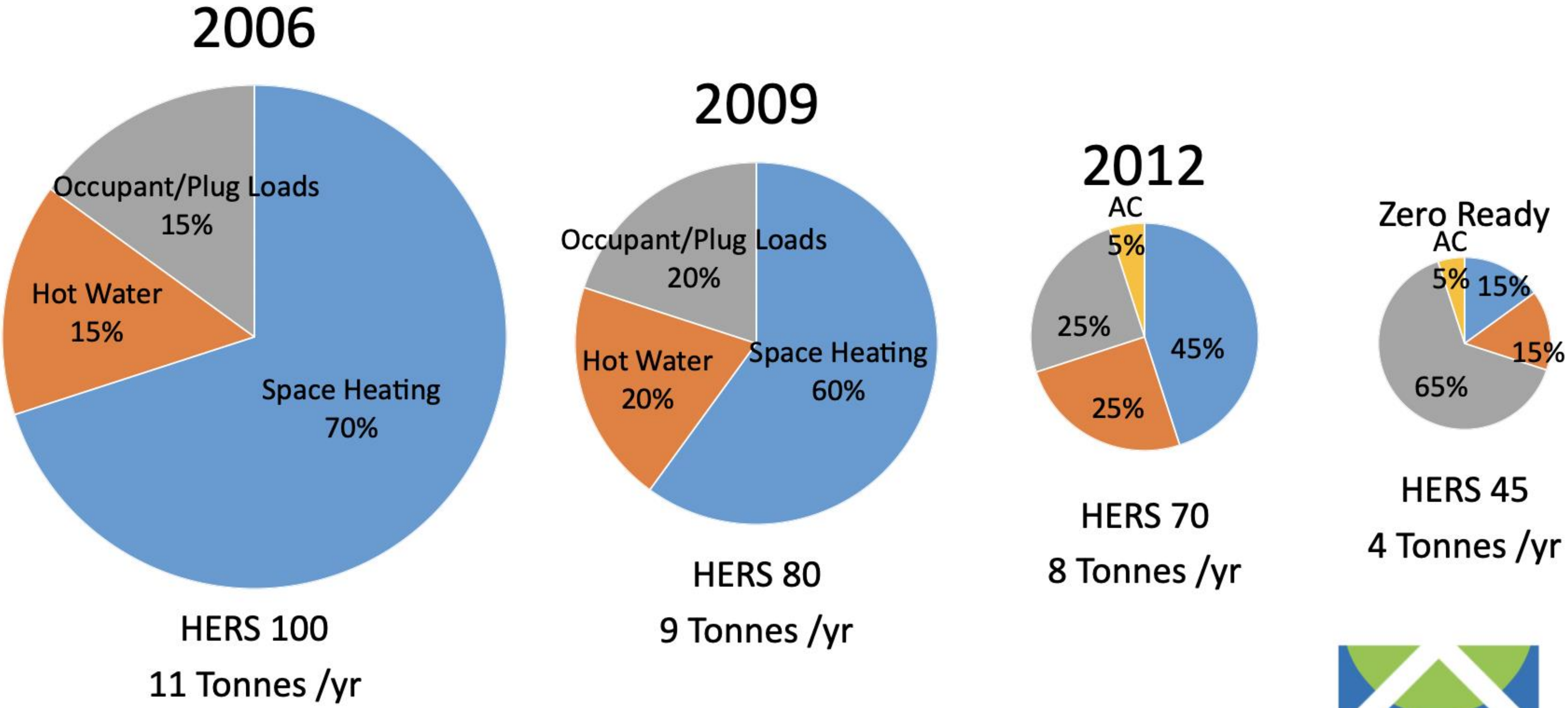
REM/Rate™

Common energy modelling tools will be adding GHG reports

- Some regional, annual fine tuning will be worked on to ensure consistency

Codes Have Changed… Operational Carbon has improved

Operational Carbon Improvement - Cold Climate



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Operational Carbon Emissions and heat pumps

The news on electrification is complex and grid-dependent

- IMPACT on operating cost significant-Elec vs Gas
- Enclosure and passive enhancements(with electrification) increase in ROI
- Results will change overtime e.g. Grid changes and Energy production costs

Which homes would benefit from heat pumps?

Four distinct scenarios for electric heat pumps in Canadian housing:

The low-hanging fruit
Switching oil furnaces to heat pumps

- Saves energy, $ and GHGs across Canada

5-15 year payback
(Cost of GHG saved: < $0 / tonne)

The toughest nut to crack
Switching gas furnaces to heat pumps

- Saves GHGs, but increases $ in ON, MB and BC.
- Homeowners are worse off

No Payback
(Cost of GHG saved: $70-300 / tonne)

The cost-effective alternative
Switching electric baseboards to heat pumps

- Saves energy and $ across Canada
- Saves GHGs in AB, SK, ON and Atlantic Canada

5-15 year payback
(Cost of GHG saved: < $0 / tonne)

Unintended consequences
Switching gas furnaces to heat pumps

- Increases GHGs and $ in AB, SK and NS, due to extensive coal and oil based electricity generation in those provinces

No Payback, no GHGs saved

Natural Resources Canada Ressources naturelles Canada

Canada

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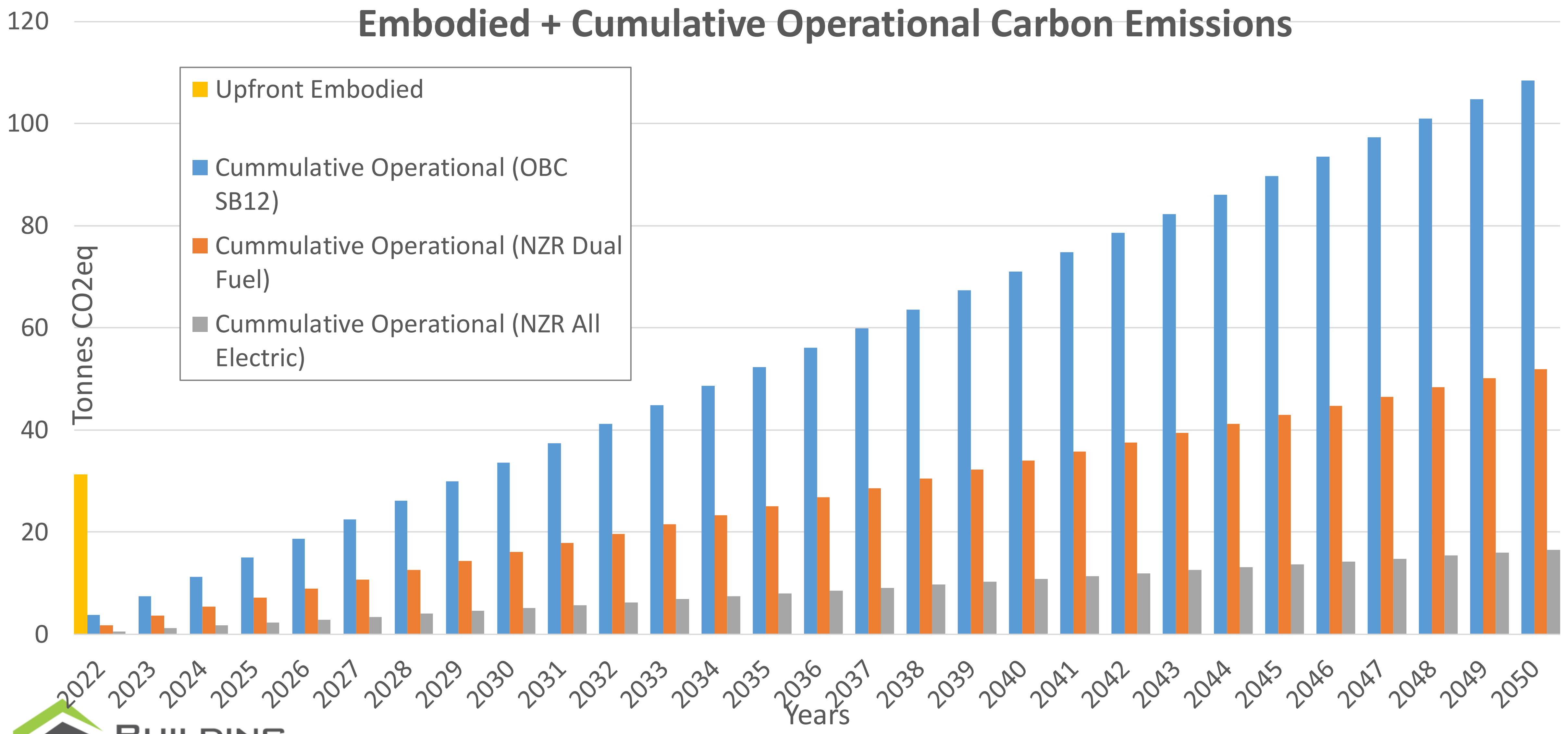
A Tale of 2 Grids –Ontario vs Alberta

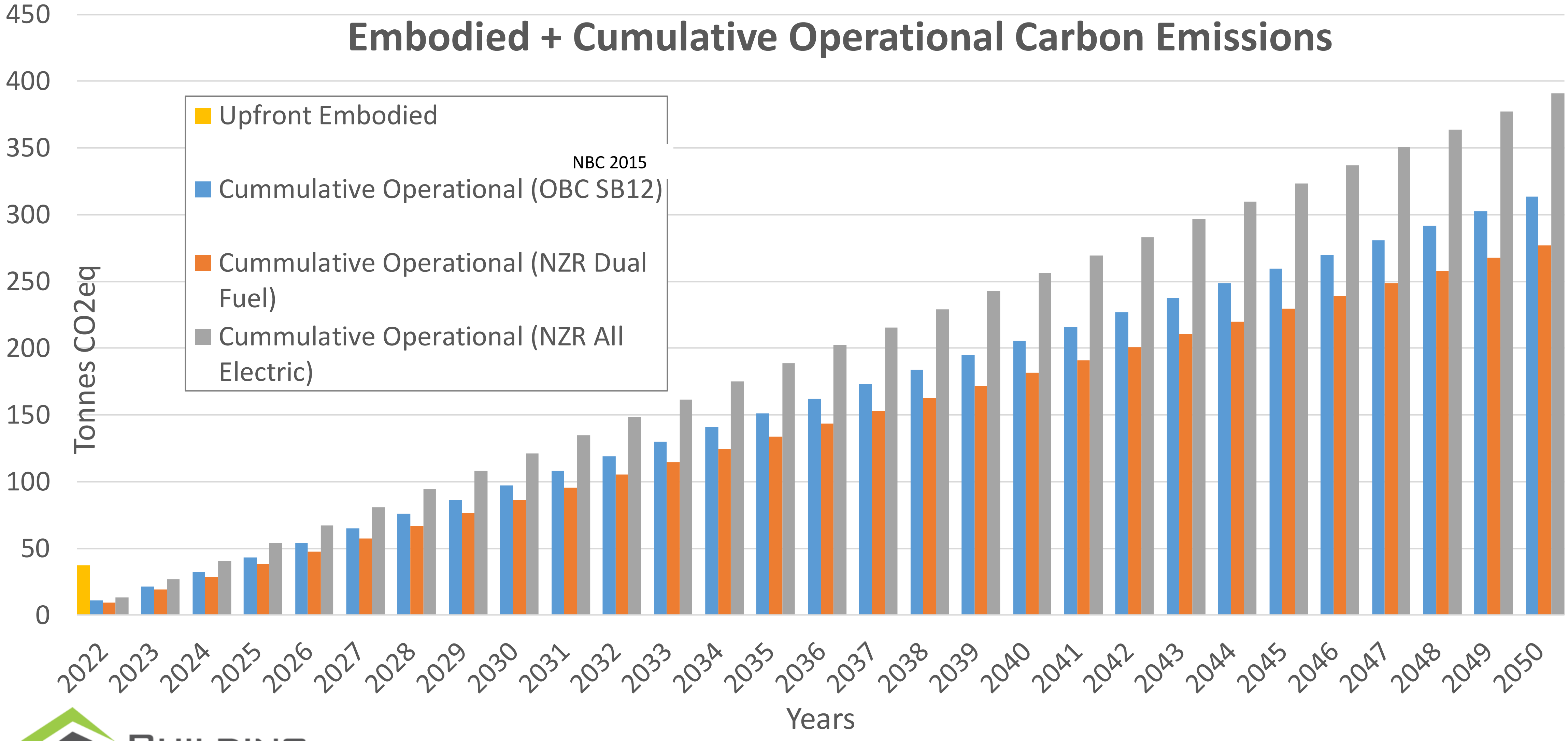
30 Year Impact, 2300 sqft SD Home. **Ottawa, ON cz6**



BUILDING KNOWLEDGE CANADA INC.

A Tale of 2 Grids –Ontario vs Alberta

30 Year Impact, 2300 sqft SD Home. **Calgary AB, ON cz7**



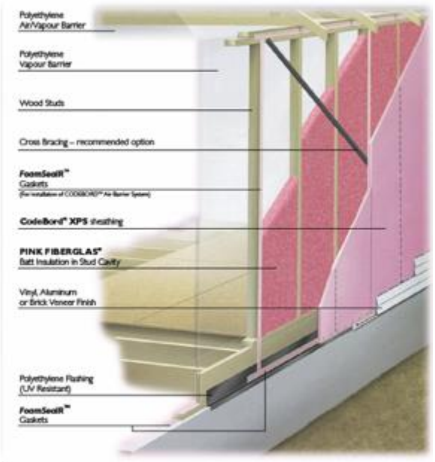
Common Energy Efficiency Improvements

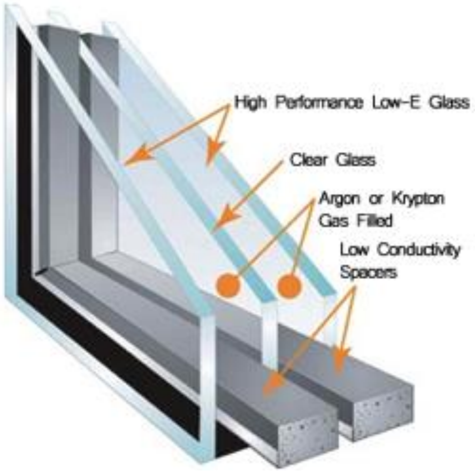
What improvements have you made in your homes?

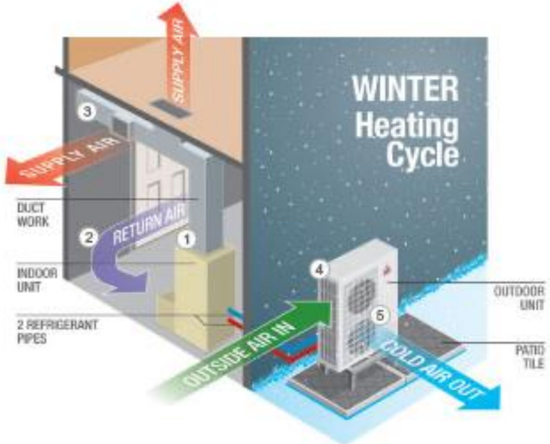
- Better air tightness
- More attic insulation
- Better windows
- Improved HVAC efficiency
- Improved water heater efficiency
- Add a heat recovery ventilator
- Thicker walls
- Advanced framing
- More insulation on foundation walls
- Under-slab insulation
- Better lights and appliances
- Addition of renewable energy generation - solar

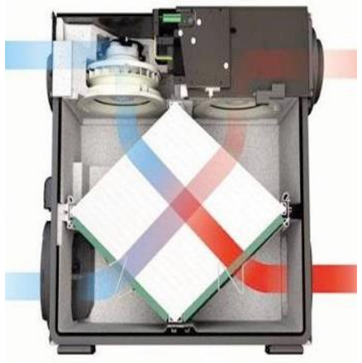
*Which of these might significantly impact **embodied** energy?*

Choices, Alternatives & Options









VS

The Base EEBA Carbon House – Chicago cz 5

- 2 Story, All brick
- Full basement
- R49 Attic insulation
- 2x6 Above grade walls - R21 Batts
- R11 Basement walls, no slab insulation
- Double-glazed, Low E, argon windows
- 3.0 ACH@50Pa Air tightness
- 95% Gas furnace, 13 SEER AC
- Power vented gas water heater 0.56 EF

What improvements have you made already?

The Base EEBA Carbon House – Minneapolis cz 6

- 2 Storey, All brick
- Full basement
- R49 Attic insulation
- 2x6 Above grade walls - R21 Batts
- R11 Basement walls, no slab insulation
- Double-glazed, Low E, argon windows
- 3.0 ACH@50Pa Air tightness
- 95% Gas furnace, 13 SEER AC
- Power vented gas water heater 0.56 EF

What improvements have you made already?

Cold Climate Upgrade Examples

Three Examples of Enclosure Energy Improvements(Passive) on **Operational Carbon**

1. Improved air tightness
2. Addition of continuous insulation
3. Upgrade to triple-glazed windows

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Warm / Mild Climate Upgrade Examples

Three Examples of Enclosure Energy Improvements (Passive) on **Operational Carbon**

1. Improved air tightness
2. Addition of continuous insulation
3. Getting ducts in conditioned space

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Energy and Carbon Impact of Improved Air Tightness

Chicago Base House cz5

ACH50	MMBTUs/yr	CO_2e Tonnes/yr
3.0	**108.1**	**7.82**
2.0	103.2	7.56
1.5	100.9	7.44
0.60	96.6	7.21

A 5% reduction in Tonnes CO_2e/yr

What changes will be required?

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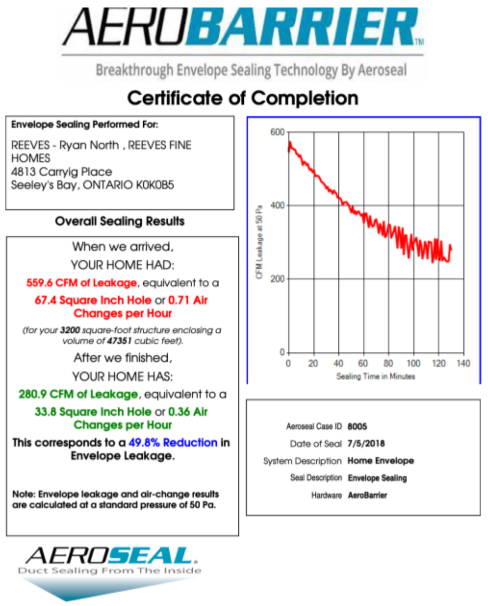
Improved air tightness requires:

- Tapes,
- Caulks
- Sprays
- Committed, trained labor

There are helpful new technologies

Under 1.5 ACH50 is now achievable by all builders


AEROBARRIER
Breakthrough Envelope Sealing Technology By Aeroseal

Certificate of Completion

Envelope Sealing Performed For:
REEVES - Ryan North , REEVES FINE HOMES
4813 Carryig Place
Seeley's Bay, ONTARIO K0K0B5

Overall Sealing Results

When we arrived,
YOUR HOME HAD:
559.6 CFM of Leakage, equivalent to a **67.4 Square Inch Hole** or **0.71 Air Changes per Hour**
(for your ***3200*** *square-foot structure enclosing a volume of* ***47351*** *cubic feet).*
After we finished,
YOUR HOME HAS:
280.9 CFM of Leakage, equivalent to a **33.8 Square Inch Hole** or **0.36 Air Changes per Hour**
This corresponds to a 49.8% Reduction in Envelope Leakage.

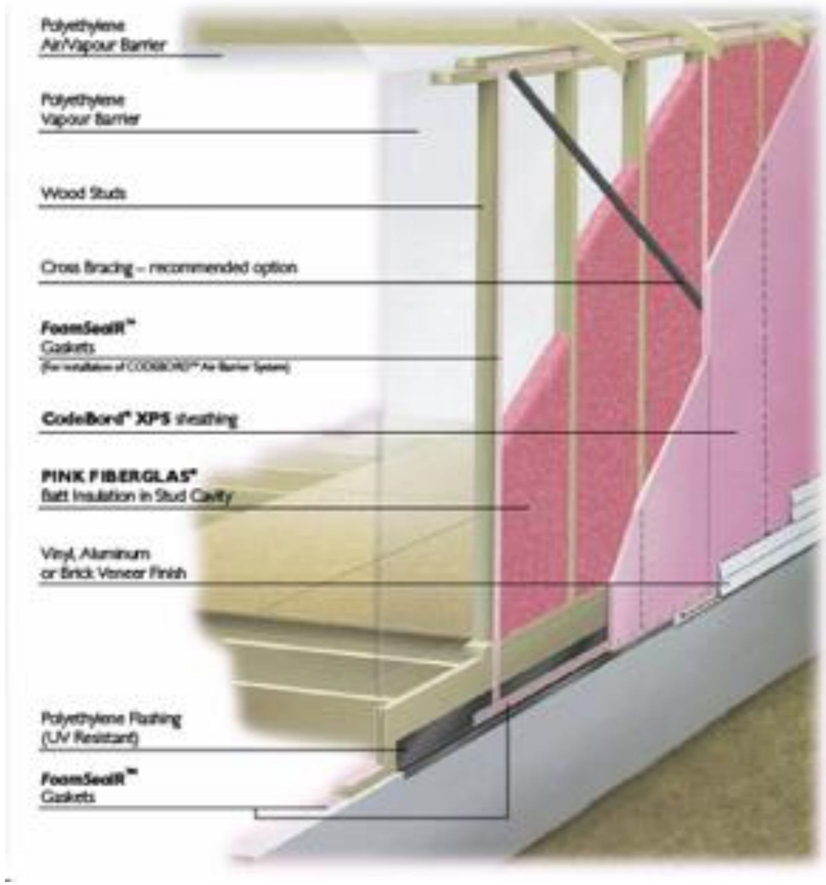
Note: Envelope leakage and air-change results are calculated at a standard pressure of 50 Pa.

Aeroseal Case ID	**8005**
Date of Seal	**7/5/2018**
System Description	**Home Envelope**
Seal Description	**Envelope Sealing**
Hardware	**AeroBarrier**

AEROSEAL
Duct Sealing From The Inside

Energy and Carbon Impact of Continuous Exterior Insulation

Chicago Base House cz5



Exterior R-Value	MMBTUs/yr	CO_2e Tonnes/yr
0	**108.1**	**7.82**
5	103.5	7.57
10	100.5	7.41

A 5% reduction in Tonnes CO_2e/yr

What changes will be required?

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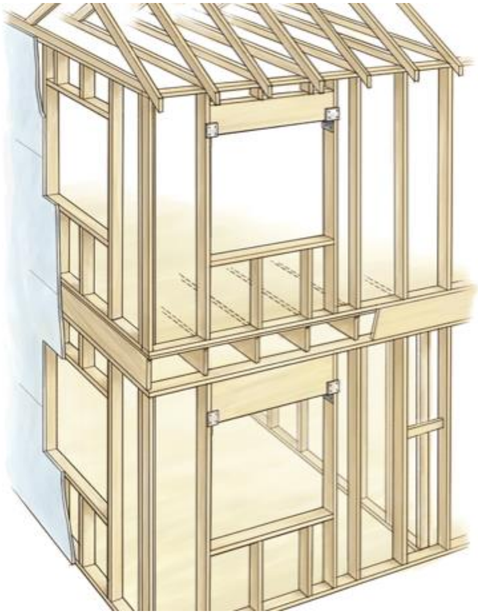
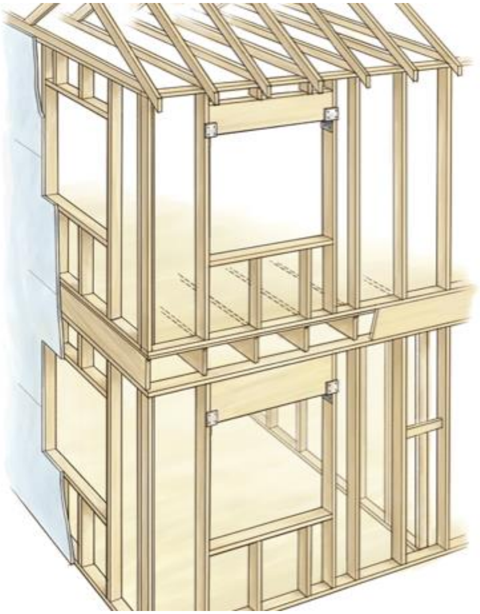
3 Ways to improve Effective R-values

- More cavity insulation
- Advanced / Optimized framing
- **Continuous insulation**



3 Ways to improve Effective R-values

- More cavity insulation
- **Advanced / Optimized framing**
- Continuous insulation



2 x 6 Wall Total Effective R-Value

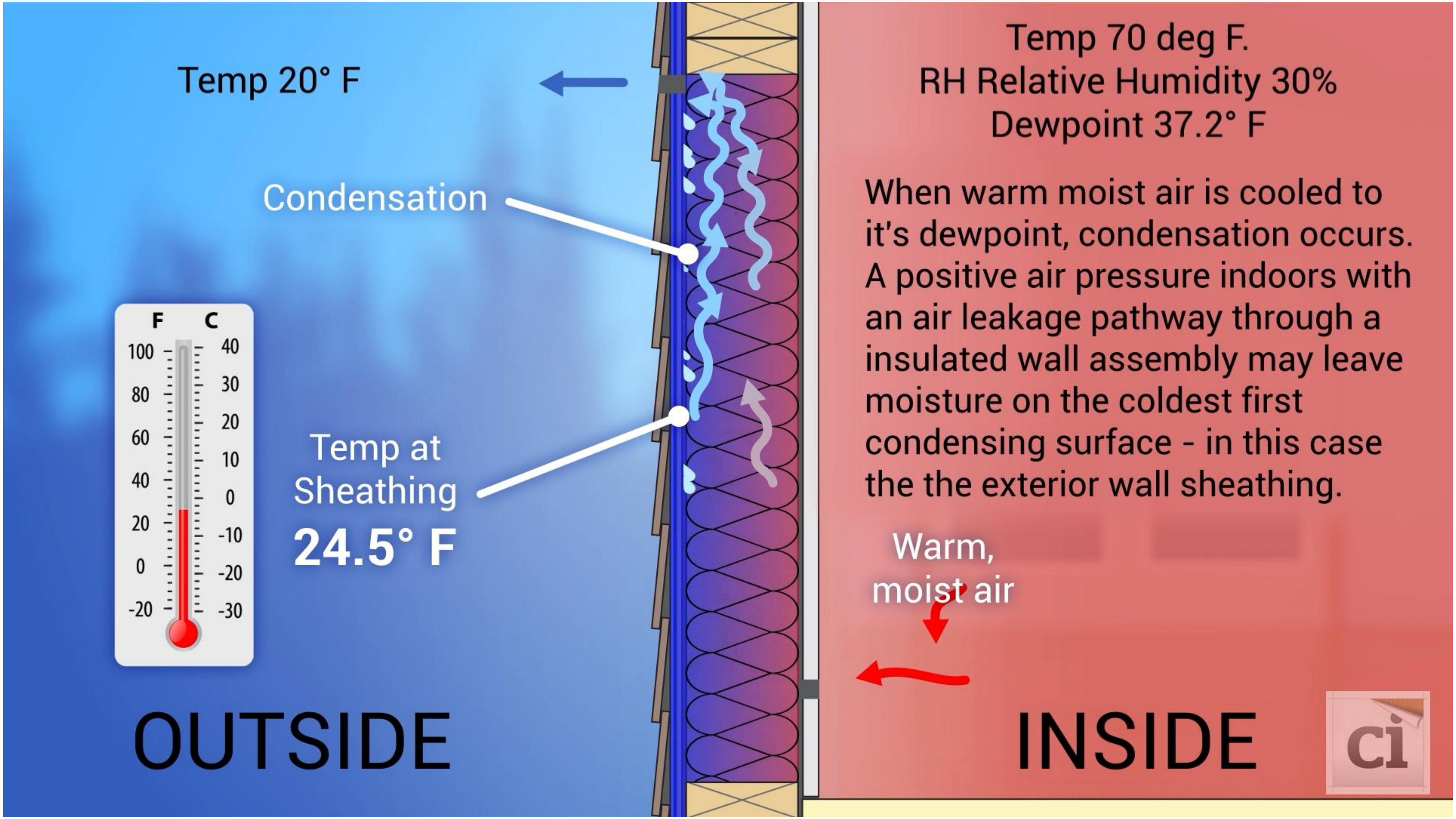
Framing Percentage	**R-Value**	
19%	Cavity	Studs
Outside air film	0.17	0.17
Exterior insulation	**0**	0
7/16" OSB	0.62	0.62
Cladding/Siding	0.62	0.62
Framing - 2 x 6	n/a	5.83
cavity insulation	**22**	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Sub-Totals	24.54	8.37
Total Wall R- Value	**16.95**	

2 x 6 Wall Total Effective R-Value

Framing Percentage	R-Value		
19%	Cavity	Studs	
Outside air film	0.17	0.17	
Exterior insulation	**5**	5	
7/16" OSB	0.62	0.62	
Cladding/Siding	0.62	0.62	
Framing - 2 x 6	n/a	5.83	
cavity insulation	**22**	n/a	
½" gypsum	0.45	0.45	
Interior air film	0.68	0.68	
Sub-Totals	29.54	13.37	7% 1441%
Total Wall R- Value	**21.95**		

2 x 4 Wall + R5 Total Effective R-Value

Framing Percentage	R-Value	
25%	Cavity	Studs
Outside air film	0.17	0.17
Exterior insulation	**5**	5
7/16” OSB	0.62	0.62
Cladding/Siding	0.62	0.62
Framing - 2 x 4	n/a	3.71
cavity insulation	**13**	n/a
½” gypsum	0.45	0.45
Interior air film	0.68	0.68
Sub-Totals	20.54	11.25
Total Wall R- Value	**15.54**	



Exterior Continuous Insulation Lowers Risks of Condensation

2 x 4 Wall + R12 Total Effective R-Value

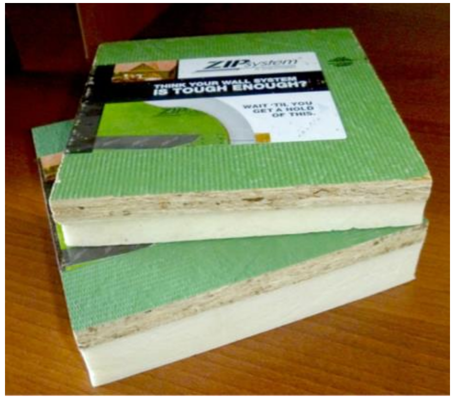
Framing Percentage	**R-Value**	
25%	Cavity	Studs
Outside air film	0.17	0.17
Exterior insulation	**12**	12
7/16" OSB	0.62	0.62
Cladding/Siding	0.62	0.62
Framing - 2 x 4	n/a	3.71
cavity insulation	**13**	n/a
½" gypsum	0.45	0.45
Interior air film	0.68	0.68
Sub-Totals	27.54	18.25
Total Wall R- Value	**22.54**	

13%
800%

Various Options

How would these impact your build process?

How might these choices impact the the overall greenhouse gas emissions of the homes you build?



Continuous Insulation:

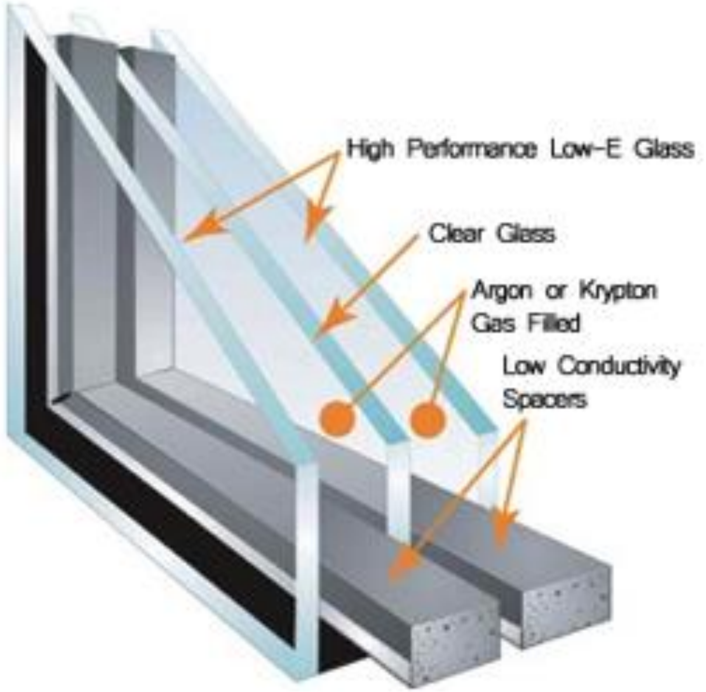
- Design changes
- Process changes
- Material selection
- Cladding implications

There are many options

It may even allow a return to a 2x4 wall

Energy and Carbon Impact of Triple-Glazed Windows

Chicago Base House cz5



Glazing	**MMBTUs/yr**	**CO_2e Tonnes/yr**
Double, Low E, Argon	108.1	**7.82**
Triple, 2 Coats Low E, Argon	**103.9**	**7.55**

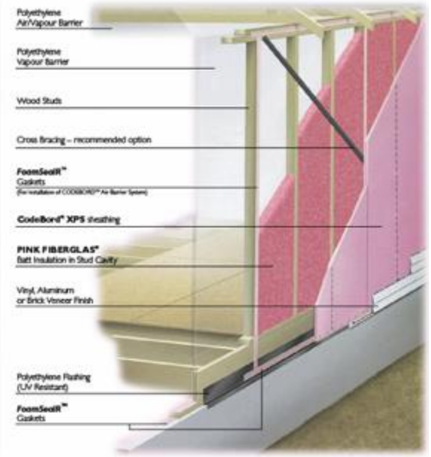
A 3% reduction in Tonnes CO_2e/yr

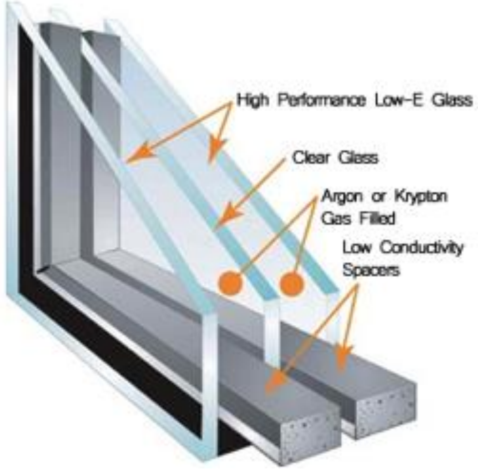
What changes will be required?

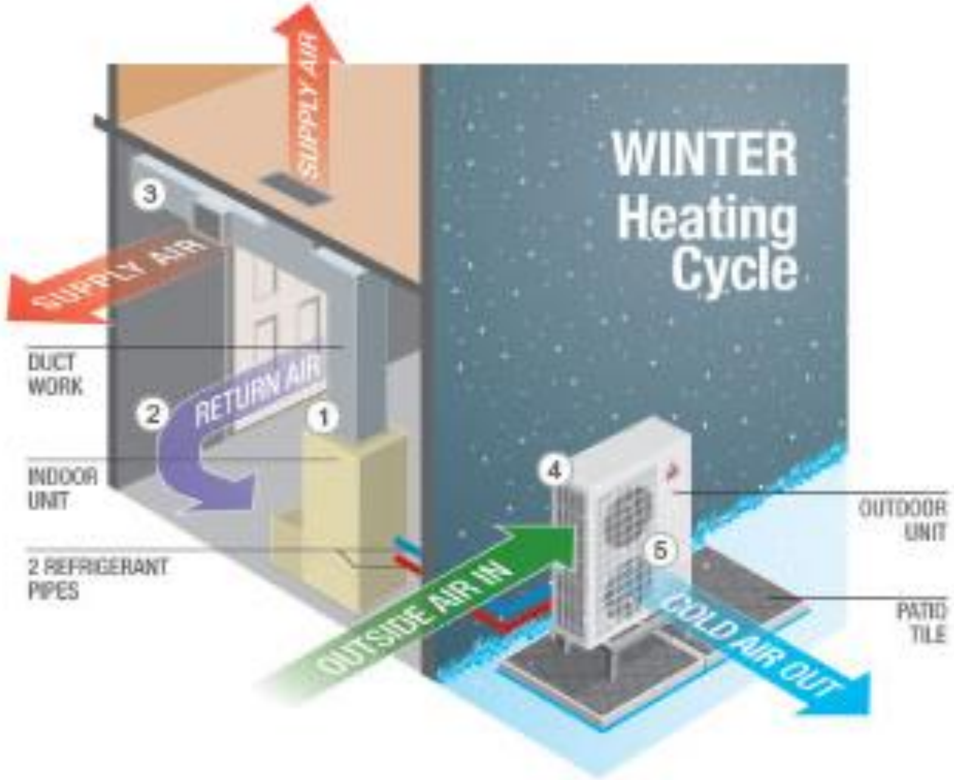
Select the right Low E coatings to optimize winter and summer loads

The Synergies of Enclosure Improvements

- Lowers Heating & Cooling Loads:
  - Winter design
  - Summer design
- Operative Temp improvement (Comfort –ASHRAE 55)
- Enclosure Durability: Dew point and condensation control
- Thermal “storage” –peak load off-set







This Make Heat Pumps More Viable

Impact of Enclosure Improvements on Design HVAC Loads

Chicago Base House cz5

Upgrades:
3 ACH to 1.5 ACH
R10 Exterior Insulation
Triple- Glazed Windows
Then add a Heat Pump for heating

	Base House	Upgraded House
Heating Load	44,000 BTU/hr	31,000
Cooling Load	22,200 BTU/hr	15,500
CO_2e Tonnes/yr	7.82	6.8 with Nat. gas 5.9 with Dual Fuel HP
Heat Pump Size	3.5 Ton	2.5 Ton

A 25% reduction in Operational Carbon

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Operational Carbon Summary

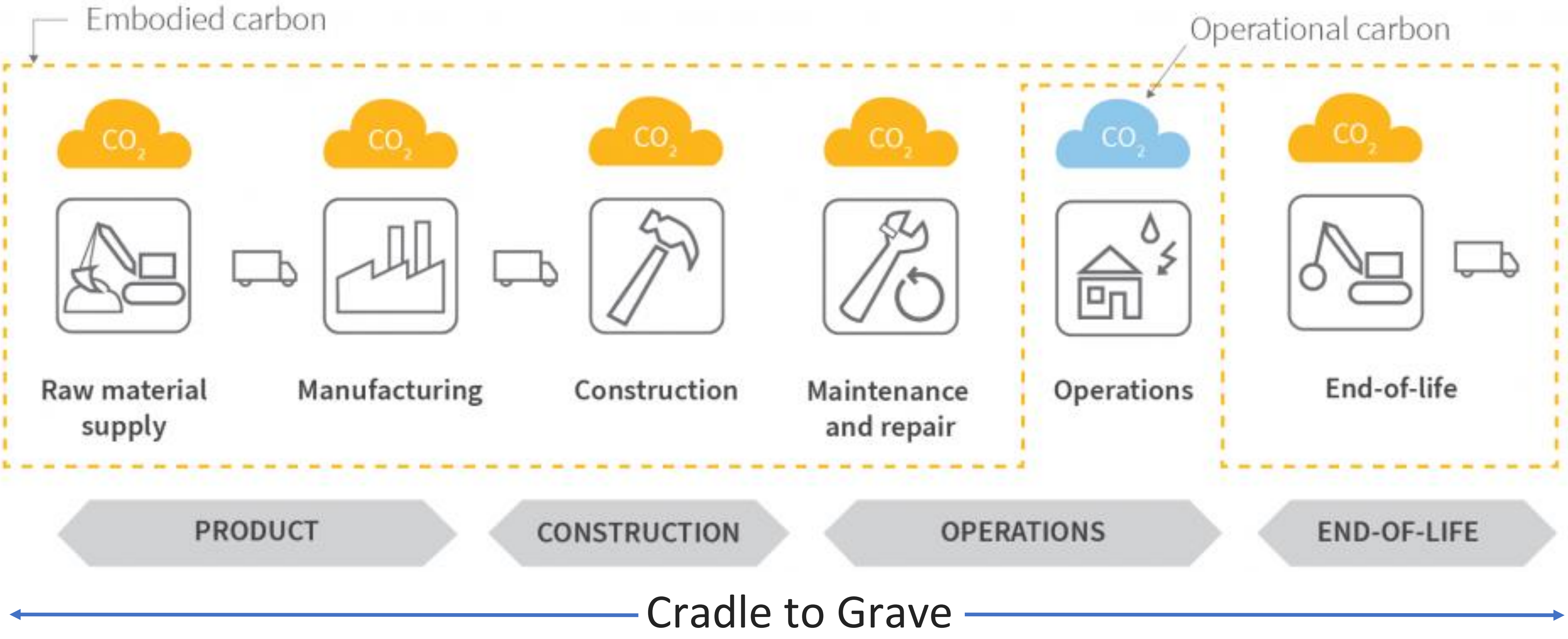
- It's based on energy modelling, hence it will **vary**:
  - Size of home
  - Energy efficiency features
  - Climate
- It will **vary** depending on how "clean" the fuel sources are:
  - Space Heating and Hot Water
    - Natural gas, propane, electricity, fuel oil
  - Electricity for cooling, lights, appliances
    - Hydro, nuclear, natural gas, solar, wind
- Current common energy models do **not** account for regional electric grid differences
- Hand calculations are needed for best accuracy in any market

Exercise

- Review the 4 energy efficiency upgrades (including the addition of a heat pump) and discuss the changes required to your processes and any barriers you envision.
- Rank the 4 energy upgrade options as to when you would implement them

Embodied Carbon

Building Lifecycle



Consider the total life cycle of the homes you create when making design, material and building technique decisions:

- *How long do you expect your homes to last?*
- *Consider examples of decisions you could make to increase the service life of the homes you build?*

Embodied Carbon

Currently assessed as a function of the making of each building material:

- Extraction
- Transportation to the factory
- Production

Cradle to Gate - the gate of the manufacturing

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Carbon Emissions : OC+MCE
What can we easily account for today?

Operational Carbon Emissions (OC)

Material Carbon Emissions (MCE)

Carbon Emissions : OC+MCE

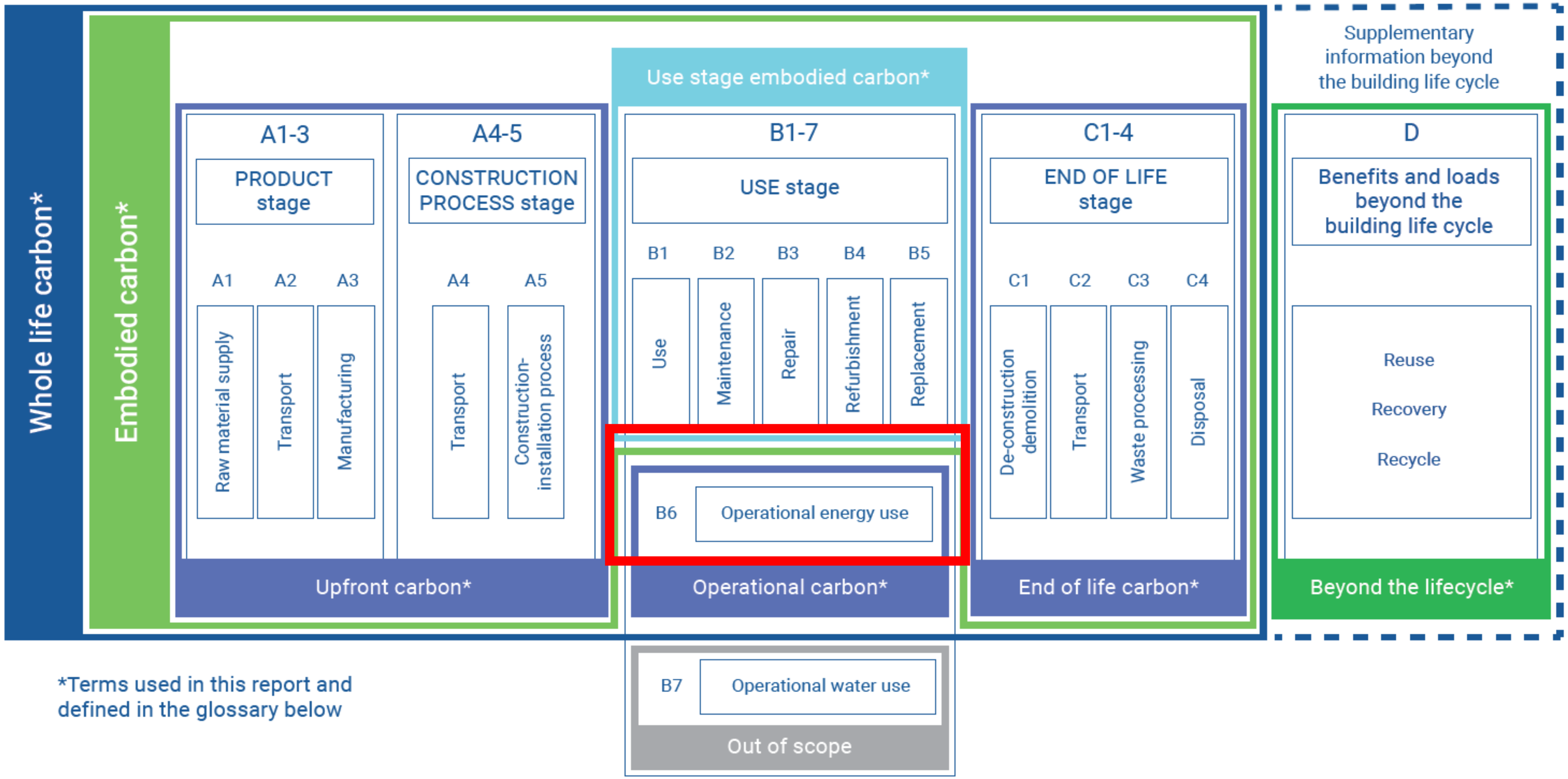

Figure 1: Terminology used in this report cross-referenced to terms and lifecycle stages defined in EN 15978

From: World Green Building Council, 2019. *Bringing embodied carbon upfront.* https://www.worldgbc.org/sites/default/files/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf

OC Operational Carbon from energy use during building use phase

B6 Operational Energy Use

- E.g., Natural gas furnace
- E.g., Electricity use

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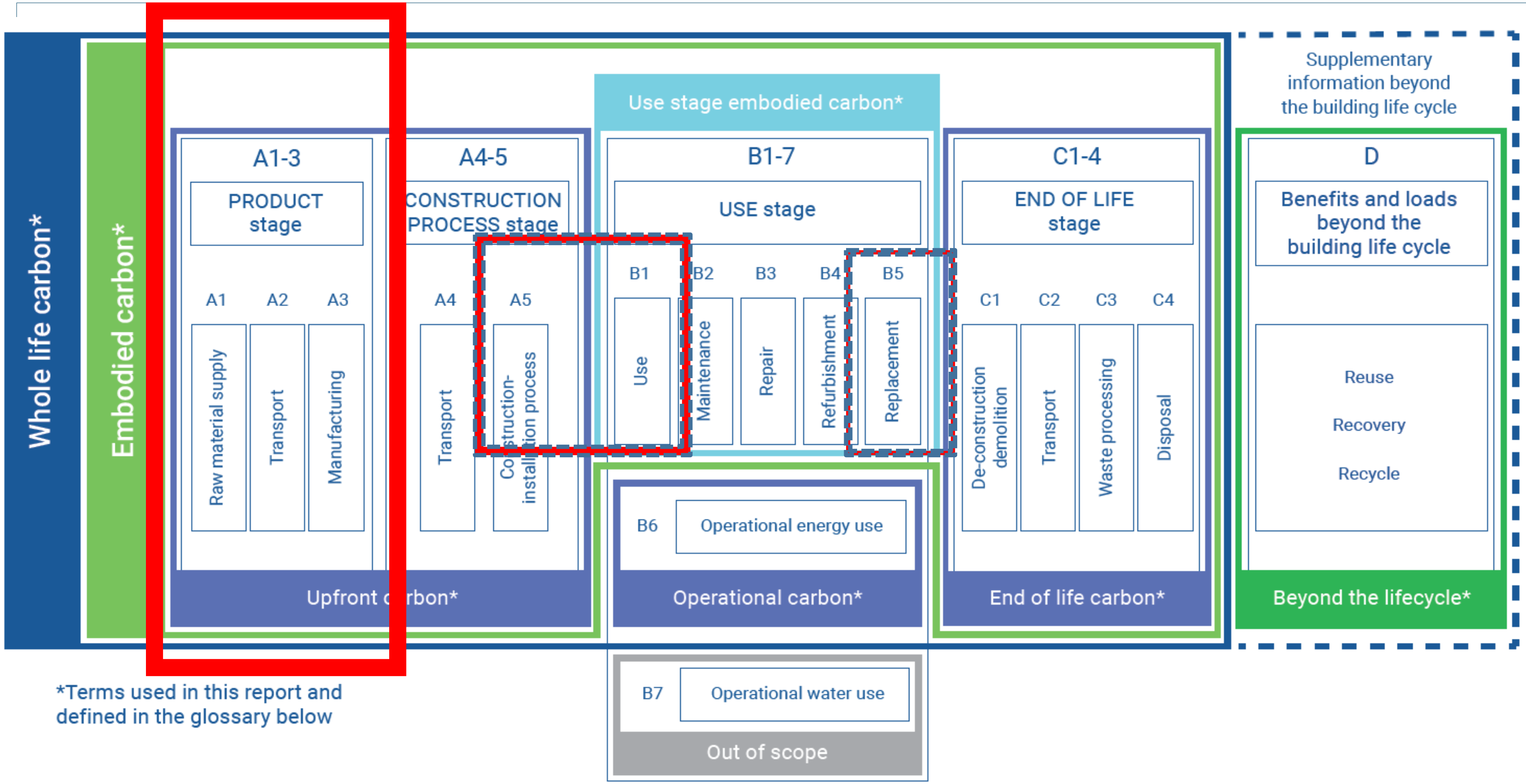
Carbon Emissions : OC+MCE



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A1-A3 MCEs account for 85% of Embodied Carbon for typical building

A1-3 of the building lifecycle

A5-B1 for well-known building materials that have immediate, well-understood emissions during installation (e.g., spray foam insulation)

B5 (replacement) for asphalt singles (15 years)

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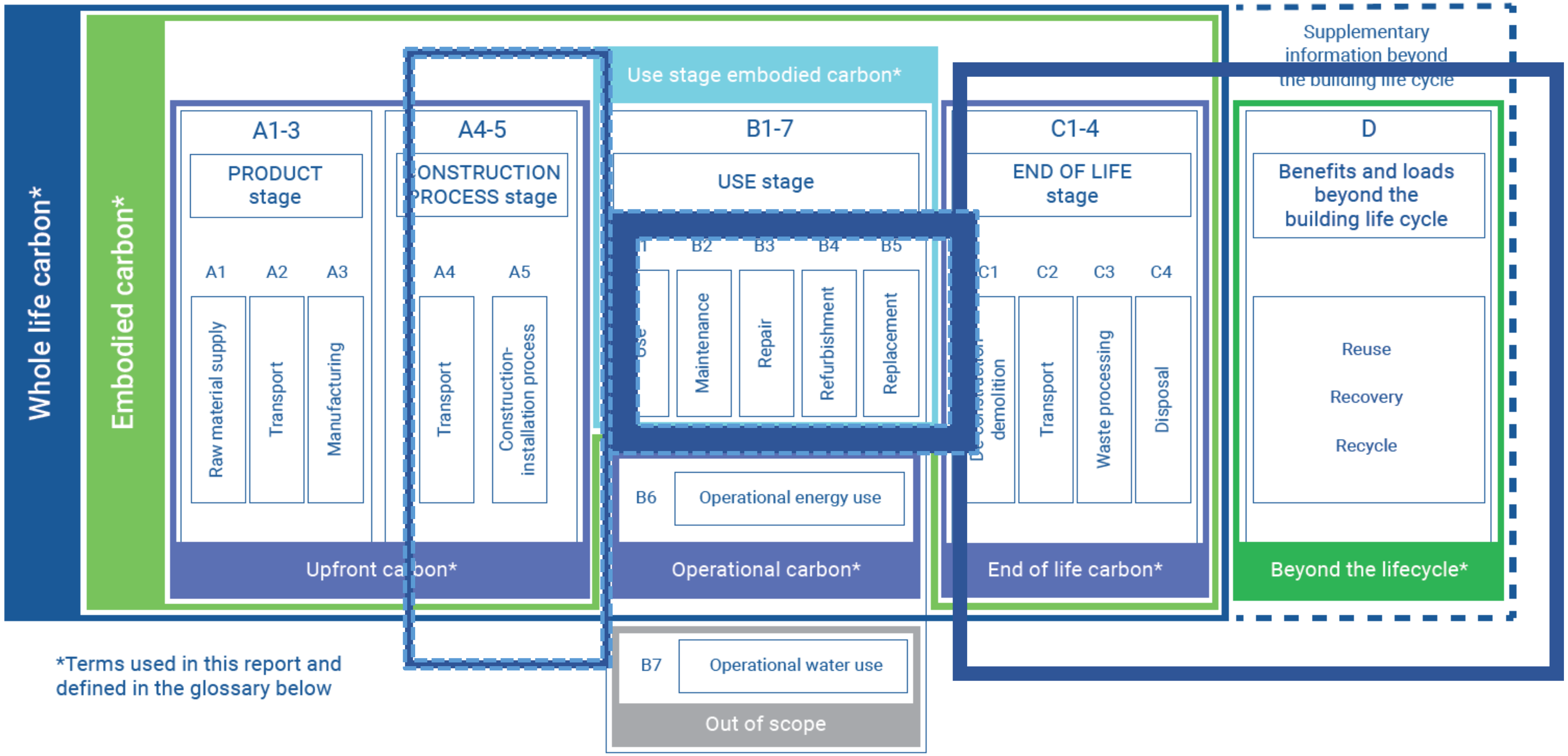
Carbon Emissions : OC+MCE



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MCE does NOT account for:

- **A4** – Transport
- **A5*** – Construction, installation processes
- **B1*-5*** – Use stage (and B7 – water use)
- **C** – demolition, deconstruction, waste processing, end-of-life
- **D** – Reuse, recovery, recycling

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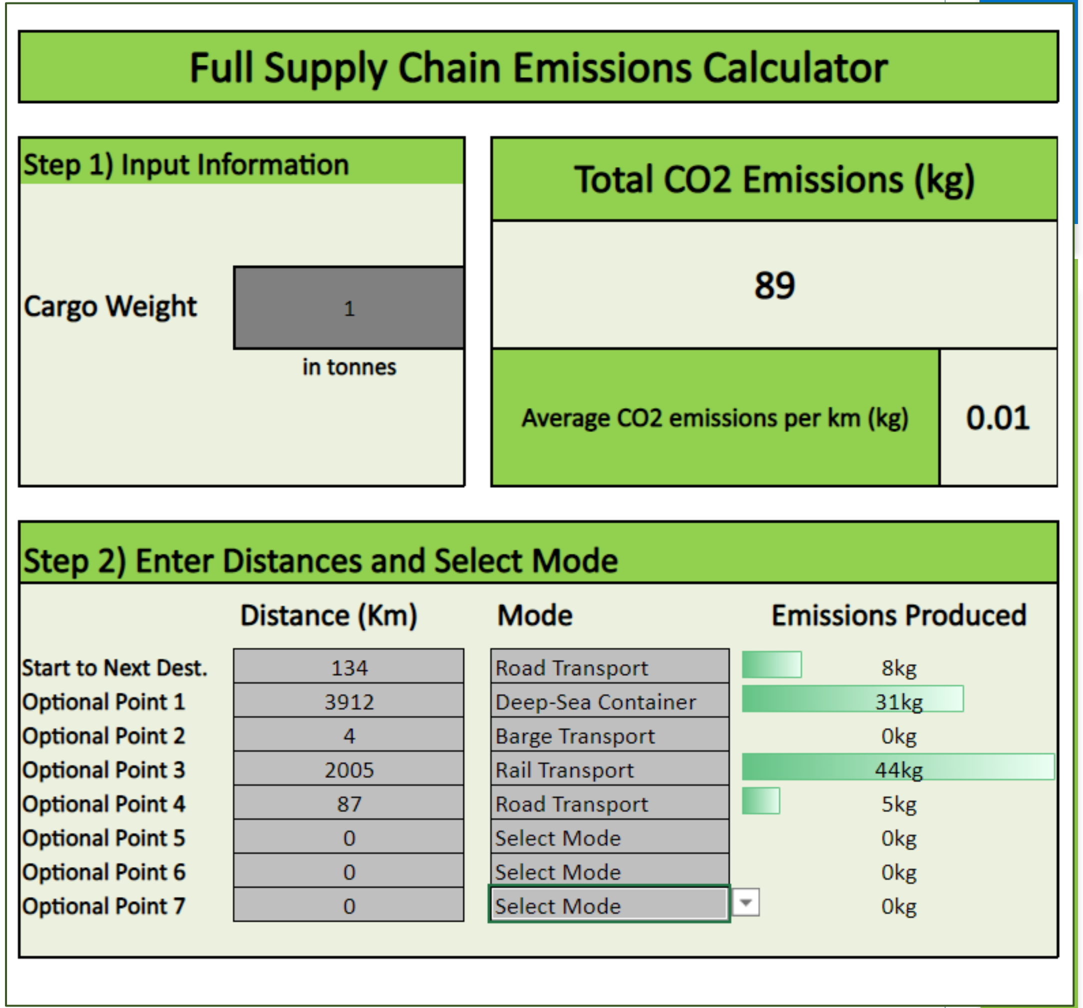
Not Included in MCE

A4 – Transport

- Transport of materials to construction site typically adds about **5-10%** to the embodied carbon emissions

- Can be calculated, if you know the shipping information for every material (mass of material, distance and transport type)

- Example online calculator – website



From: World Green Building Council, 2019. *Bringing embodied carbon upfront.* https://www.worldgbc.org/sites/default/files/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf

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Not Included **A5** Construction, Installation

- A5 **included for some products** – those with necessary, sizable, predictable GHG emissions, such as **spray foam insulations**
- Not included for most materials; e.g., emissions from equipment, machinery used on site during construction
- Typically, **A5 would add another 5-10% to embodied carbon emissions**
- Can reduce construction site emissions by **using cleaner energy on site** (e.g., grid electricity vs. diesel generator)

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Carbon Emissions : OC+MCE

Not Included B Use Stage

B1 – Use
B2 – Maintenance
B3 – Repair
B4 – Refurbishment
B5 – Replacement

- Most building **materials have no or few emissions** during the use stage
- B1 included for some products – those that have well-understood **off-gassing during use stage, such as certain rigid-foam insulations**
- **B5 is included for asphalt shingles (assumed need replacing once over 30 years)**

Carbon Emissions : OC+MCE

Not Included
C
End-of-Life

and

D
Beyond the Building Lifecycle

- Most Tools , including MCE[2], use a timeframe of 30 years
- Residential buildings assumed to last longer than 30 years
- End-of-life processes (especially decades into the future) are largely variable and unknown

EEBA

Embodied Carbon

Where do we get the info ?

EEBA

Environmental Product Declaration (EPD)

- Third party-verified
- Registered (e.g., with CSA)

Created according to **product category rules (PCRs)**

- **PCRs** ensure comparability between different products with the same function
- **PCRs** ensure that manufacturers are following the same rules for accounting for the emissions from their products

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE			
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal

ENVIRONMENTAL PRODUCT DECLARATION

OWENS CORNING ®

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

FOAMULAR® NGX™ XPS Insulation

According to ISO 14025, EN 15804 and ISO 21930:2017

4.1. Life Cycle Impact Assessment Results

Results by functional unit are available in this section. To convert to results for a particular product, please see section 4.3.

Table 9. LCIA Results for North America (TRACI) for FOAMULAR® NGX™ XPS Insulation (1 m², R_{SI}-1)

TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	6.92E+00	1.44E-01	2.24E-03	2.67E+00	MND	MND	2.10E-02	MND	1.40E-02
ODP [kg CFC-11 eq]	2.08E-05	3.56E-08	1.21E-10	0.00E+00	MND	MND	5.19E-09	MND	2.02E-09
AP [kg SO2 eq]	[illegible]	8.97E-04	3.19E-06	0.00E+00	MND	MND	1.31E-04	MND	3.66E-05
EP [kg N eq]	7.79E-03	1.79E-04	1.06E-06	0.00E+00	MND	MND	2.61E-05	MND	7.80E-06
POCP [kg O3 eq]	1.88E-01	2.43E-02	8.67E-05	3.72E-04	MND	MND	3.55E-03	MND	8.69E-04
ADP_{fossil} [MJ, LHV]	9.56E+00	3.20E-01	1.10E-03	0.00E+00	MND	MND	4.66E-02	MND	1.87E-02

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

Table 10. LCIA Results for North America (TRACI) for Laminate Addon for FOAMULAR® NGX™ Insulating Sheathing (1 m²)

TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	1.02E-01	6.23E-03	MND	MND	MND	MND	9.24E-04	MND	1.84E-04
ODP [kg CFC-11 eq]	3.51E-09	1.54E-09	MND	MND	MND	MND	2.28E-10	MND	8.89E-11
AP [kg SO2 eq]	4.21E-04	3.88E-05	MND	MND	MND	MND	5.75E-06	MND	1.61E-06
EP [kg N eq]	1.41E-04	7.75E-06	MND	MND	MND	MND	1.15E-06	MND	3.43E-07
POCP [kg O3 eq]	5.64E-03	1.05E-03	MND	MND	MND	MND	1.56E-04	MND	3.83E-05
ADP_{fossil} [MJ, LHV]	3.93E-01	1.38E-02	MND	MND	MND	MND	2.05E-03	MND	8.25E-04

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

Table 11. LCIA Results for North America (TRACI) for Laminate Addon for FOAMULAR® NGX™ PROPINK® (1 m²)

TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	2.83E-01	1.63E-02	MND	MND	MND	MND	2.30E-03	MND	4.57E-04
ODP [kg CFC-11 eq]	1.58E-08	4.02E-09	MND	MND	MND	MND	5.68E-10	MND	2.21E-10
AP [kg SO2 eq]	1.19E-03	1.01E-04	MND	MND	MND	MND	1.43E-05	MND	4.00E-06
EP [kg N eq]	5.44E-04	2.02E-05	MND	MND	MND	MND	2.86E-06	MND	8.54E-07
POCP [kg O3 eq]	1.69E-02	2.75E-03	MND	MND	MND	MND	3.88E-04	MND	9.51E-05
ADP_{fossil} [MJ, LHV]	9.81E-01	3.61E-02	MND	MND	MND	MND	5.11E-03	MND	2.05E-03

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

MATERIAL CARBON EMISSIONS : SOURCES & REFERENCES

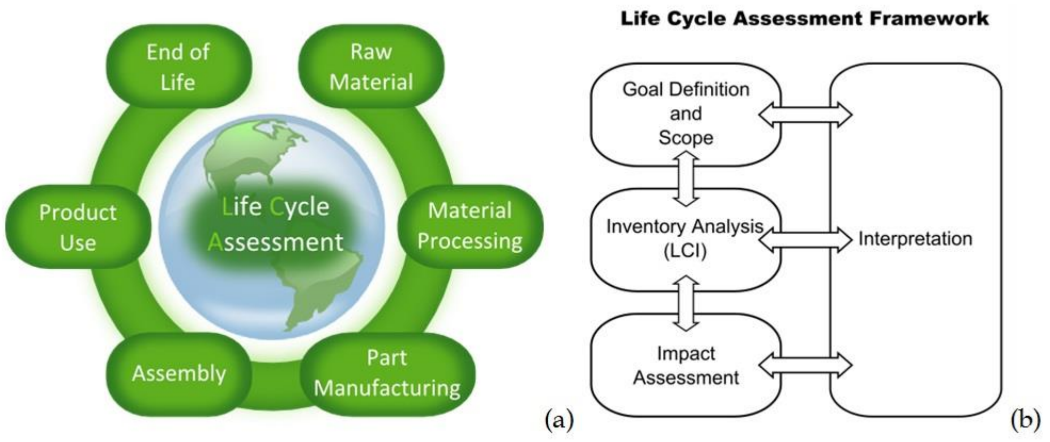
1. Life cycle assessments (LCAs)
2. Environmental Product Declarations (EPDs)
3. Materials Emissions Databases

LCA Life Cycle Assessment

Reports the lifecycle environmental impacts of products or services

- Includes GWP, but **also other impacts…**

Done according to standards:



(a) Cradle-to-grave Life Cycle Assessment and

(b) LCA Framework according to ISO standards 14040 and 14044

(International Organization for Standardization 2006).

From: intechopen.com

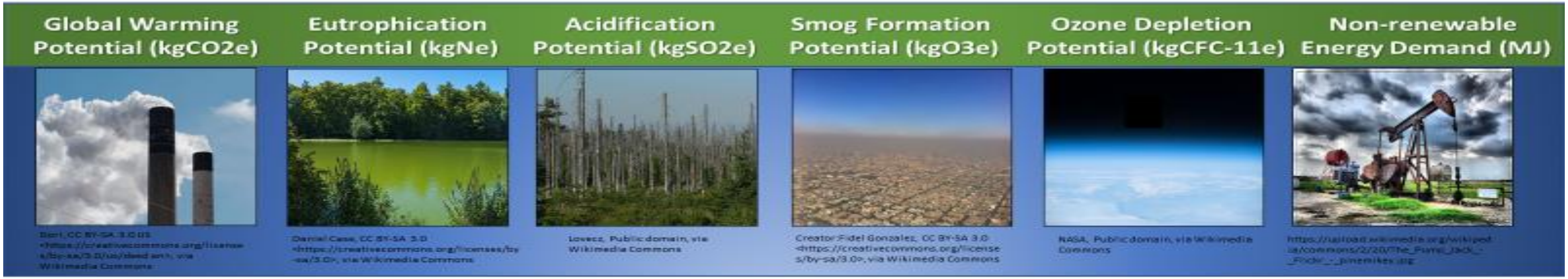
From: http://www.intechopen.com/books/third-generation-photovoltaics/life-cycle-assessment-of-organic-photovoltaics

Life-Cycle Assessment

US EPA

TRACI Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts

LCA Impact Categories (TRACI v2.1)



These are the impact categories that are considered in LEED. TRACI has other categories as well, such as Ecotoxicity Potential and particulate emissions (kgPM2.5e).

LCA Life Cycle Assessment
Beyond just carbon

Athena
Sustainable Materials
Institute

- **Primary energy (PE)** measures the total amount of primary energy directly withdrawn from the hydrosphere, atmosphere, geosphere or energy source without any anthropogenic change, including both non-renewable and renewable resources.
- **Global warming potential (GWP)** measures the amount of CO_2 released over the life of the building.
- **Ozone depletion potential (ODP)** measures the amount of ozone depleting gases (R11) created by human emissions.
- Photochemical ozone creation potential (POCP) measures the amount of ethylene (C_2H_4) created by partial combustion.
- **Acidification potential (AP)** measures the amount of sulphur dioxide (SO_2) from combustion processes in power stations and industrial buildings, in homes, by cars and small consumers.
- **Eutrophication potential (EP)** measures the amount of phosphate (PO_4) from fertilisers, combustion engines, domestic wastewater, industrial waste and wastewa

EEBA

Tools: True LCA Analysis

Athena Sustainable Materials Institute

Athena Sustainable Materials Institute

Carbon is just part of the picture

ATHENA® EcoCalculator for assemblies

TOTAL IMPACTS BY BUILDING COMPONENT	Primary Energy (MJ) TOTAL	GWP (tonnes) TOTAL	Weighted Resource Use (tonnes) TOTAL	Air Pollution Index TOTAL	H2O Pollution Index TOTAL
COLUMNS & BEAMS	0	0	0	0	0.00
INTERMEDIATE FLOORS	0	0	0	0	0.00
EXTERIOR WALLS	0	0	0	0	0.00
WINDOWS	0	0	0	0	0.00
INTERIOR WALLS	0	0	0	0	0.00
ROOF	0	0	0	0	0.00
WHOLE BUILDING	0	0	0	0	0.00

C. EXTERIOR WALLS

ATHENA ASSEMBLY EVALUATION TOOL v2.3—Toronto Low-Rise Building

IN THE YELLOW CELLS BELOW, ENTER THE AREA (in m²) THAT EACH ASSEMBLY IS USED IN YOUR BUILDING

		Assembly R-value	m²	Percentage of total	Primary Energy per m² (MJ)	GWP per m² (kg)	Weighted Resource Use per m² (kg)	Air Pollution Index per m²	H2O Pollution Index per m²
Average:					1421.11	88.76	319.71	18.36	7.43
8" CONCRETE BLOCK									
1	Concrete block, brick cladding rigid insulation, vapor barrier	21.80	0		2254.83	113.76	256.98	27.99	0.0198
2	Concrete block, steel cladding, rigid insulation, vapor barrier	21.61	0		2519.28	208.41	190.63	37.45	47.3227
3	Concrete block, stucco cladding rigid insulation, vapor barrier	21.11	0		1530.64	88.82	213.63	16.79	0.0310
4	Concrete Block, EIFS, vapor barrier	16.51	0		1227.71	72.38	136.73	14.51	0.0131
5	Concrete Block, precast cladding, rigid insulation, vapor barrier	21.00	0		1464.18	93.18	301.72	16.58	0.0557
6	Concrete block, brick cladding rigid insulation, vapor barrier gypsum board, latex paint	22.36	0		2394.08	118.17	275.66	29.89	0.0198
7	Concrete block, steel cladding rigid insulation, vapor barrier gypsum board, latex paint	22.17	0		2658.52	212.82	209.30	39.35	47.3227
8	Concrete block, stucco cladding rigid insulation, vapor barrier gypsum board, latex paint	21.67	0		1669.89	93.23	232.30	18.69	0.0310
9	Concrete block, EIFS, vapor barrier, gypsum board, latex paint	17.07	0		1366.95	76.79	155.41	16.41	0.0131
	Concrete block, precast cladding, rigid								

WELCOME & HOW-TO / COLUMNS AND BEAMS / INTERMEDIATE FLOORS / EXTERIOR WALLS / WINDOWS / INTERIOR WALLS / ROOFS

Environmental Product Declaration (EPD)

- Third party-verified
- Registered (e.g., with CSA)

Created according to **product category rules (PCRs)**

- **PCRs** ensure comparability between different products with the same function
- **PCRs** ensure that manufacturers are following the same rules for accounting for the emissions from their products

PRODUCT STAGE			CONSTRUCTION PROCESS STAGE		USE STAGE							END OF LIFE STAGE			
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4
Raw material supply	Transport	Manufacturing	Transport from gate to site	Assembly/Install	Use	Maintenance	Repair	Replacement	Refurbishment	Building Operational Energy Use During Product Use	Building Operational Water Use During Product Use	Deconstruction	Transport	Waste processing	Disposal

ENVIRONMENTAL PRODUCT DECLARATION

OWENS CORNING®

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

FOAMULAR® NGX™ XPS Insulation

According to ISO 14025, EN 15804 and ISO 21930:2017

4.1. Life Cycle Impact Assessment Results

Results by functional unit are available in this section. To convert to results for a particular product, please see section 4.3.

Table 9. LCIA Results for North America (TRACI) for FOAMULAR® NGX™ XPS Insulation (1 m², R_{SI}-1)

TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	6.92E+00	1.44E-01	2.24E-03	2.67E+00	MND	MND	2.10E-02	MND	1.40E-02
ODP [kg CFC-11 eq]	2.08E-05	3.56E-08	1.21E-10	0.00E+00	MND	MND	5.19E-09	MND	2.02E-09
AP [kg SO2 eq]	[illegible]	8.97E-04	3.19E-06	0.00E+00	MND	MND	1.31E-04	MND	3.66E-05
EP [kg N eq]	7.79E-03	1.79E-04	1.06E-06	0.00E+00	MND	MND	2.61E-05	MND	7.80E-06
POCP [kg O3 eq]	1.88E-01	2.43E-02	8.67E-05	3.72E-04	MND	MND	3.55E-03	MND	8.69E-04
ADP_{fossil} [MJ, LHV]	9.56E+00	3.20E-01	1.10E-03	0.00E+00	MND	MND	4.66E-02	MND	1.87E-02

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

Table 10. LCIA Results for North America (TRACI) for Laminate Addon for FOAMULAR® NGX™ Insulating Sheathing (1 m²)

TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	1.02E-01	6.23E-03	MND	MND	MND	MND	9.24E-04	MND	1.84E-04
ODP [kg CFC-11 eq]	3.51E-09	1.54E-09	MND	MND	MND	MND	2.28E-10	MND	8.89E-11
AP [kg SO2 eq]	4.21E-04	3.88E-05	MND	MND	MND	MND	5.75E-06	MND	1.61E-06
EP [kg N eq]	1.41E-04	7.75E-06	MND	MND	MND	MND	1.15E-06	MND	3.43E-07
POCP [kg O3 eq]	5.64E-03	1.05E-03	MND	MND	MND	MND	1.56E-04	MND	3.83E-05
ADP_{fossil} [MJ, LHV]	3.93E-01	1.38E-02	MND	MND	MND	MND	2.05E-03	MND	8.25E-04

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

Table 11. LCIA Results for North America (TRACI) for Laminate Addon for FOAMULAR® NGX™ PROPINK® (1 m²)

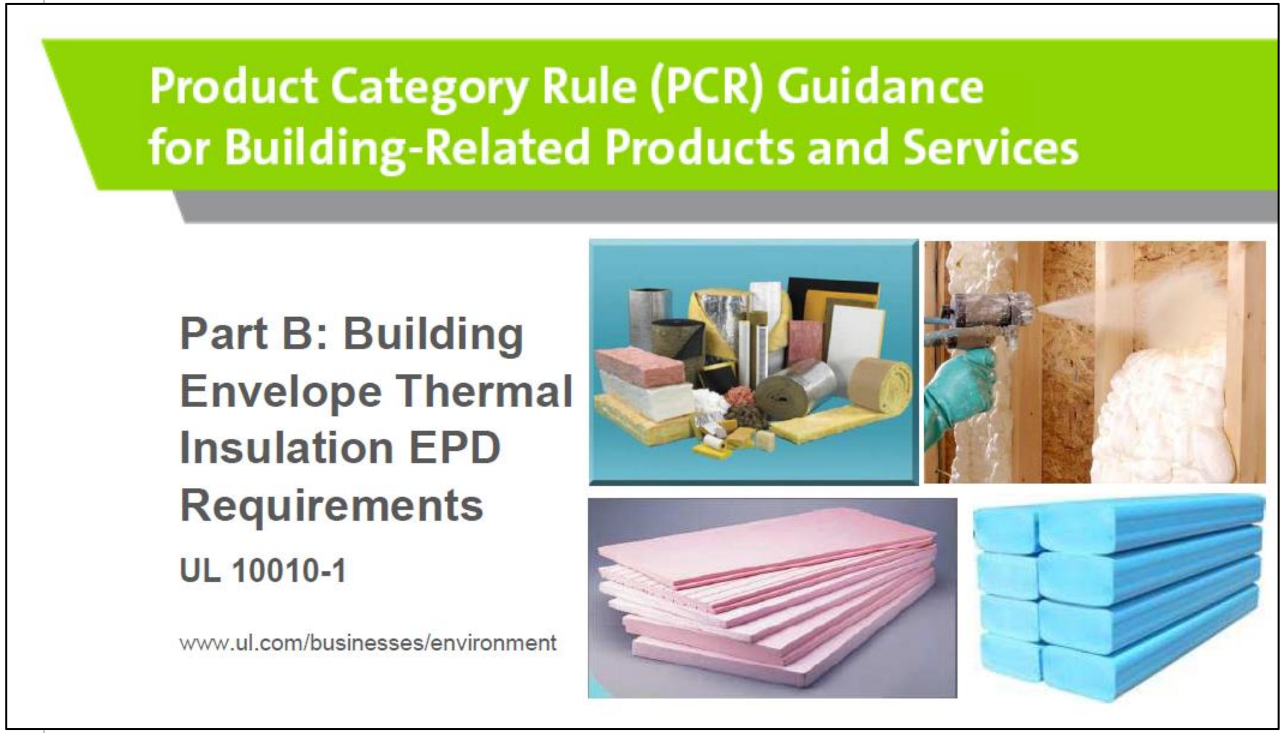
TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	2.83E-01	1.63E-02	MND	MND	MND	MND	2.30E-03	MND	4.57E-04
ODP [kg CFC-11 eq]	1.58E-08	4.02E-09	MND	MND	MND	MND	5.68E-10	MND	2.21E-10
AP [kg SO2 eq]	1.19E-03	1.01E-04	MND	MND	MND	MND	1.43E-05	MND	4.00E-06
EP [kg N eq]	5.44E-04	2.02E-05	MND	MND	MND	MND	2.86E-06	MND	8.54E-07
POCP [kg O3 eq]	1.69E-02	2.75E-03	MND	MND	MND	MND	3.88E-04	MND	9.51E-05
ADP_{fossil} [MJ, LHV]	9.81E-01	3.61E-02	MND	MND	MND	MND	5.11E-03	MND	2.05E-03

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

EEBA

Environmental Product Declaration (EPD)

Example Product Category Rules

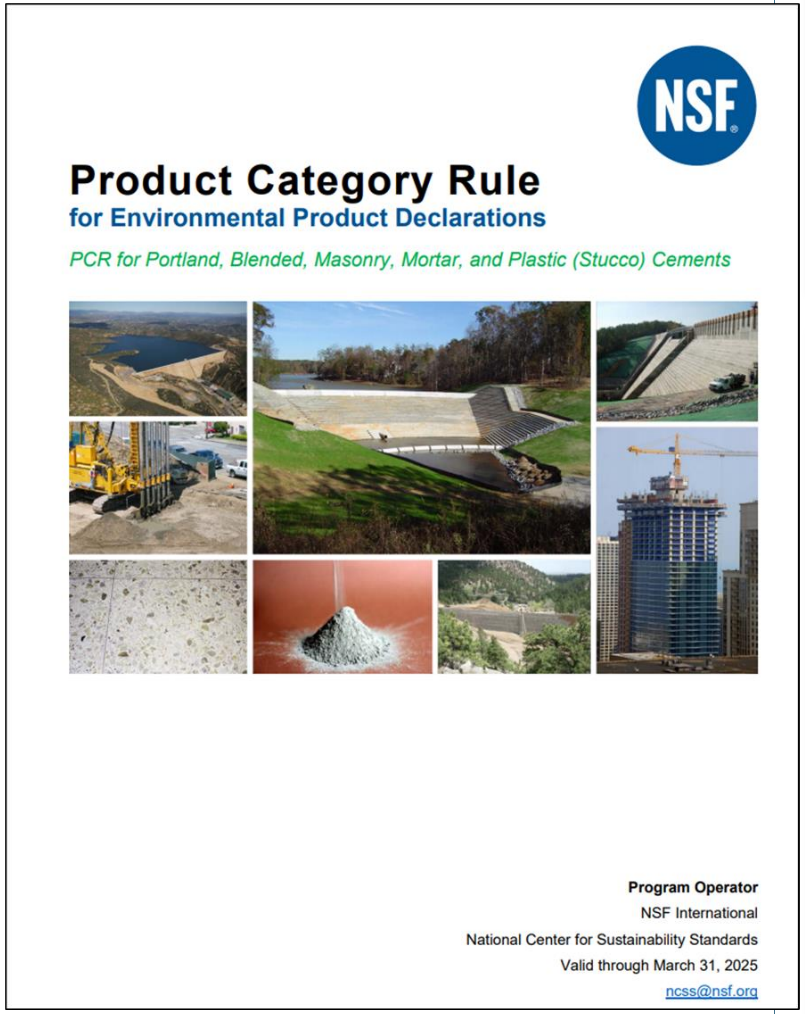

Product Category Rule (PCR) Guidance
for Building-Related Products and Services

Part B: Building Envelope Thermal Insulation EPD Requirements

UL 10010-1

www.ul.com/businesses/environment

From: https://www.shopulstandards.com/


NSF

Product Category Rule
for Environmental Product Declarations

PCR for Portland, Blended, Masonry, Mortar, and Plastic (Stucco) Cements

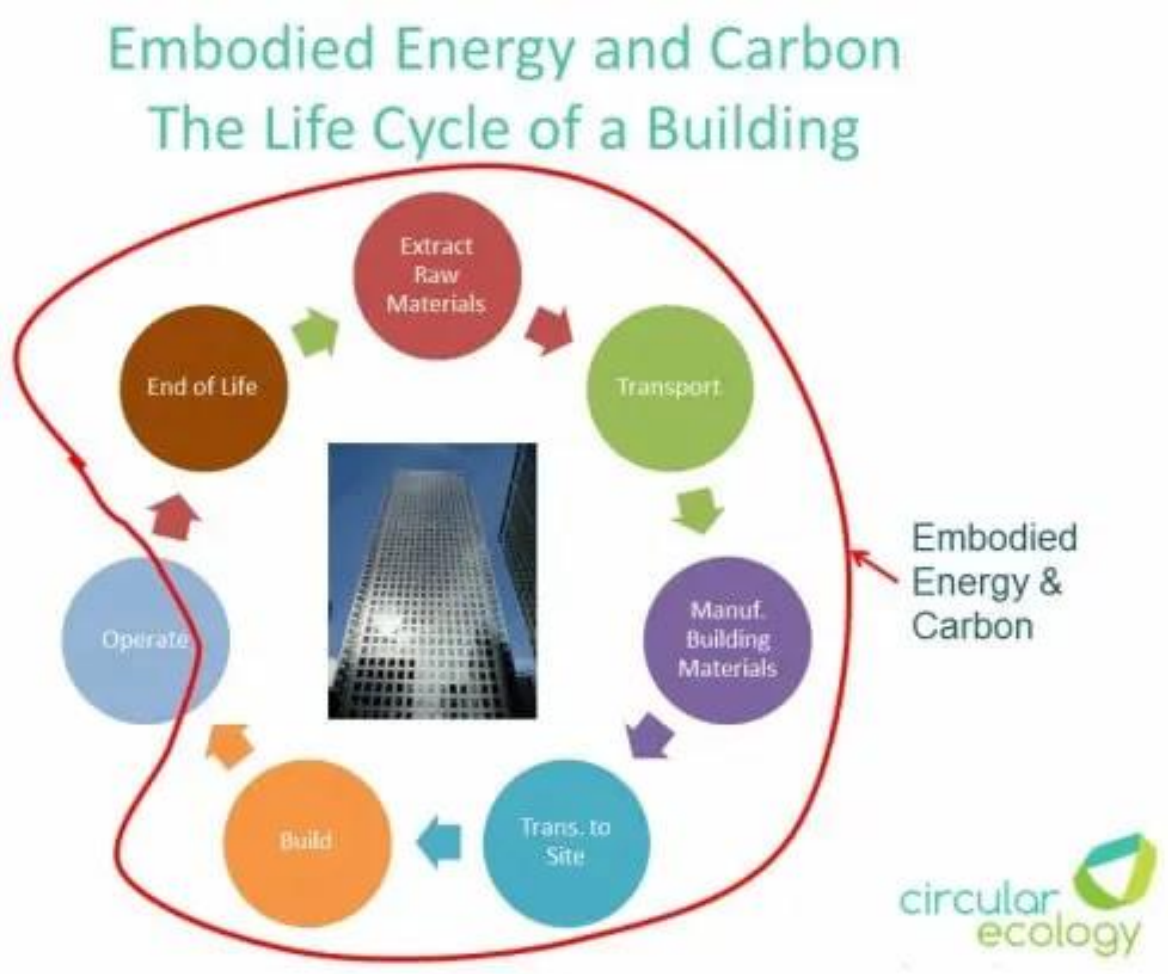
Program Operator
NSF International
National Center for Sustainability Standards
Valid through March 31, 2025
ncss@nsf.org

ASTM: https://www.astm.org/CERTIFICATION/EpdAndPCRs.html

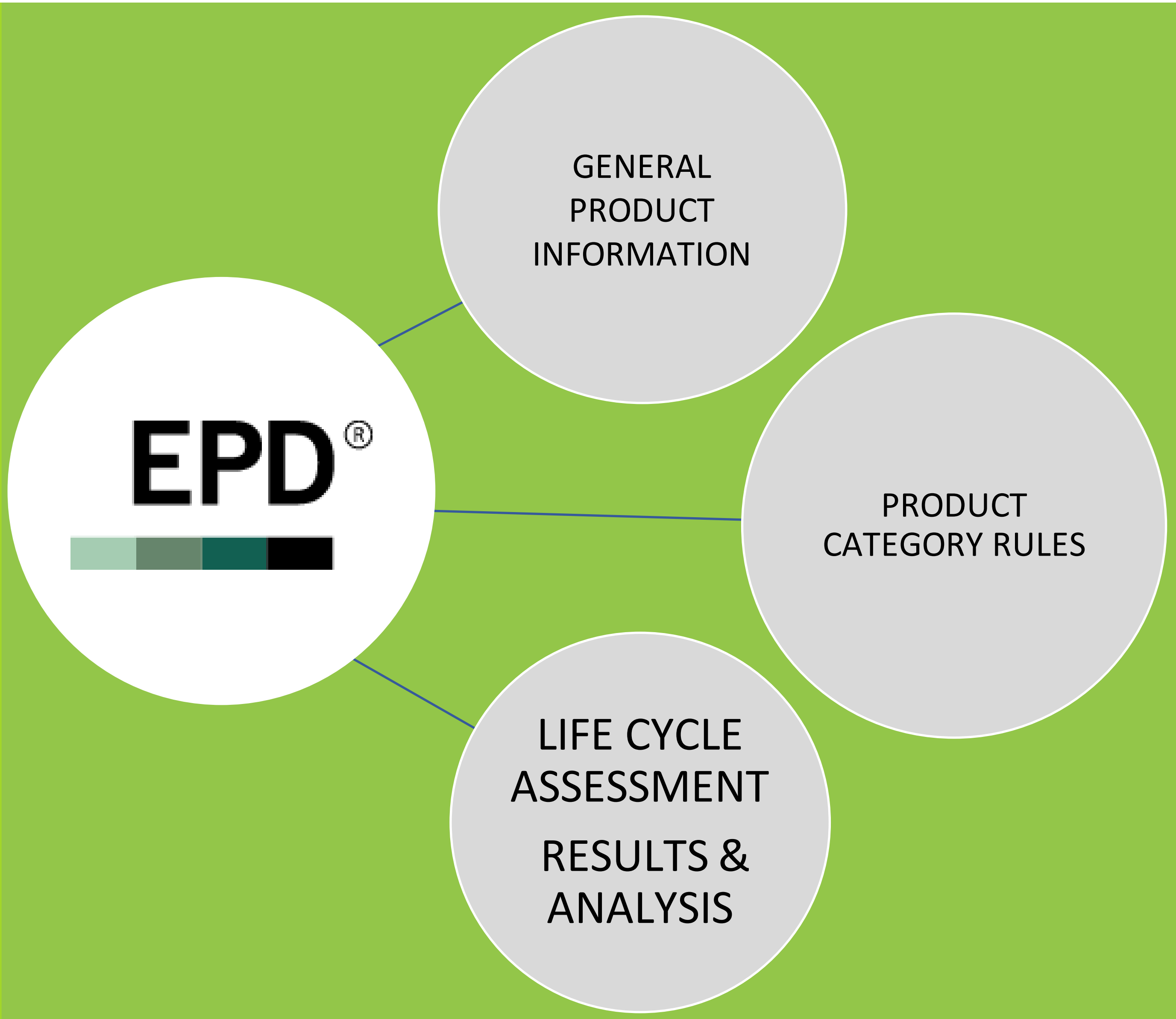
Material Emissions Database

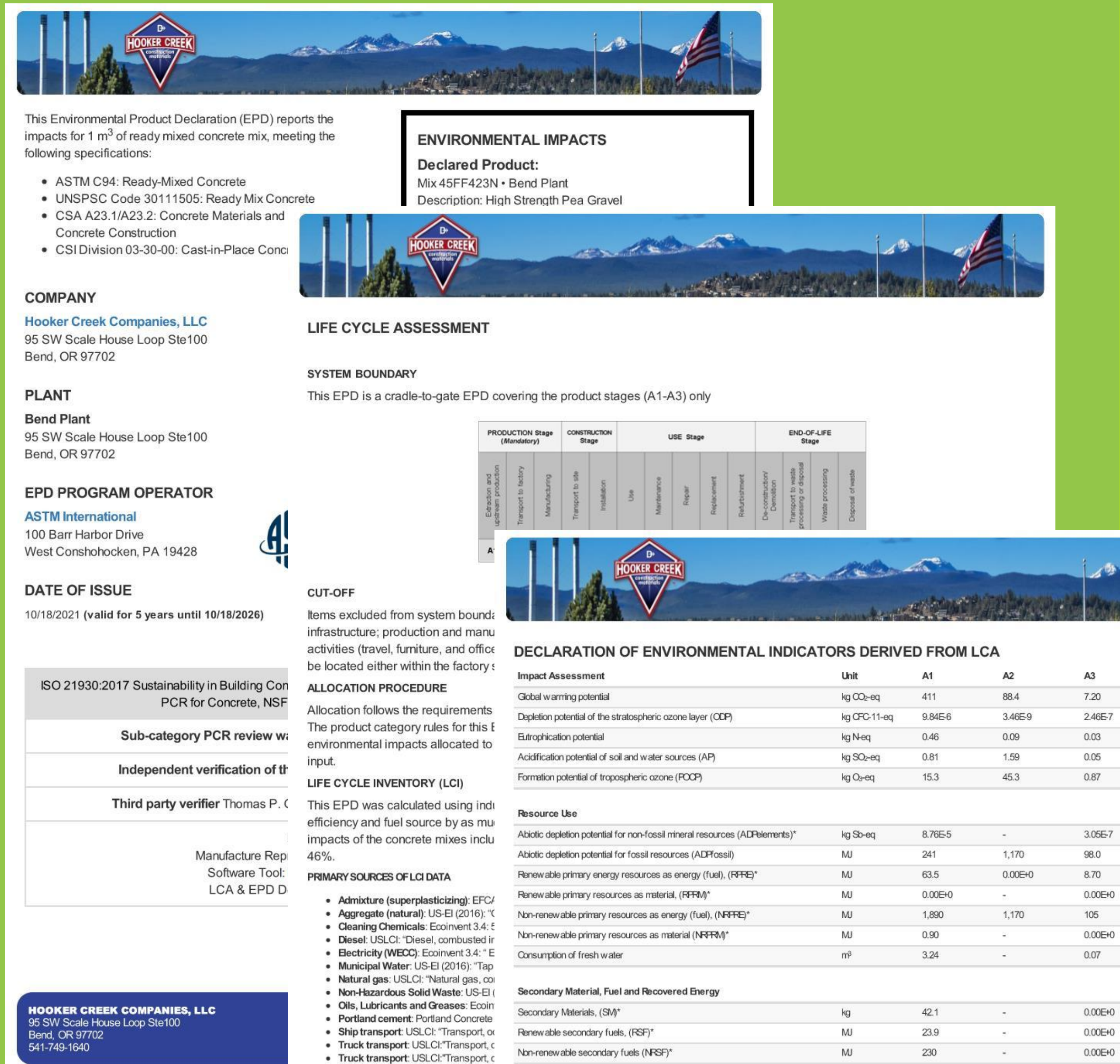
- ICE-UK (Inventory of carbon and energy, United Kingdom)

https://circularecology.com/embodied-carbon-footprint-database.html



It starts with Environmental Product Declarations (EPDs)





This Environmental Product Declaration (EPD) reports the impacts for 1 m^3 of ready mixed concrete mix, meeting the following specifications:

- ASTM C94: Ready-Mixed Concrete
- UNSPSC Code 30111505: Ready Mix Concrete
- CSA A23.1/A23.2: Concrete Materials and Concrete Construction
- CSI Division 03-30-00: Cast-in-Place Conc

ENVIRONMENTAL IMPACTS

Declared Product:
Mix 45FF423N • Bend Plant
Description: High Strength Pea Gravel

COMPANY
Hooker Creek Companies, LLC
95 SW Scale House Loop Ste100
Bend, OR 97702

PLANT
Bend Plant
95 SW Scale House Loop Ste100
Bend, OR 97702

EPD PROGRAM OPERATOR
ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428

DATE OF ISSUE
10/18/2021 (valid for 5 years until 10/18/2026)

ISO 21930:2017 Sustainability in Building Con
PCR for Concrete, NSF

Sub-category PCR review wa

Independent verification of th

Third party verifier Thomas P. C

Manufacture Rep
Software Tool:
LCA & EPD D

HOOKER CREEK COMPANIES, LLC
95 SW Scale House Loop Ste100
Bend, OR 97702
541-749-1640

LIFE CYCLE ASSESSMENT

SYSTEM BOUNDARY
This EPD is a cradle-to-gate EPD covering the product stages (A1-A3) only

CUT-OFF
Items excluded from system bounda infrastructure; production and manu activities (travel, furniture, and office be located either within the factory s

ALLOCATION PROCEDURE
Allocation follows the requirements The product category rules for this E environmental impacts allocated to input.

LIFE CYCLE INVENTORY (LCI)
This EPD was calculated using indu efficiency and fuel source by as mu impacts of the concrete mixes inclu 46%.

PRIMARY SOURCES OF LCI DATA

- **Admixture (superplasticizing)**: EFCA
- **Aggregate (natural)**: US-EI (2016): "C
- **Cleaning Chemicals**: Ecoinvent 3.4: 5
- **Diesel**: USLCI: "Diesel, combusted in
- **Electricity (WECC)**: Ecoinvent 3.4: " E
- **Municipal Water**: US-EI (2016): "Tap
- **Natural gas**: USLCI: "Natural gas, co
- **Non-Hazardous Solid Waste**: US-EI (
- **Oils, Lubricants and Greases**: Ecoin
- **Portland cement**: Portland Concrete
- **Ship transport**: USLCI: "Transport, oc
- **Truck transport**: USLCI:"Transport, c
- **Truck transport**: USLCI:"Transport, c

DECLARATION OF ENVIRONMENTAL INDICATORS DERIVED FROM LCA

Impact Assessment	Unit	A1	A2	A3
Global warming potential	kg CO_2-eq	411	88.4	7.20
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC-11-eq	9.84E-6	3.46E-9	2.46E-7
Eutrophication potential	kg N-eq	0.46	0.09	0.03
Acidification potential of soil and water sources (AP)	kg SO_2-eq	0.81	1.59	0.05
Formation potential of tropospheric ozone (POCP)	kg O_3-eq	15.3	45.3	0.87
Resource Use				
Abiotic depletion potential for non-fossil mineral resources (ADPelements)*	kg Sb-eq	8.76E-5	-	3.05E-7
Abiotic depletion potential for fossil resources (ADPfossil)	MJ	241	1,170	98.0
Renewable primary energy resources as energy (fuel), (RPRE)*	MJ	63.5	0.00E+0	8.70
Renewable primary resources as material, (RPRM)*	MJ	0.00E+0	-	0.00E+0
Non-renewable primary resources as energy (fuel), (NRPRE)*	MJ	1,890	1,170	105
Non-renewable primary resources as material (NRPRM)*	MJ	0.90	-	0.00E+0
Consumption of fresh water	m^3	3.24	-	0.07
Secondary Material, Fuel and Recovered Energy				
Secondary Materials, (SM)*	kg	42.1	-	0.00E+0
Renewable secondary fuels, (RSF)*	MJ	23.9	-	0.00E+0
Non-renewable secondary fuels (NRSF)*	MJ	230	-	0.00E+0

What are EPD Standards?

- The concept of EPDs is based on the ISO 14025 and ISO 21930 standards, which provides the rules for the development of EPDs in the construction sector.
  - (Internationally recognized)
- EPDs quantify a wide array of environmental information on the life cycle of a product.
- EPDs can be used for all types of goods and services.
- EPDs contain verified environmental information, based on the principles of ISO standards development - consensus-based, voluntary, market-relevant

Start asking suppliers / manufacturers for them now

BRICK SIDING EPD - Generic

Table 7. Life-cycle results for clay brick production

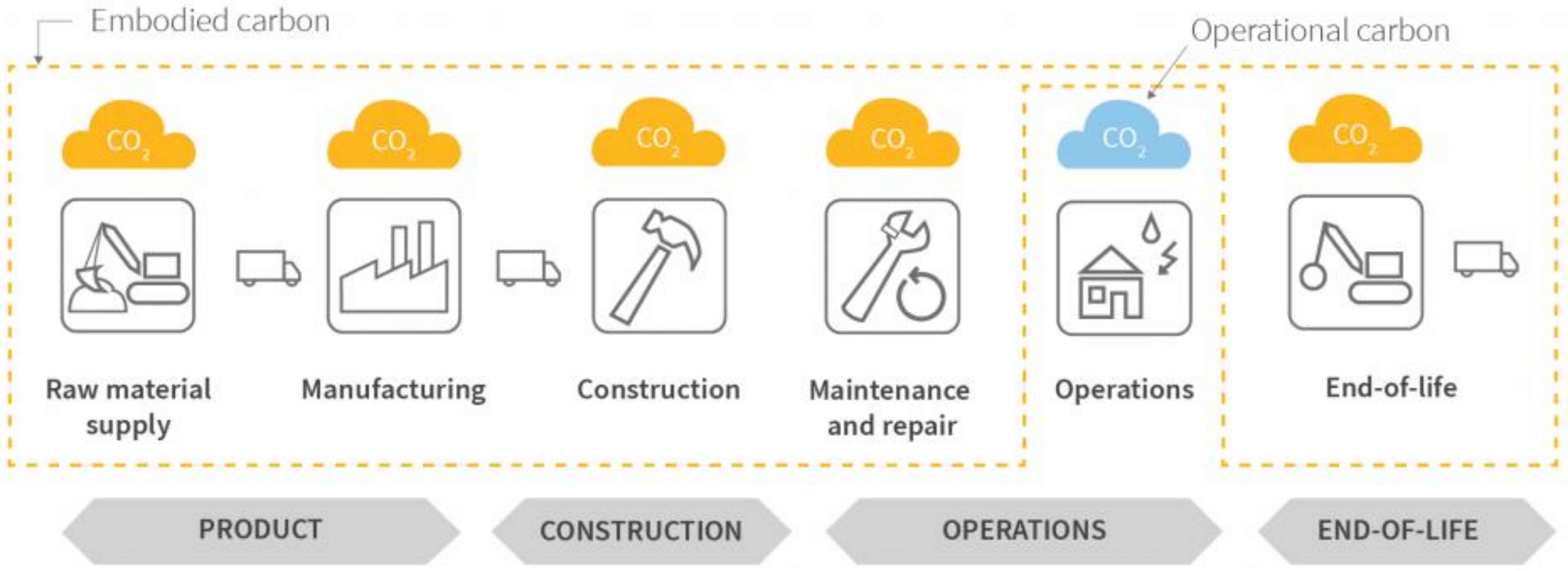
Metric	Cradle-to-gate total, per cubic meter of brick	Unit
Environmental impact		
Global Warming Potential	503	kg CO_2 eq
Acidification Potential	1.52	kg SO_2 eq
Eutrophication Potential	0.888	kg N eq
Smog Potential	15.6	kg O_3 eq
Ozone Depletion Potential	0.0000629	kg CFC-11 eq
Total primary energy consumption		
Nonrenewable Fossil	8,210	MJ
Nonrenewable Nuclear	516	MJ
Renewable (Solar, Wind, Hydroelectric and Geothermal)	38.3	MJ
Renewable (Biomass)	140	MJ
Material resources consumption		
Nonrenewable Material Resources	2,280	kg
Renewable Material Resources	0.00298	kg
Net Fresh Water (Inputs Minus Outputs)	2,810	L
Total waste generation		
Non-Hazardous Waste Generated	2.56	kg
Hazardous Waste Generated	0.00674	kg

503 Kg CO_2e per cubic meter of brick

- Production only
- Does not consider transport & installation
- Calculate the amount of brick per house model
- Consider a waste factor
- It may vary by manufacturer

https://info.nsf.org/Certified/Sustain/ProdCert EPD10447.pdf

Building Lifecycle



Cradle to Gate
A1-A3

To Site
A4-A5

Operation &
Maintenance
B1-B7

Demolition & Disposal
C1-C4

Cradle to Grave

What information can we find?

SECTION 4 (LCA ANALYSIS)

DECLARATION OF ENVIRONMENTAL INDICATORS DERIVED FROM LCA

Impact Assessment	Unit	A1	A2	A3	Total
Global warming potential	kg CO_2-eq	411	88.4	7.20	507
Depletion potential of the stratospheric ozone layer (ODP)	kg CFC-11-eq	9.84E-6	3.46E-9	2.46E-7	1.01E-5
Eutrophication potential	kg N-eq	0.46	0.09	0.03	0.57
Acidification potential of soil and water sources (AP)	kg SO_2-eq	0.81	1.59	0.05	2.45
Formation potential of tropospheric ozone (POCP)	kg O_3-eq	15.3	45.3	0.87	61.4

Resource Use					
Abiotic depletion potential for non-fossil mineral resources (ADPelements)*	kg Sb-eq	8.76E-5	-	3.05E-7	8.79E-5
Abiotic depletion potential for fossil resources (ADPfossil)	MJ	241	1,170	98.0	1,510
Renewable primary energy resources as energy (fuel), (RPRE)*	MJ	63.5	0.00E+0	8.70	72.2
Renewable primary resources as material, (RPRM)*	MJ	0.00E+0	-	0.00E+0	0.00E+0

GLOBAL WARMING POTENTIAL (kg CO2e)

Covers carbon emissions in product stages A1 – A3

What are EPD Standards?

A1-A6 + B6(30yr) = 65% of Total Carbon emissions

Description of the system boundary (X = included in lca; MND = module not declared; MNR = module not relevant)																
Product stage			Construction process stage		Use stage							End of life stage				Benefits and loads beyond the system boundaries
Raw material supply	Transport	Manufacturing	Transport from the gate to the site	Assembly	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	De-construction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling-potential
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
X	X	X	X	X	X	MND	MNR	MNR	MNR	MND	MND	X	X	MND	X	X

What stages & inputs should be considered?

VINYL SIDING EPD - Generic

Part B- Life Cycle Impact Assessment Results												
Functional Unit: 100 square feet												
Part B.1 TRACI 2.1		**A1**	**A2**	**A3**	**A4**	**A5**	**B2**	**C1**	**C2**	**C3**	**C4**	**Units**
GWP	Global warming potential	4.47E+01	1.27E+00	5.07E+00	.40E-01	7.66E-01	4.79E-01	0.00E+00	3.58E-02	0.00E+00	9.75E+00	kg CO_2 Eq.
ODP	Depletion potential of the stratospheric ozone layer	2.61E-06	7.55E-08	1.46E-07	3.59E-11	5.11E-08	2.90E-08	0.00E+00	1.37E-12	0.00E+00	2.67E-07	kg CFC 11 Eq.
AP	Acidification potential	1.93E-01	9.86E-03	3.90E-02	5.61E-03	4.17E-03	2.46E-03	0.00E+00	2.14E-04	0.00E+00	2.33E-02	kg SO_2 Eq.
EP	Eutrophication potential	4.86E-02	1.14E-03	5.45E-03	3.13E-04	3.33E-03	2.08E-03	0.00E+00	1.19E-05	0.00E+00	1.54E-02	kg N Eq.
POCP	Photochemical ozone creation potential	1.73E+00	2.78E-01	3.19E-01	1.54E-01	3.46E-02	2.93E-02	0.00E+00	5.85E-03	0.00E+00	2.37E-01	kg O_3 Eq.
ADPF	Abiotic depletion potential for fossil resources	1.37E+02	2.23E+00	5.42E+00	1.69E+00	6.47E-01	3.63E-01	0.00E+00	6.45E-02	0.00E+00	2.69E+00	MJ surplus energy
Part B.2 CML		**A1**	**A2**	**A3**	**A4**	**A5**	**B2**	**C1**	**C2**	**C3**	**C4**	**Units**
GWP	Global Warming Potential	4.47E+01	1.27E+00	5.07E+00	9.40E-01	7.66E-01	4.79E-01	0.00E+00	3.58E-02	0.00E+00	9.75E+00	kg CO_2 Eq.
ODP	Depletion potential of stratospheric ozone layer	2.43E-06	5.64E-08	1.15E-07	3.55E-11	3.89E-08	2.22E-08	0.00E+00	1.35E-12	0.00E+00	1.88E-07	kg CFC-11 Eq.
AP	Acidification potential	1.93E-01	9.86E-03	3.90E-02	5.61E-03	4.17E-03	2.46E-03	0.00E+00	2.14E-04	0.00E+00	2.33E-02	kg SO_2 Eq.
EP	Eutrophication potential	2.81E-02	1.70E-03	3.73E-03	8.21E-04	1.59E-03	1.14E-03	0.00E+00	3.12E-05	0.00E+00	7.33E-03	kg $(PO_4)^{3-}$ Eq.
POCP	Photochemical ozone creation potential	1.24E-02	3.03E-04	2.46E-03	2.14E-04	2.72E-04	7.57E-04	0.00E+00	8.13E-06	0.00E+00	9.88E-04	kg ethane Eq.

All use phase stages have been considered and only maintenance (B2) contains non-zero environmental impacts, which is reported above.

51 Kg CO_2e per 100 ft^2

- Provided by the industry association
- We don't consider transport to site & installation
- Calculate the amount of siding per house model
- Consider the "overage" factor when calculating quantities
- It may vary by manufacturer

ENVIRONMENTAL PRODUCT DECLARATION

VINYL SIDING INSTITUTE

Industry Averaged Vinyl Siding (0.040" Double 4.5")

CEMENT BOARD SIDING - EPD

Environmental indicator results for the A1 - A3 modules on an aggregated basis and the A4 module are shown in the following tables for the declared unit of $1m^2$ of fibre cement panel.

Modules A1 - A3		Unit	Hardie® Panel	Hardie® Plank	Hardie® VL Plank
Climate change - GWP100	GWP	kg CO_2-eq	8.94E+00	7.34E+00	1.20E+01
Ozone layer depletion - ODP steady state	ODP	kg CFC11-eq	5.13E-07	4.51E-07	7.39E-07
Acidification potential - average Europe	AP	kg SO_2-eq	2.75E-02	2.51E-02	3.54E-02
Eutrophication - generic	EP	kg PO_4^{3-}-eq	4.05E-03	3.44E-03	6.02E-03
Photochemical oxidant creation potential	POCP	kg ethene-eq	1.51E-03	1.46E-03	2.04E-03
Depletion of abiotic resources - elements, ultimate reserves	ADPE	kg Sb-eq	2.95E-05	2.76E-05	4.33E-05
Depletion of abiotic resources - fossil fuels	ADPFF	MJ	8.92E+01	8.26E+01	1.32E+02

8.9 Kg CO_2e per 1 m^2

ENGINEERED WOOD SIDING - EPD

TABLE 6 LCIA Results Summary for Cradle-to-Gate production of 1 m^3 of LP® SmartSide® products.

CORE MANDATORY IMPACT INDICATOR			A1: EXTRACTION	A2: RAW MATERIAL TRANSPORT	A3: MANUFACTURING	A4: PRODUCT TRANSPORT	TOTAL
Global warming potential	GWP_{BIO}	kg CO_2e	(1,756.19)	27.49	2,076.01	74.24	421.55
Global warming potential	GWP_{TRACI}	kg CO_2e	129.86	27.49	189.96	74.24	421.55
Depletion potential of the stratospheric ozone layer	ODP	kg CFC11e	2.57E-07	6.05E-07	7.27E-06	2.64E-06	0.00
Acidification potential of soil and water sources	AP	kg SO_2e	0.8409	0.1806	0.9850	0.4915	2.50
Eutrophication potential	EP	kg Ne	0.0732	0.0190	1.1495	0.0566	1.30
Formation potential of tropospheric ozone	SFP	kg O_3e	16.90	5.28	14.76	14.27	51.22
Abiotic depletion potential (ADPfossil) for fossil resources	ADPf	MJ, NCV	2,500.91	346.81	2,267.14	941.01	6,055.87
Fossil fuel depletion	FFD	MJ Surplus	3.69E+02	5.15E+01	2.10E+02	1.39E+02	769.37

347.5 Kg CO_2e / m^3
A1-A3

- Note the -(1,756) Kg for extraction.
- The carbon is considered to be **sequestered.**

Wood is given credit for the CO_2 that has been absorbed and stored over the years

WOOD SIDING EPD - Red Cedar

Impact Category	Unit	Total	Production	Construction		Use	End-of-life		
			Cradle-to-gate Product Manufacturing	Transport to Customer	Installation	Use , Maintainance, Repair	Dismantling	Waste Transport	Disposal
			A1, A2, A3	A4	A5	B1, B2	C1	C2	C4
Global Warming	kg CO_2 eq	5.93	2.14	0.20	1.86	0.70	0.00	0.13	0.89
Ozone depletion	kg CFC-11 eq	5.24E-07	1.14E-07	4.68E-11	2.89E-07	8.95E-08	0.00	3.02E-11	1.89E-09
Acidification	kg SO_2 eq	0.04	0.02	3.33E-03	0.01	3.55E-03	0.00	8.14E-04	2.11E-03
Eutrophication	kg N eq	0.02	0.01	2.21E-04	0.01	1.24E-03	0.00	5.81E-05	1.72E-03
Smog	kg O_3 eq	0.63	0.28	0.11	0.11	0.04	0.00	0.02	0.07

2.14 Kg CO_2e per 1 m^2

- A1-A3 combined
- Sequestration of carbon already accounted for

https://www.realcedar.com/static/6e57fdcd0c8d7a7e440290b0b745d301/Typical-Cedar-Siding-EPD-Febuary-2018.pdf

CLADDING SUMMARY(FROM BEAM TOOL) * BASED ON BASE HOUSE Quantities*

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
EXTERIOR WALL CLADDING								
COMMON BRICK								
	Brick, Clay / Interstate / Avg Face Brick / 3-5/8" x 2-3/4" x 7-5/8" (92 x 70 x 194 mm) incl. 3/8" mortar	2,699.7	ft²	100%	☐	11,911	11,911	0
	Brick, Clay, Generic Modular / 3-5/8" x 2-3/4" x 7-5/8" incl. 3/8" mortar / Brick Industry Association / [Industry Avg | US-Canada]	2,699.7	ft²	100%	☐	11,850	11,850	0
	Brick, Cement / MidWest / Architectural Face Brick / 3-5/8" x 2-3/4" x 7-5/8" (92 x 70 x 194 mm) incl. 3/8" mortar	2,699.7	ft²	100%	☐	9,080	9,080	0
	Brick, Calcium Silicate / Arriscraft / Contemporary Brick / 3-1/8" x 3-1/2" x any length, incl. mortar and ties	2,699.7	ft²	100%	☐	7,559	7,559	0
ACRYLIC STUCCO								
	Synthetic Stucco (Acrylic) / Sto / Stolit Freeform & Freeform Dark Colors (avg)	2,699.7	ft²	100%	☐	12,766	12,766	0
	Synthetic Stucco (Acrylic) / Sto / Stolit 1.5 & 1.5 Dark Colors (avg)	2,699.7	ft²	100%	☐	8,227	8,227	0
	Synthetic Stucco (Acrylic) / Sto / Stolit 1.0 & 1.0 Dark Colors (avg)	2,699.7	ft²	100%	☐	7,223	7,223	0
FIBER CEMENT SIDING								
	Fiber Cement siding / Cembrit / Solid & Express / 8 mm (5/16")	2,699.7	ft²	100%	☐	6,078	6,357	279
	Fiber Cement siding / Cembrit / Patina / 8 mm (5/16")	2,699.7	ft²	100%	☐	2,526	2,806	279
VINYL SIDING								
	Vinyl Siding / Vinyl Siding Institute / 0.040" Double 4.5" [Industry Avg | US & CA]	2,699.7	ft²	100%	☑	1,349	1,349	0
WOOD SIDING								
	Cedar Siding / Western Red Cedar Lumber Assn / 1x6 Boards [Industry Avg | CA]	2,699.7	ft²	100%	☐	432	432	0
	Wood / SPF / 3/4" boards / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	302	302	0

From 302 Kg CO_2e for wood siding to 12,766 Kg CO_2e for Stucco

NORTH AMERICAN SOFTWOOD PLYWOOD EPD

ENVIRONMENTAL PRODUCT DECLARATION

AMERICAN WOOD COUNCIL

Canadian Wood Council / Conseil canadien du bois

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

North American Softwood Plywood
North American Structural and Architectural Wood Products

According to ISO 14025, EN 15804 and ISO 21930:2017

3.1. Life Cycle Impact Assessment Results

Table 8. Impact Assessment Results for 1 m³ of North American Plywood

TRACI v2.1	TOTAL	A1	A2	A3
GWP_{TRACI} [kg CO_2 eq]	219.32	70.03	10.28	139.00
GWP_{BIO} (incl. biogenic carbon) [kg CO_2 eq]	219.32	(2,057.39)	10.28	2,266.42*
ODP [kg CFC-11 eq]	8.66E-06	8.26E-07	1.43E-08	7.82E-06
AP [kg SO_2 eq]	1.07	0.42	0.07	0.58
EP [kg N eq]	0.87	0.10	0.01	0.77
POCP [kg O_3 eq]	22.44	7.53	1.88	13.03
ADP_{fossil} [MJ, LHV]	3,402.99	1,560.69	131.97	1,710.32
Fossil fuel depletion [MJ surplus]	429.32	121.64	19.76	287.92

*A3 Results for GWP_{BIO} include downstream emissions that occur in information module A5 and C3/C4. See Table 11 for detailed LCI of biogenic carbon.

219.3 Kg CO_2e / m^3
A1-A3

https://awc.org/wp-content/uploads/2021/11/AWC_EPD_NorthAmericanSoftwoodPlywood_20200605.pdf

NORTH AMERICAN SOFTWOOD LUMBER EPD

ENVIRONMENTAL PRODUCT DECLARATION

AMERICAN WOOD COUNCIL

Canadian Wood Council / Conseil canadien du bois

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION UL.COM/EPD

North American Softwood Lumber
North American Structural and Architectural Wood Products

According to ISO 14025, EN 15804 and ISO 21930:2017

3.1. Life Cycle Impact Assessment Results

Table 9. Impact Assessment Results for 1 m³ of North American Softwood Lumber

TRACI v2.1	TOTAL	A1	A2	A3
GWP_{TRACI} [kg CO_2 eq]	63.12	10.55	10.01	42.56
GWP_{BIO} (incl. biogenic carbon) [kg CO_2 eq]	63.12	(2,042.32)	10.01	2,095.43*
ODP [kg CFC-11 eq]	2.8E-06	1.1E-07	1.0E-08	2.7E-06
AP [kg SO_2 eq]	0.52	0.14	0.08	0.30
EP [kg N eq]	0.25	0.02	0.01	0.23
POCP [kg O_3 eq]	13.68	4.43	2.14	7.11
ADP_{fossil} [MJ, LHV]	833.37	141.22	136.57	555.58
Fossil fuel depletion [MJ surplus]	101.51	21.58	19.79	60.14

*A3 Results for GWP_{BIO} include downstream emissions that occur in information module A5 and C3/C4. See Table 12 for detailed LCI of biogenic carbon.

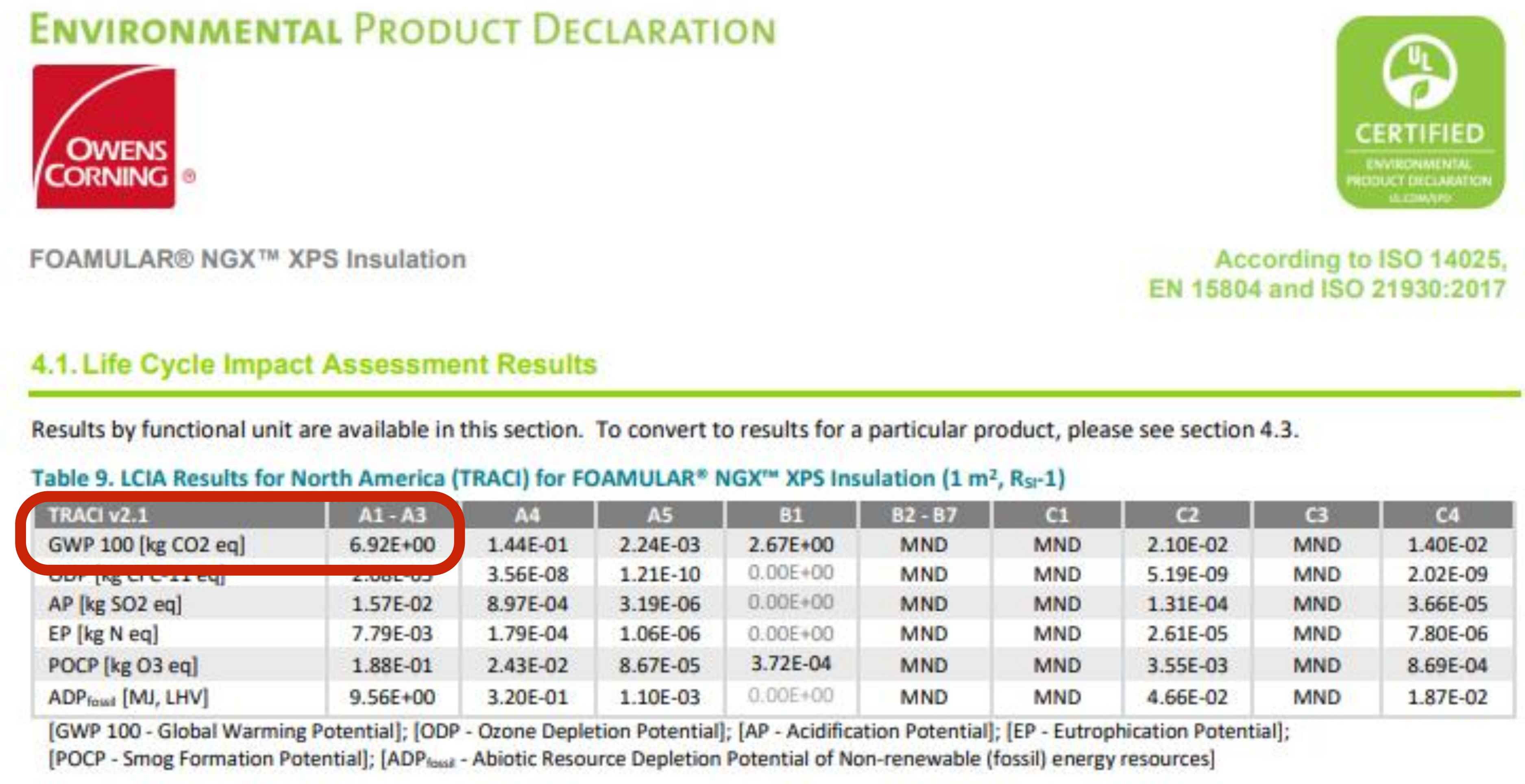
63.12 Kg CO_2e / m^3

A1-A3

Wood is Good

https://awc.org/wp-content/uploads/2021/11/AWC_EPD_NorthAmericanSoftwoodLumber_20200605.pdf

XPS EXTERIOR INSULATION - EPD



ENVIRONMENTAL PRODUCT DECLARATION

OWENS CORNING®

CERTIFIED ENVIRONMENTAL PRODUCT DECLARATION

FOAMULAR® NGX™ XPS Insulation

According to ISO 14025, EN 15804 and ISO 21930:2017

4.1. Life Cycle Impact Assessment Results

Results by functional unit are available in this section. To convert to results for a particular product, please see section 4.3.

Table 9. LCIA Results for North America (TRACI) for FOAMULAR® NGX™ XPS Insulation (1 m^2, R_{SI}-1)

TRACI v2.1	A1 - A3	A4	A5	B1	B2 - B7	C1	C2	C3	C4
GWP 100 [kg CO2 eq]	6.92E+00	1.44E-01	2.24E-03	2.67E+00	MND	MND	2.10E-02	MND	1.40E-02
ODP [kg CFC-11 eq]	[illegible]	3.56E-08	1.21E-10	0.00E+00	MND	MND	5.19E-09	MND	2.02E-09
AP [kg SO2 eq]	1.57E-02	8.97E-04	3.19E-06	0.00E+00	MND	MND	1.31E-04	MND	3.66E-05
EP [kg N eq]	7.79E-03	1.79E-04	1.06E-06	0.00E+00	MND	MND	2.61E-05	MND	7.80E-06
POCP [kg O3 eq]	1.88E-01	2.43E-02	8.67E-05	3.72E-04	MND	MND	3.55E-03	MND	8.69E-04
ADP_{fossil} [MJ, LHV]	9.56E+00	3.20E-01	1.10E-03	0.00E+00	MND	MND	4.66E-02	MND	1.87E-02

[GWP 100 - Global Warming Potential]; [ODP - Ozone Depletion Potential]; [AP - Acidification Potential]; [EP - Eutrophication Potential]; [POCP - Smog Formation Potential]; [ADP_{fossil} - Abiotic Resource Depletion Potential of Non-renewable (fossil) energy resources]

6.92 Kg CO_2e / m^2

A1-A3

- Significant advancements are being made
- GWP of XPS has been reduced by 75%
- Underscores importance of updating EPD info annually

https://dcpd6wotaa0mb.cloudfront.net/mdms/dms/Shared/10024576/FOAMULAR-NGX-XPS-Insulation-EPD_UL_corrected.pdf?v=1646664386000

EPD Summary

- Start asking manufacturers and suppliers for their EPDs
- For now, look at Cradle to Gate of manufacture: A1 - A3
- Many EPDs are done by industry associations - generic
- Most carbon accounting software tools are pre-populated with common EPDs.
- They are one tool to use in making material choices
- Manufacturers are making improvements now
- There are significant differences within the same element category
  - Insulation
  - Cladding
  - etc.

Impact Category	Unit	Total	Production Cradle-to-gate Product Manufacturing A1, A2, A3
Global Warming	kg CO_2 eq	5.93	2.14
Ozone depletion	kg CFC-11 eq	5.24E-07	1.44E-07
Acidification	kg SO_2 eq	0.04	0.02
Eutrophication	kg N eq	0.02	0.01
Smog	kg O_3 eq	0.63	0.28

For a comprehensive listing of EPDs:

https://www.buildingtransparency.org/

Carbon Accounting Metrics and Tools

Carbon Emission Assessment Tools: LCA And More…

WBLCA Software

Athena Impact Estimator for Buildings	tally	One Click LCA
Stand-alone desktop app	Plug-in for Autodesk Revit	Web-based, with BIM integration
Free!	$695US/y plus Revit ($995US for premium)	Starter: $790US/y Business: $1690US/y Expert: $3000US/y
ISO14040/44 compliant, TRACI impact assessment, can be used for LEED v4.1	ISO14040/44 compliant, TRACI impact assessment, can be used for LEED v4.1	ISO14040/44 compliant, TRACI impact assessment, can be used for LEED v4.1
https://calculatelca.com/software/impact-estimator/	https://www.choosetally.com/	https://www.oneclicklca.com/

EEBA

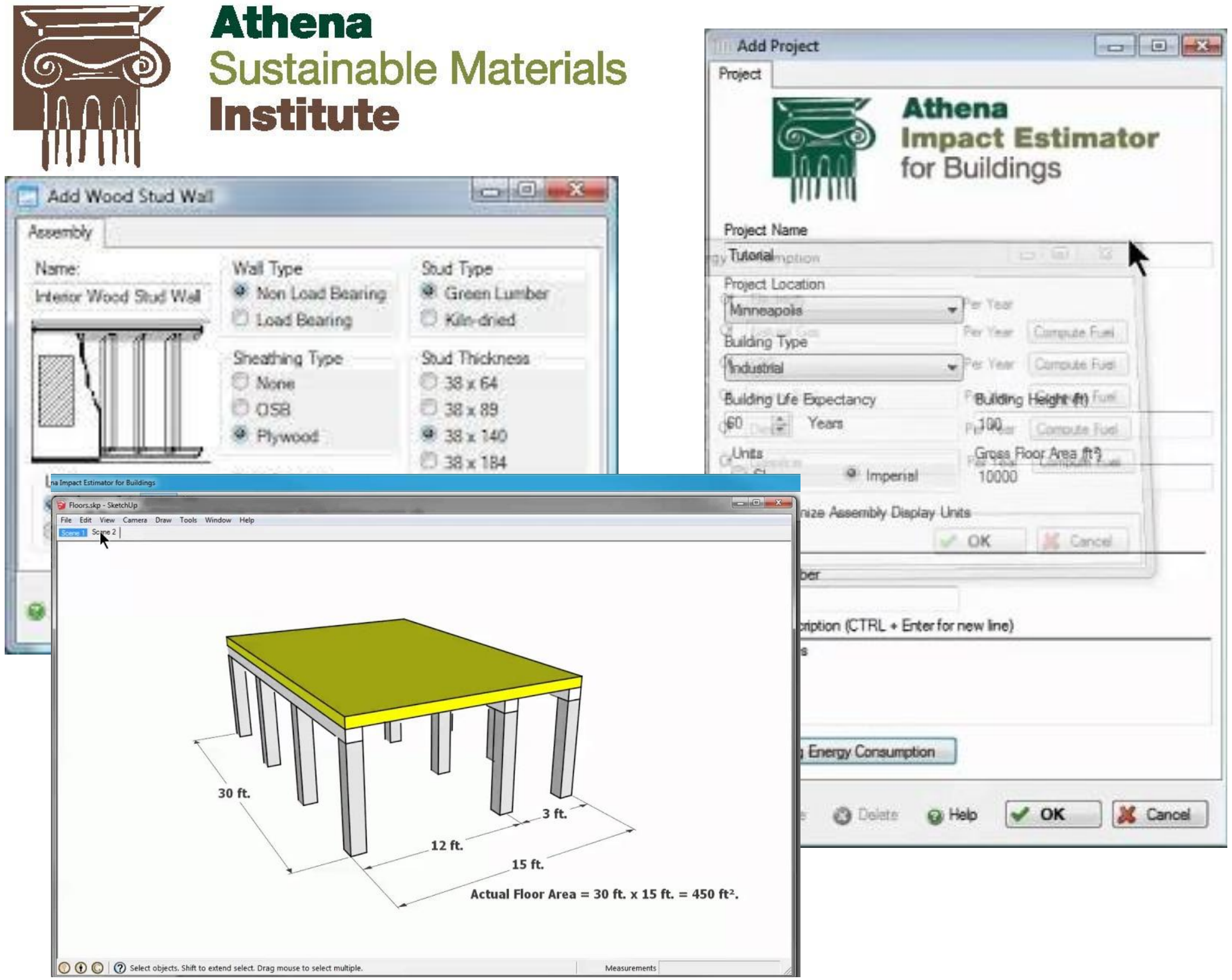
There are Options for Estimating Embodied Carbon

FEATURES	BEAM	Athena Impact Estimator	EC3
TYPE	Residential, Multi-Unit/Apartments, Townhomes (Small – Medium size buildings)	Office Buildings, Warehouses (Large scale buildings)	Construction Material Database (All Building Types)
EFFECTIVENESS	Excellent	Good	Excellent
EASE OF USE	Easy	Hard	Hard
UPDATES & NEW DATA	Yes	Infrequent	Yes
Energy Modelling Compatibility	No	No	No

- Each have advantages and challenges
- All are being refined and enhanced
- New EPDs will be added over time.
- Energy use or Operational Carbon is typically not included

Choose one to get consistent comparisons

Athena Impact Estimator

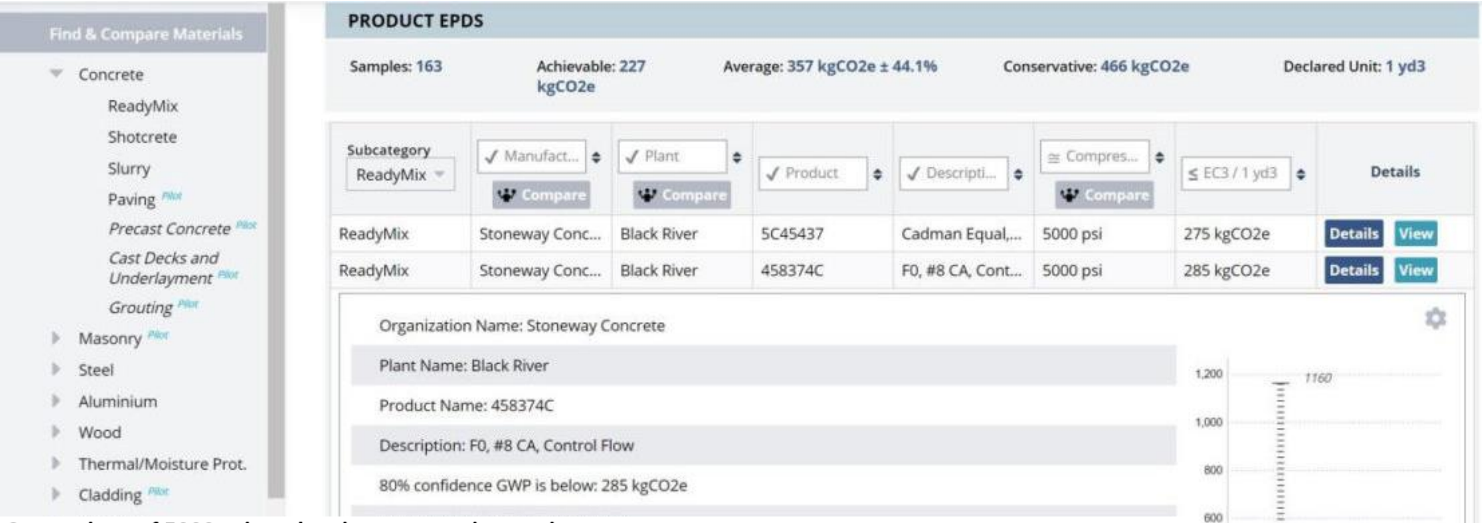


The Estimator takes into account the environmental impacts of:

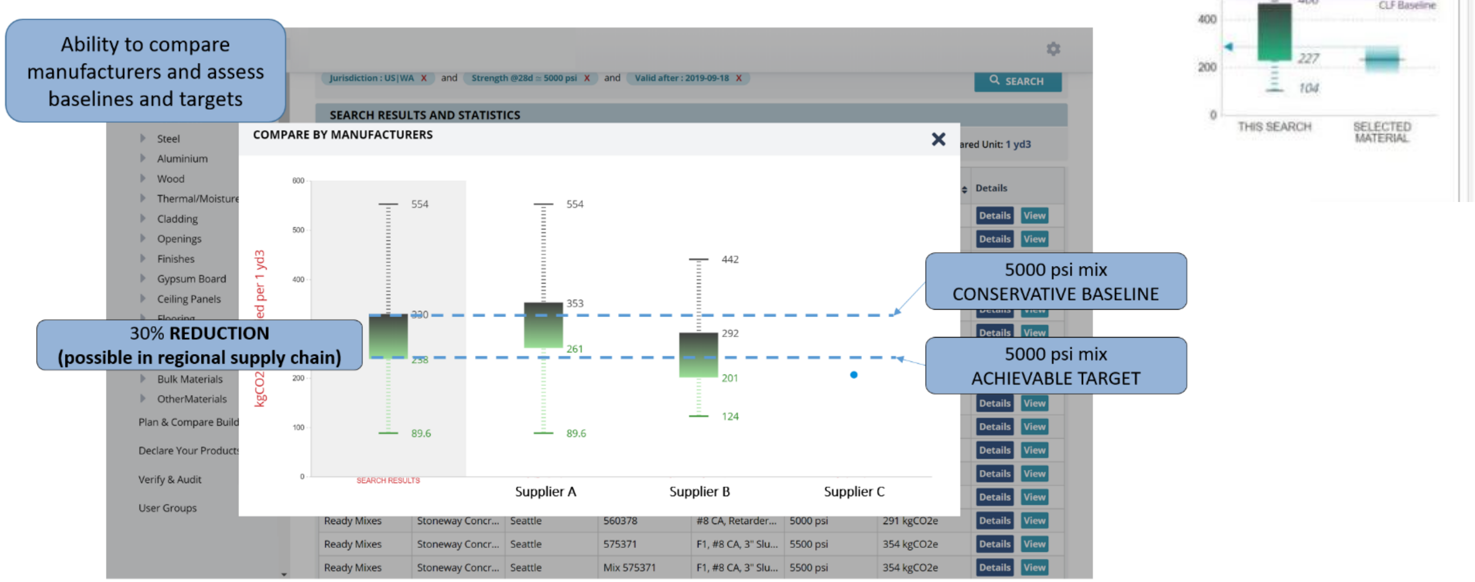
- Full LCA Tool
- Material manufacturing (resource extraction, transportation, and recycled content)
- On-site construction, building type and assumed lifespan
- Maintenance and replacement effects
- Demolition and disposal

- This program has a lot of features adding to the complexity of the program, but provides a very detailed analysis of results.

EC3 Calculator



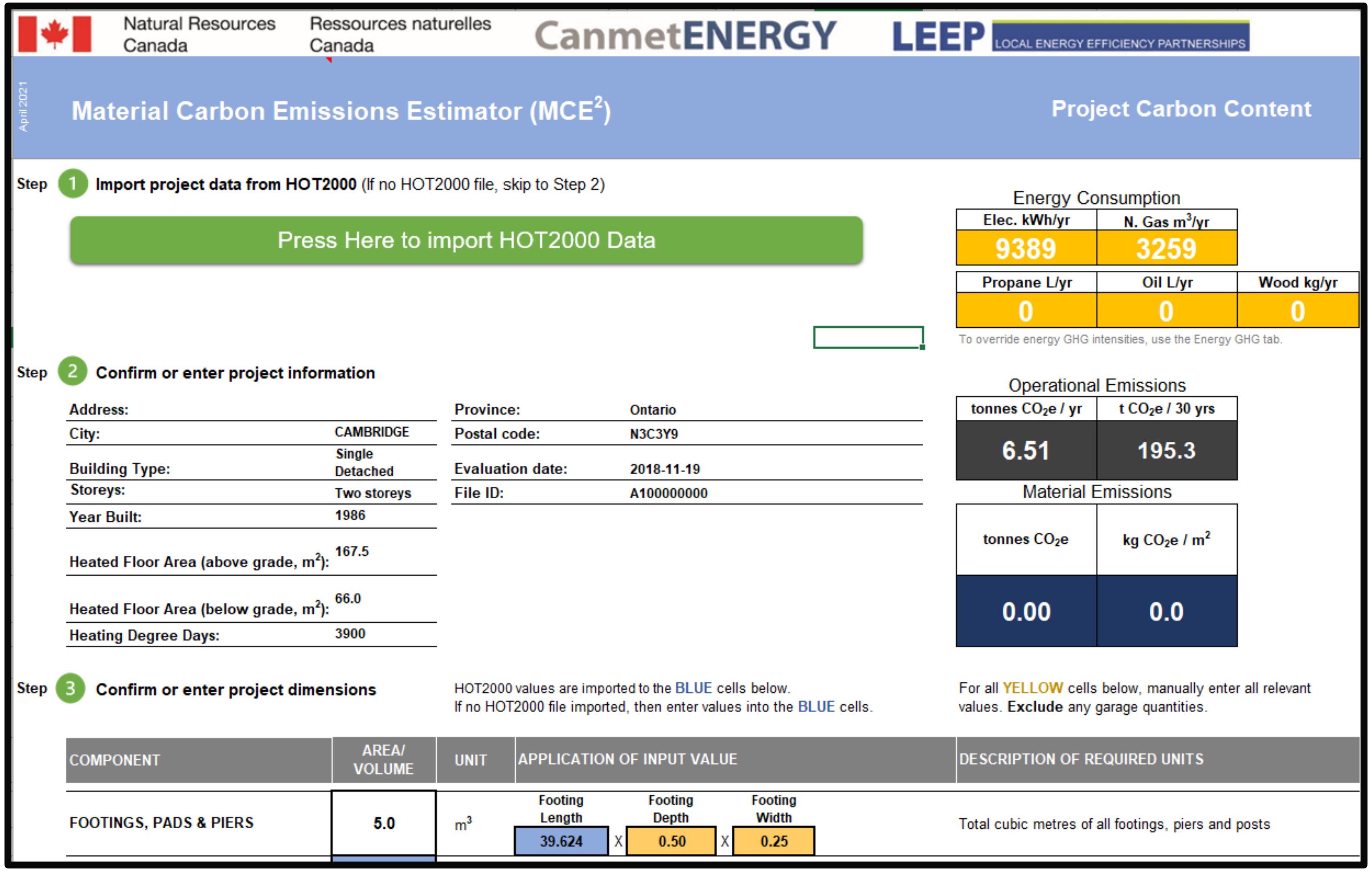
Comparison of 5000 psi ready mix concretes in a region



The Embodied Carbon in Construction Calculator (EC3) is a tool that allows benchmarking, assessment and reductions in embodied carbon, focused on the upfront supply chain emissions of construction materials

- Free and easy to use
- Contains the largest source of EPDs (Worldwide)
- Easily compare different materials and search for brands
- Software level: Intermediate difficulty
- Not intended for whole building assessments

NRCAN MCE2 Carbon Estimator



- Efficient for residential construction and small buildings
- Contains a range of common materials used in North America
- Easy to learn and navigate
- Data is summarized effectively
- HOT2000 Energy Simulation compatible
- Preferred calculator for residential construction in Canada

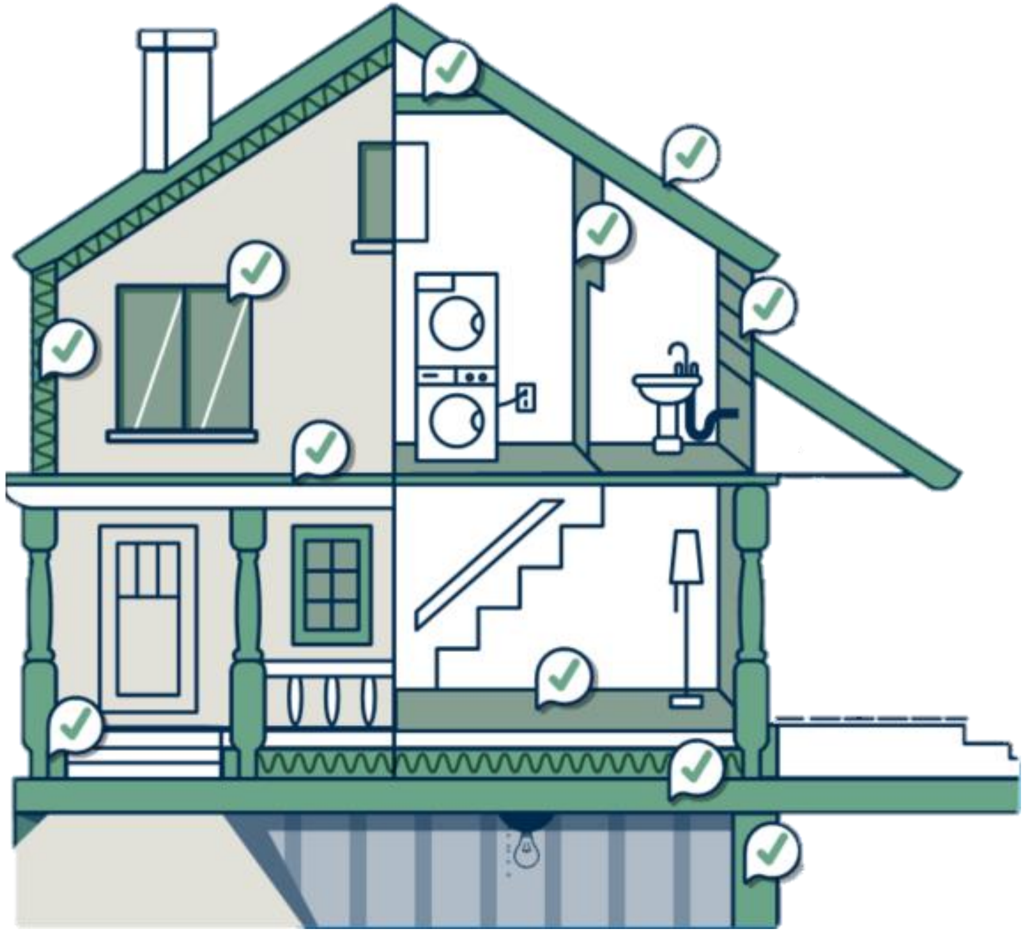
BEAM Estimator

The Building Emissions Accounting for Materials tool helps designers and builders make informed climate smart choices

- Free (contributions encouraged) and easy to use
- Simple selection of building materials
- Offers alternative "green" choices and comparisons
- On-line training
- Designed specifically for low and mid-rise residential construction

The BEAM Estimator is used for all case studies in this workshop

What's included in the BEAM model



Structure & Finishes

Not: Furnishings, fixtures, appliances, exterior elements

Calculating Embodied Carbon Estimates

MATERIAL CARBON PROJECT RESULTS

BUILDERS FOR CLIMATE ACTION · BEAM

PROJECT INFORMATION			
Project Name	EEBA Basement (Brick)	**Construction Year**	
Design Firm(s)		**Number of Bedrooms**	
Engineering Firm(s)		**Stories Above Grade**	2
Builder / Developer			
Development Project		**CONDITIONED AREA**	
Street Address		**Above Grade**	3285 ft²
City		**Below Grade**	1467 ft²
Province / State		**Total**	4752 ft²
Country	United States		
		GROSS AREA	
Building Type	Single Detached House	**Excluding Garage**	4810 ft²
Construction Type	New Construction	**Garage**	390 ft²
Project Stage	Construction in Progress	**Total**	5200 ft²

Very similar to energy modelling and HVAC design processes

BEAM BUILDING EMISSIONS ACCOUNTING FOR MATERIALS

Input Units: **Imperial**

Input Legend:

- Required for saving projects
- Used for materials calculations
- Non-essential
- Read-only

Project Information

Project Name	2 Story Sample House (CZ5)
Designer	
Engineer	
Builder / Developer	
Development Project	
Address	
City	
Province / State (Can./US only)	
Country	United States
Building Type	Single Detached House
Construction Type	New Construction
Project Development Stage	Construction in Progress

Construction Year		
Number of Bedrooms		
Stories Above Grade	2	
Total Floor Area	5200	ft^2
Above Grade Conditioned Area	3285	ft^2
Below Grade Conditioned Area	1467	ft^2

Enter Project Information and characteristics

EEBA

Enter Dimensions

DIMENSION NAME	QTY	UNIT	DESCRIPTION	USED TO CALCULATE TAKE-OFFS FOR
CONTINUOUS FOOTINGS VOLUME	37.6	yd^3	Length (ft) 169.17 X Height (in.) 36.00 X Width (in.) 24.00 Exclude: garage	Continuous (aka "strip") foundation wall footings (exterior and interior)
COLUMN PADS & PIERS VOLUME	1.2	yd^3	otal volume of discontinuous column footings, pad, piers, etc. xcludes: garage	Discontinuous footing elements aside from continuous footings (ext. and int.)
FOUNDATION WALL AREA	1440.6	ft^2	otal foundation wall surface area (centerline length x height) ncludes: basement, party walls. Excludes: openings, garage foundation	Foundation & basement wall insulation (ext. and int.), interior framing, and wall cladding
FOUNDATION SLAB AREA	1702.0	ft^2	otal foundation slab surface area xcludes: garage slab	Aggregate base, sub-slab insulation, slab, and basement flooring
EXTERIOR WALL AREA	2699.7	ft^2	urface area of exterior walls. ncludes: gable ends. Excludes: window & door openings, party walls, garage walls	Framing, insulation, sheathing, exterior cladding, and interior cladding of exterior walls
WINDOW AREA	384.8	ft^2	rea of window frames (preferrable) or rough openings ncludes: full glazing area, skylights. Excludes: garage windows	Windows of main building
PARTY WALL AREA	0.0	ft^2	Vall area that partitions this unit from others ypical for townhouses & apartment units	Party wall framing, insulation, sheathing, and interior cladding
INTERIOR WALL AREA	2407.9	ft^2	ne side only (i.e. centerline) of all interior walls. ncludes: interior door area. Excludes: exterior, garage partition and party walls	Interior wall framing and cladding (assumes both sides of walls are finished by default)
FRAMED FLOOR AREA	3284.7	ft^2	bove grade flooring area xcludes: basement floor slab, and floor openings	Floor framing, subfloor, floor insulation, finish flooring
FINISHED CEILING AREA	1904.0	ft^2	otal finished ceiling area ncludes: basement ceilings. Excludes: garage ceilings	Ceiling cladding
ROOF INSULATION AREA	1904.0	ft^2	rea associated with roof insulation ypically equal to the ceiling area directly below the roof	Flat or sloped roof insulation
ROOF SURFACE AREA	2668.7	ft^2	oofing surface area. Calculated with roof pitch xcludes: overhangs	Roof framing, decking, roofing, and insulation parallel to roof surface
TIMBER FRAMING VOLUME	2.4	yd^3	otal volume of wood in heavy timber posts & beams eparate inputs for steel found in Structural Elements section	Mass timber framing elements

Select Construction Elements from Drop-down menus

FOUNDATION WALLS

SECTION COMPLETE? ☑

SUBTOTAL (kg CO_2e): 11,645

BUILDERS FOR CLIMATE ACTION

BEAM

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)	FOOTNOTE
CONCRETE FOUNDATION WALLS	WALL THICKNESS	9.0	in						
CONCRETE – <=25 MPA – CANADA									
	Concrete – 0-25 MPa, 0-14% FA/SL, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	11,870	11,870	0	Expired 2022
	Concrete – 0-25 MPa, Canadian Benchmark Average / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	11,282	11,282	0	Expired 2022
	Concrete – 0-25 MPa, 15-29% Fly Ash, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	10,711	10,711	0	Expired 2022
	Concrete – 0-25 MPa, 25-34% Slag, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	9,715	9,715	0	Expired 2022
	Concrete – 0-25 MPa, 30-40% Fly Ash, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	9,458	9,458	0	Expired 2022
	Concrete – 0-25 MPa, 35-50% Slag, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	8,854	8,854	0	Expired 2022
CONCRETE – 26-30 MPA – CANADA									
	Concrete – 26-30 MPa, 0-14% FA/SL, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	13,348	13,348	0	Expired 2022
	Concrete – 26-30 MPa, Canadian Benchmark Average / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	12,955	12,955	0	Expired 2022
	Concrete – 26-30 MPa, 15-29% Fly Ash, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	12,021	12,021	0	Expired 2022
	Concrete – 26-30 MPa, 25-34% Slag, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	10,881	10,881	0	Expired 2022
	Concrete – 26-30 MPa, 30-40% Fly Ash, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	10,587	10,587	0	Expired 2022
	Concrete – 26-30 MPa, 35-50% Slag, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	9,895	9,895	0	Expired 2022
CONCRETE – 31-35 MPA – CANADA									
	Concrete – 31-35 MPa, 0-14% FA/SL, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	15,493	15,493	0	Expired 2022
	Concrete – 31-35 MPa, Canadian Benchmark Average / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	15,451	15,451	0	Expired 2022
	Concrete – 31-35 MPa, 15-29% Fly Ash, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	13,921	13,921	0	Expired 2022
	Concrete – 31-35 MPa, 25-34% Slag, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	12,571	12,571	0	Expired 2022
	Concrete – 31-35 MPa, 30-40% Fly Ash, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	12,222	12,222	0	Expired 2022
	Concrete – 31-35 MPa, 35-50% Slag, GU / CRMCA [Industry Avg | CA]	1,744.4	ft²	100%	☐	[illegible]	[illegible]	0	[illegible]
CONCRETE – <= 2500 PSI – N.AMERICA									
	Concrete - 0-2500 psi, Standard mix / NRMCA [Industry Avg | US & CA]	1,744.4	ft²	100%	☑	11,471	11,471	0	
	Concrete - 0-2500 psi, 20-29% Fly Ash / NRMCA [Industry Avg | US & CA]	1,744.4	ft²	100%	☐	[illegible]	[illegible]	0	
	Concrete - 0-2500 psi, 30-39% FA/SL / NRMCA [Industry Avg | US & CA]	1,744.4	ft²	100%	☐	8,974	8,974	0	

EEBA

Select Construction Elements from Drop-down menus

FOUNDATION WALLS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e): 11,456

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
MINERAL WOOL BATT INSULATION								
	Mineral wool batt / Owens Corning / Thermafiber UltraBatt / R 4.3/inch	1,440.6	ft²	100%	☐	1,037	1,037	0
	Mineral wool batt / Rockwool / ComfortBatt R24 (5.5") / R 4.4/inch	1,440.6	ft²	100%	☐	442	442	0
	Mineral wool batt / [BEAM Avg]	1,440.6	ft²	100%	☐	439	439	0
	Mineral wool batt / Rockwool / ComfortBatt R15 (3.5") / R 4.3/inch	1,440.6	ft²	100%	☐	340	340	0
	Mineral wool batt / Rockwool / Safe'n'Sound, ComfortBatt / R 3.8/inch	1,440.6	ft²	100%	☐	340	340	0
	Mineral wool batt / Rockwool / ComfortBatt R14 (3.5") / R 4.0/inch	1,440.6	ft²	100%	☐	306	306	0
	Mineral wool batt / Rockwool / ComfortBatt R22 (5.5") / R 4.0/inch	1,440.6	ft²	100%	☐	306	306	0
	Mineral wool batt / Rockwool / ComfortBatt R24 SS (6" Steel Studs) / R 4.0/inch	1,440.6	ft²	100%	☐	306	306	0
MINERAL WOOL LOOSE FILL INSULATION								
	Mineral wool loose fill / NAIMA / R 3/inch [Industry Avg | N.America]	1,440.6	ft²	100%	☐	404	404	0
FIBERGLASS LOOSE FILL INSULATION								
	Fiberglass loose fill / CertainTeed / InsulSafe, Optima, TruComfort / R 2.6/inch	1,440.6	ft²	100%	☐	334	334	0
	Fiberglass loose fill / ~R2.6/inch [BEAM Avg]	1,440.6	ft²	100%	☐	260	260	0
	Fiberglass loose fill / Owens Corning / AttiCat, ProCat, ProPink / R 2.8/inch	1,440.6	ft²	100%	☐	255	255	0
	Fiberglass loose fill / Knauf / Jet Stream ULTRA / R 2.2/inch	1,440.6	ft²	100%	☐	189	189	0
FIBERGLASS BATT INSULATION								
	Fiberglass batt / CertainTeed / Sustainable Insulation / R 3.6/inch	1,440.6	ft²	100%	☐	244	244	0
	Fiberglass batt / R 3.6/inch [BEAM Avg]	1,440.6	ft²	100%	☑	174	174	0
	Fiberglass batt / Knauf / EcoBatt / R 3.6/inch	1,440.6	ft²	100%	☐	158	158	0
	Fiberglass batt / Owens Corning / EcoTouch Pink batt and roll / R 3.6/inch	1,440.6	ft²	100%	☐	120	120	0

STRUCTURAL ELEMENTS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e)
441

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
STRUCTURAL TIMBER								
STRUCTURAL COMPOSITE LUMBER								
	Laminated veneer lumber (LVL) / AWC & CWC [Industry Avg | US & CA]	1.4	yd^3	59%	☑	394	394	0
	Laminated veneer lumber (LVL) / RedBuilt / RedLam	2.4	yd^3	100%	☐	664	664	0
	Laminated strand lumber (LSL) / AWC & CWC [Industry Avg | US & CA]	2.4	yd^3	100%	☐	507	507	0
	Glued Laminated Timber (Glulam) / AWC & CWC [Industry Avg | US & CA]	2.4	yd^3	100%	☐	253	253	0
TIMBER FRAMING LUMBER								
	Wood / SPF / Lumber by volume / AWC & CWC [Industry Avg | US & CA]	1.0	yd^3	41%	☑	48	48	0
	Wood / Redwood / Lumber by volume / AWC & CWC [Industry Avg | US & CA]	2.4	yd^3	100%	☐	70	70	0
STRUCTURAL STEEL – WIDE FLANGE BEAMS								
WIDE FLANGE – W150 (US W6)								
	Structural Steel / Wide Flange / W150x30 (US W6x20) / AISC [Industry Avg | US]		ft	100%	☐	0	0	0
	Structural Steel / Wide Flange / W150x22 (US W6x15) / AISC [Industry Avg | US]		ft	100%	☐	0	0	0
WIDE FLANGE – W200 (US W8)								
	Structural Steel / Wide Flange / W200x71 (US W8x48) / AISC [Industry Avg | US]		ft	100%	☐	0	0	0
	Structural Steel / Wide Flange / W200x59 (US W8x40) / AISC [Industry Avg | US]		ft	100%	☐	0	0	0
	Structural Steel / Wide Flange / W200x42 (US W8x28) / AISC [Industry Avg | US]		ft	100%	☐	0	0	0
	Structural Steel / Wide Flange / W200x36 (US W8x24) / AISC [Industry Avg |		ft	100%	☐	0	0	0

EXTERIOR WALLS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e): 2,170

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
LIGHT WOOD FRAME WALLS	FRAMING SPACING	16	in					
FRAMING LUMBER – SPRUCE-PINE-FIR								
	Wood / SPF / 2x8 Lumber / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	729	729	0
	Wood / SPF / 2x6 Lumber / AWC & CWC [Industry Avg | US & CA]	3,774.2	ft²	140%	☑	773	773	0
	Wood / SPF / 2x4 Lumber / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	352	352	0
	Wood / SPF / 2x3 Lumber / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	251	251	0
WOOD I-JOIST (TJI) STUD FRAMING	FRAMING SPACING		in					
	Wood I joist / TJI 230/360 / 11-7/8" Depth / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	0	0	0
	Wood I joist / TJI 230/360 / Industry Average Depth / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	0	0	0
	Wood I joist / TJI 230/360 / 9-1/2" Depth / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	0	0	0
STRUCTURAL SHEATHING								
ORIENTED STRAND BOARD (OSB)								
	OSB sheathing / 5/8" / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☑	966	966	0
	OSB sheathing / 1/2" / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	773	773	0
PLYWOOD								
	Plywood / 3/4" / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	1,048	1,048	0
	Plywood / 5/8" / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	875	875	0
	Plywood / 1/2" / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	699	699	0
WOOD BOARDS								
	Wood / SPF / 3/4" boards / AWC & CWC [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	302	302	0

EXTERIOR WALLS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e): 2,170

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
FIBERGLASS LOOSE FILL INSULATION								
	Fiberglass loose fill / CertainTeed / InsulSafe, Optima, TruComfort / R 2.6/inch	2,699.7	ft²	100%	☐	1,197	1,197	0
	Fiberglass loose fill / ~R2.6/inch [BEAM Avg]	2,699.7	ft²	100%	☐	929	929	0
	Fiberglass loose fill / Owens Corning / AttiCat, ProCat, ProPink / R 2.8/inch	2,699.7	ft²	100%	☐	912	912	0
	Fiberglass loose fill / Knauf / Jet Stream ULTRA / R 2.2/inch	2,699.7	ft²	100%	☐	677	677	0
FIBERGLASS BATT INSULATION								
	Fiberglass batt / CertainTeed / Sustainable Insulation / R 3.6/inch	2,699.7	ft²	100%	☐	872	872	0
	Fiberglass batt / R 3.6/inch [BEAM Avg]	2,699.7	ft²	100%	☐	623	623	0
	Fiberglass batt / Knauf / EcoBatt / R 3.6/inch	2,699.7	ft²	100%	☐	566	566	0
	Fiberglass batt / Owens Corning / EcoTouch Pink batt and roll / R 3.6/inch	2,699.7	ft²	100%	☑	430	430	0
HEMP FIBER WOOL INSULATION								
	Hemp fiber batt / NaturFibre / Hemp Wool / R 3.7/inch	2,699.7	ft²	100%	☐	-504	1,610	2,115
CELLULOSE INSULATION								
	Cellulose / loose fill / R 3.7/inch / CIMA [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	-986	452	1,437
	Cellulose / batt / CMS / EcoCell / R 3.6/inch	2,699.7	ft²	100%	☐	-1,654	452	2,106
	Cellulose / spray applied / R 3.75/inch / International Cellulose Corp. / K-13, ThermoCon	2,699.7	ft²	100%	☐	-1,949	301	2,251
	Cellulose / dense pack / R 3.7/inch / CIMA [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	-1,971	904	2,875
WOOD FIBER INSULATION								
	Wood fiber loose fill / GUTEX / ThermoFiber / R 3.6/inch	2,699.7	ft²	100%	☐	-1,351	560	1,910
	Wood fiber batt / GUTEX / ThermoFlex / R 4/inch [EU]	2,699.7	ft²	100%	☐	-1,994	348	2,342
	Wood fiber batt / Steico / SteicoFlex / R 3.8/inch [EU]	2,699.7	ft²	100%	☐	-2,185	406	2,591

EXTERIOR WALLS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e): 2,170

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
CONTINUOUS INSULATION	R-VALUE	5.0						
XPS FOAM BOARD (LEGACY FORMULAS)								
	XPS foam board / DuPont / Styrofoam / HFC-filled / R 5.6/inch	2,699.7	ft²	100%	☐	13,428	13,428	0
	XPS foam board / Owens Corning / Foamular 250 / HFC-filled / R 5.0/inch	2,699.7	ft²	100%	☐	11,154	11,154	0
XPS FOAM BOARD (REDUCED GWP)								
	XPS foam board / DuPont / Styrofoam / Reduced GWP / R 5.6/inch	2,699.7	ft²	100%	☐	8,061	8,061	0
SPRAY POLYURETHANE FOAM – HIGH DENSITY								
	Spray polyurethane foam - High Density (HFC gas) / R 6.3/inch / SPFA [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	3,759	3,759	0
	Spray polyurethane foam - High Density (HFO gas) / R 6.5/inch / SPFA [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	1,093	1,093	0
XPS FOAM BOARD								
	XPS foam board / Owens Corning / Foamular NGX 250 / R 5.0/inch	2,699.7	ft²	100%	☐	1,793	1,793	0
	XPS foam board / R 5.0/inch [BEAM Avg | US & CA]	2,699.7	ft²	100%	☐	1,083	1,083	0
	XPS foam board / DuPont / Styrofoam ST-100 / R 5.0/inch	2,699.7	ft²	100%	☐	1,031	1,031	0
	XPS foam board / SOPREMA / SOPRA-XPS / R 5.0/inch	2,699.7	ft²	100%	☐	425	425	0
EPS FOAM BOARD								
	EPS foam board / R 4.3/inch, Type XV, 60 psi (400 kPa) / EPS Industry Alliance [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	1,718	1,718	0
	EPS foam board / R 4.0/inch avg [BEAM Avg | US & CA]	2,699.7	ft²	100%	☐	1,055	1,055	0
	EPS foam board / R 4.2/inch, Type IX, 25 psi (170 kPa) / EPS Industry Alliance [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	1,054	1,054	0
EPS FOAM BOARD WITH GRAPHITE								
	EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type IX	2,699.7	ft²	100%	☐	755	755	0
	EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type II, 15 psi (Type 2, 110 kPa)	2,699.7	ft²	100%	☐	610	610	0

FLOORS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e)
7,451

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
	Wood I joist / TJI 230/360 / 16" Depth / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	1,895	1,895	0
	Wood I joist / TJI 230/360 / 14" Depth / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	1,788	1,788	0
	Wood I joist / TJI 230/360 / 11-7/8" Depth / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☑	1,625	1,625	0
	Wood I joist / TJI 230/360 / Industry Average Depth / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	1,579	1,579	0
	Wood I joist / TJI 230/360 / 9-1/2" Depth / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	1,463	1,463	0
WOOD FLOOR TRUSSES								
	Wood floor truss / Common (Warren, 45 deg) web pattern / Top chord bearing, variable depth / QWEB [Industry Avg | CA]	3,284.7	ft²	100%	☐	1,548	1,548	0
FRAMING LUMBER – SPRUCE-PINE-FIR								
	Wood / SPF / 2x12 Lumber / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	691	691	0
	Wood / SPF / 2x10 Lumber / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	568	568	0
	Wood / SPF / 2x8 Lumber / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	445	445	0
	Wood / SPF / 2x6 Lumber / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	338	338	0
SUB FLOORING								
ORIENTED STRAND BOARD (OSB)								
	OSB sheathing / 3/4" / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	1,410	1,410	0
	OSB sheathing / 5/8" / AWC & CWC [Industry Avg | US & CA]	3,284.7	ft²	100%	☑	1,176	1,176	0

FLOORS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e): 7,451

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
LAMINATE FLOORING								
	Laminate flooring / Novalis / LVT	3,284.7	ft²	100%	☐	8,270	8,270	0
RUBBER FLOORING								
	Rubber flooring / Resilient Floor Covering Institute / Includes tiles and rolls / 2mm [Industry Avg | US & CA]	3,284.7	ft²	100%	☐	4,760	4,760	0
	Rubber flooring / ECOsurfaces / 6mm	3,284.7	ft²	100%	☐	1,800	1,800	0
HARDWOOD FLOORING								
	Hardwood flooring / CRAFT Artisan Wood Floors / Engineered / 5/8", SFI Certified	2,627.8	ft²	80%	☑	3,760	3,760	0
	Hardwood flooring / mafi / Natural Hardwood Planks / 3/4", 3 ply laminated solid, oil pre-finished	3,284.7	ft²	100%	☐	4,268	4,268	0
	Hardwood flooring / Action Floor Systems / 3/4" / FSC certified	3,284.7	ft²	100%	☐	3,601	3,601	0
CERAMIC TILE FLOORING								
	Ceramic tile / Crossville / Porcelain / Standard grade	3,284.7	ft²	100%	☐	7,293	7,293	0
	Ceramic tile / StonePeak / Porcelain / Porcelain, standard grade	3,284.7	ft²	100%	☐	4,950	4,950	0
	Ceramic tile / porcelain, pressed, mosaic and quarry / TCNA [Industry Avg | US & CA]	656.9	ft²	20%	☑	802	802	0
CARPET								
	Carpet / EC3 database / 150 sample conservative average [US & CA]	3,284.7	ft²	100%	☐	5,310	5,310	0
	Carpet / EC3 database / 150 sample average [US & CA]	3,284.7	ft²	100%	☐	4,059	4,059	0
	Carpet / Interface / CQUEST BioX / 1.5 mm Modular tile carpet	3,284.7	ft²	100%	☐	69	1,396	1,327
VINYL FLOORING								
	Vinyl flooring / Altro / Altro Lavencia Click /	3,284.7	ft²	100%	☐	4,333	4,333	0
	Vinyl flooring / Altro / Altro Lavencia Plus /	3,284.7	ft²	100%	☐	2,930	2,930	0

WINDOWS (FROM BEAM TOOL) *Based on total window area entered*

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
WINDOWS – DOUBLE-GLAZED								
DOUBLE-GLAZED WINDOWS – INDUSTRY AVERAGE								
	Window - double-glazed / Fiberglass frame / BfCA Study [US & CA]	384.8	ft²	100%	☐	4,076	4,076	0
	Window - double-glazed / Wood frame, aluminum cladding / BfCA Study [US & CA]	384.8	ft²	100%	☐	3,539	3,539	0
	Window - double-glazed / Vinyl frame / BfCA Study [US & CA]	384.8	ft²	100%	☑	3,075	3,075	0
	Window - double-glazed / Wood frame / BfCA Study [US & CA]	384.8	ft²	100%	☐	2,574	2,574	0
	Window - double-glazed / Wood frame / EU	384.8	ft²	100%	☐	2,141	2,141	0
	Window - double-glazed / Wood frame, aluminum cladding / EU	384.8	ft²	100%	☐	1,913	1,913	0
DOUBLE-GLAZED WINDOWS – PRODUCT-SPECIFIC								
	Window - double-glazed / Inline Fiberglass / Series 300, 325, 325, 400 / Fiberglass frame / CAN	384.8	ft²	100%	☐	2,706	2,706	0
	Window - double-glazed / Andersen / Fibrex / PVC & Wood composite / USA	384.8	ft²	100%	☐	2,470	2,470	0
WINDOWS – TRIPLE-GLAZED								
TRIPLE-GLAZED WINDOWS – INDUSTRY AVERAGE								
	Window - triple pane / Fiberglass frame / BfCA Study [US & CA]	384.8	ft²	100%	☐	4,540	4,540	0
	Window - triple pane / Wood frame, aluminum cladding / BfCA Study [US & CA]	384.8	ft²	100%	☐	4,004	4,004	0
	Window - triple pane / Vinyl frame / BfCA Study [US & CA]	384.8	ft²	100%	☐	3,539	3,539	0
	Window - triple pane / Wood frame / BfCA Study [US & CA]	384.8	ft²	100%	☐	3,039	3,039	0
	Window - triple pane / Wood frame, aluminum cladding / EU	384.8	ft²	100%	☐	2,644	2,644	0
	Window - triple pane / Wood frame / EU	384.8	ft²	100%	☐	2,263	2,263	0

CEILINGS

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e)
431

BUILDERS FOR CLIMATE ACTION

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
CEILING FINISHES								
DRYWALL – 1/2"								
	Drywall 1/2" / Pabco / QuietRock / QuietRock 1/2"	1,904.0	ft²	100%	☐	859	859	0
	Drywall 1/2" [BEAM Avg | US & CA]	1,904.0	ft²	100%	☑	431	431	0
	Drywall 1/2" / CertainTeed / M2Tech moisture resistant / 1/2" (12.7 mm)	1,904.0	ft²	100%	☐	331	331	0
	Drywall 1/2" / CertainTeed / Easi-Lite / 1/2" (12.7 mm)	1,904.0	ft²	100%	☐	270	270	0
	Drywall 1/2" / CertainTeed / AirRenew / 1/2" (12.7 mm)	1,904.0	ft²	100%	☐	263	263	0
DRYWALL – 1/2" TYPE C								
	Drywall 1/2" Type C / Georgia-Pacific / ToughRock Fireguard C /	1,904.0	ft²	100%	☐	543	543	0
DRYWALL – 5/8" TYPE X								
	Drywall 5/8" Type X / Gypsum Association [Industry Avg | US & CA]	1,904.0	ft²	100%	☐	527	527	0
	Drywall 5/8" / USG / EcoSmart Firecode / 5/8"	1,904.0	ft²	100%	☐	367	367	0

ROOF

SECTION COMPLETE! ☑

SUBTOTAL (kg CO_2e)
4,685

BUILDERS FOR CLIMATE ACTION

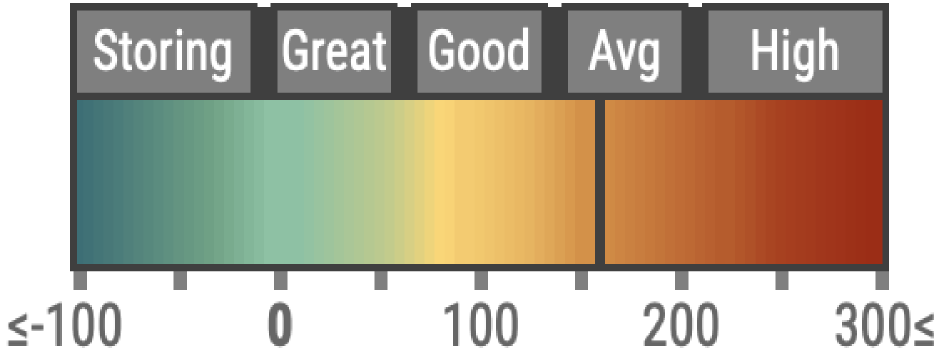
CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
WOOD ROOF FRAMING		FRAMING SPACING:	24	in				
WOOD TRUSS ROOF FRAMING								
	Wood roof truss / Gable Roof, Double Howe, 2x6 Chords, 2x4 Webs, 4:12 Pitch / QWEB [Industry Avg | CA]	2,668.7	ft²	100%	☑	1,028	1,028	0
WOOD I-JOIST ROOF FRAMING								
	Wood I joist / TJI 230/360 / 16" Depth / AWC & CWC [Industry Avg | US & CA]	2,668.7	ft²	100%	☐	981	981	0

Results for EEBA Carbon House: **71.2 Tonnes**

MATERIAL CARBON RESULTS

	MCE		MCI (Conditioned)	
Net Project Emissions	**71,235**	kg CO_2e	**161**	kg CO_2e/m^2

MCI by Area Type	Metric	Imperial
Total Area	**147.5**	**30.2**
Conditioned Area	**161.4**	**33.0**
	kg CO_2e/m^2	lb CO_2e/ft^2



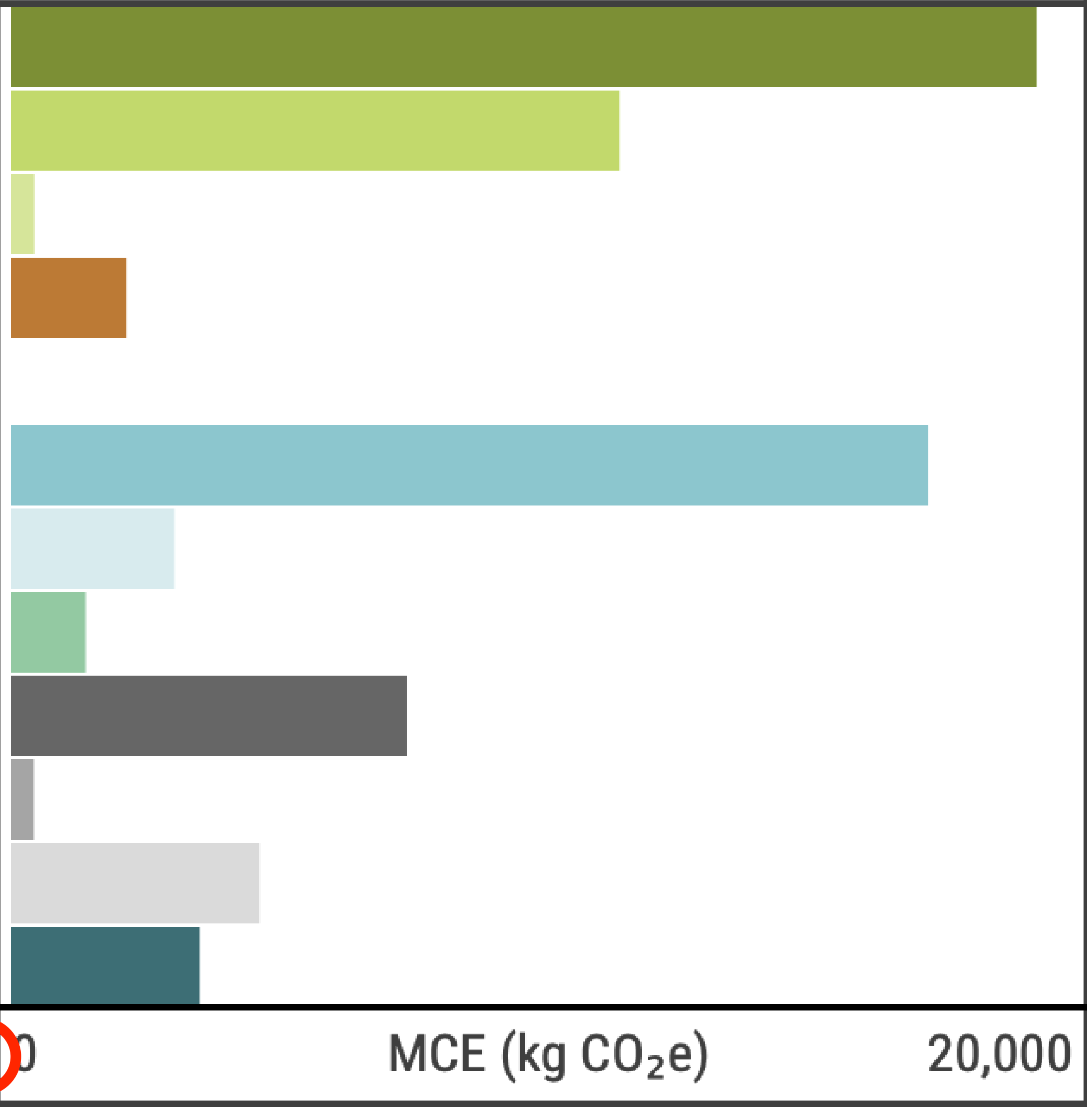
MCE: Material Carbon Emissions (net total)

MCI: Material Carbon Intensity (MCE per unit area)

EEBA

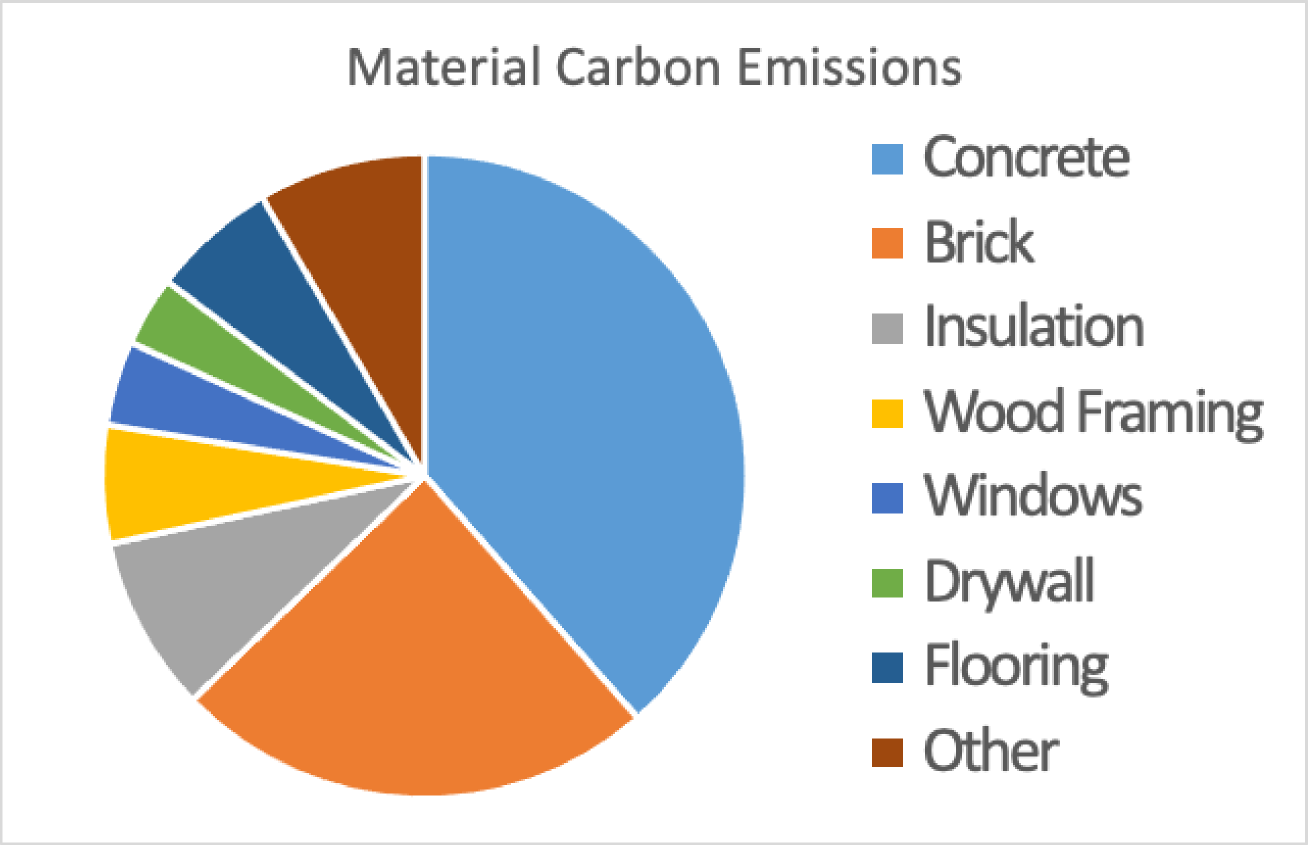
Results: Summary by Section of the House

MATERIAL CARBON EMISSIONS BY SECTION		
Footings & Slabs	19,310	kg CO_2e
Foundation Walls	11,456	kg CO_2e
Structural Elements	441	kg CO_2e
Exterior Walls	2,170	kg CO_2e
Party Walls	0	kg CO_2e
Exterior Wall Cladding	17,262	kg CO_2e
Windows	3,075	kg CO_2e
Interior Walls	1,403	kg CO_2e
Floors	7,451	kg CO_2e
Ceilings	431	kg CO_2e
Roof	4,685	kg CO_2e
Garage	3,552	kg CO_2e
NET TOTAL	71,235	kg CO_2e



HIGHEST CARBON MATERIAL APPLICATIONS		
SECTION	**kg CO_2e**	**MATERIAL**
Exterior Wall Cladding	16,567	Brick, Clay, Generic Modular / 3-5/8" x 2-3/4" x 7-5
Foundation Walls	11,282	Concrete – 0-25 MPa, Canadian Benchmark Avera
Footings & Slabs	9,767	Concrete – 0-25 MPa, Canadian Benchmark Avera
Footings & Slabs	4,892	Concrete – 0-25 MPa, Canadian Benchmark Avera
Floors	3,760	Hardwood flooring / CRAFT Artisan Wood Floors /
Windows	3,075	Window - double-glazed / Vinyl frame / BfCA Stud
Floors	1,625	Wood I joist / TJI 230/360 / 11-7/8" Depth / AWC
Roof	1,528	Fiberglass loose fill / ~R2.6/inch [BEAM Avg]
Garage	1,288	Concrete – 0-25 MPa, Canadian Benchmark Avera

Embodied Carbon - EEBA Carbon House cz5 (Chicago)



71.2 Tonnes CO_2e

Calculating Total Carbon Emissions

‘Upfront’ Embodied Carbon

Manufacturing, transportation, and installation of construction materials

Not sensitive to geographic location

Operational Carbon

Building energy consumption

Very sensitive to geographic location

EEBA

Total Carbon Emissions - over 30 years
cz5 /Chicago

	Embodied Carbon		Operational Carbon		Total Carbon
1st Year	71.235 Kg	+	7.82 Kg / yr	=	79.1 Tonnes
30 Years	71.2 tonnes	+	234.6 Tonnes	=	**305.8 Tonnes**

What is a reasonable reduction target?

Embodied Carbon Estimators Summary

- Work with your designer or Energy Rater to choose a tool
- Input at least one house to benchmark current practices
- Share results with your suppliers
- Model some changes to get a feel for the "sensitivity"
- Be accepting of changes and fine tuning of the software

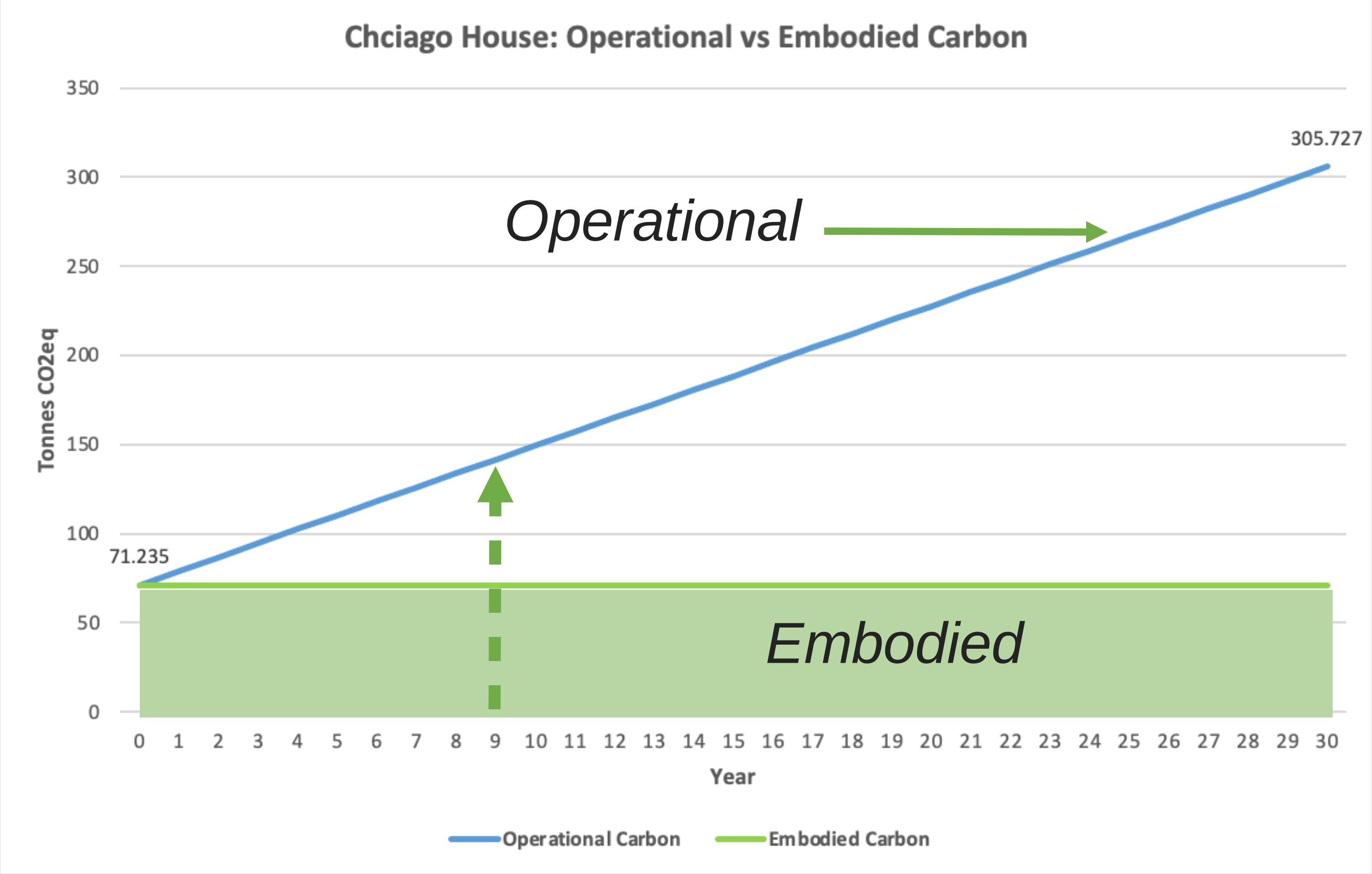
MATERIAL CARBON
PROJECT RESULTS

BUILDERS FOR CLIMATE ACTION

BEAM

PROJECT INFORMATION			
Project Name	EEBA Basement (Brick)	**Construction Year**	
Design Firm(s)		**Number of Bedrooms**	
Engineering Firm(s)		**Stories Above Grade**	2
Builder / Developer			
Development Project		**CONDITIONED AREA**	
Street Address		**Above Grade**	3285 ft²
City		**Below Grade**	1467 ft²
Province / State		**Total**	4752 ft²
Country	United States		
		GROSS AREA	
Building Type	Single Detached House	**Excluding Garage**	4810 ft²
Construction Type	New Construction	**Garage**	390 ft²
Project Stage	Construction in Progress	**Total**	5200 ft²

The 30 Year Carbon Use Opportunity



- Reduce embodied carbon as much as practical NOW.
- Improve energy efficiency with the best possible “return” on any embodied carbon invested

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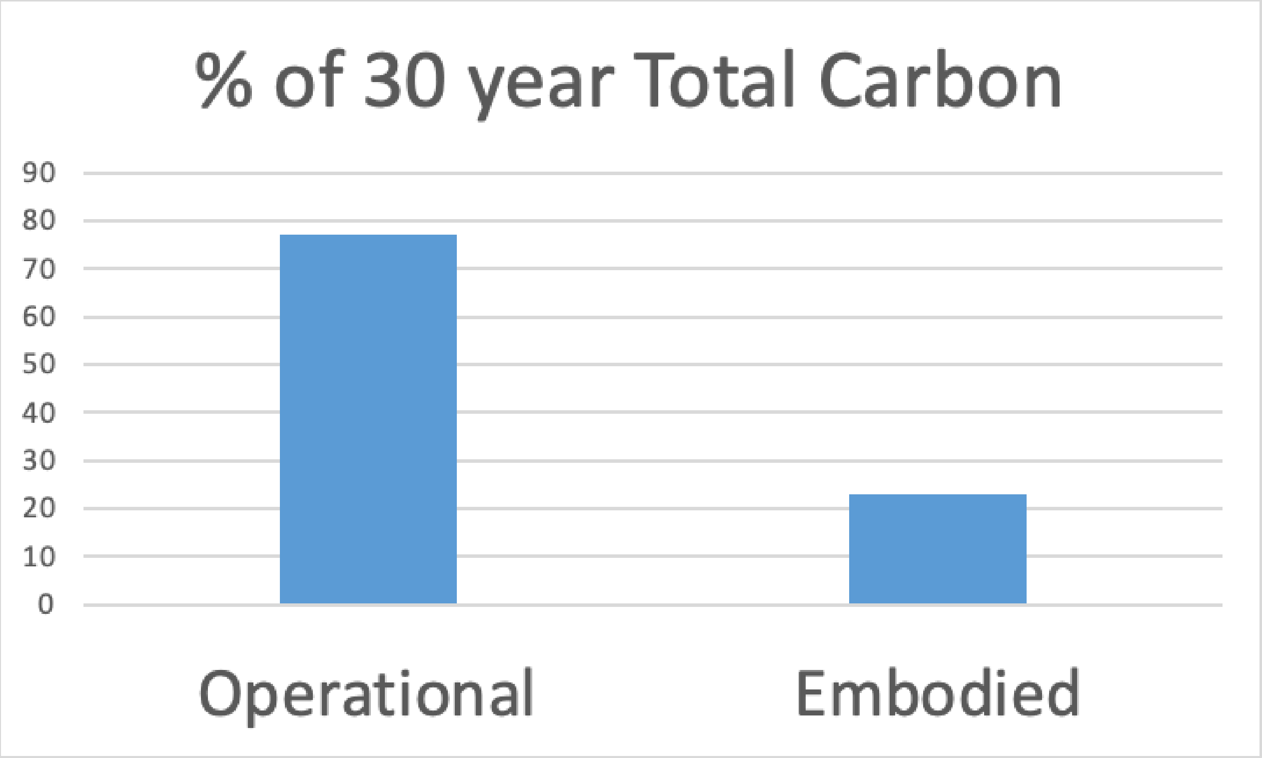
Carbon Reduction Targets

- If the Target is a 30% reduction by 2025

The EEBA Chicago House:

305 Tonnes over 30 years

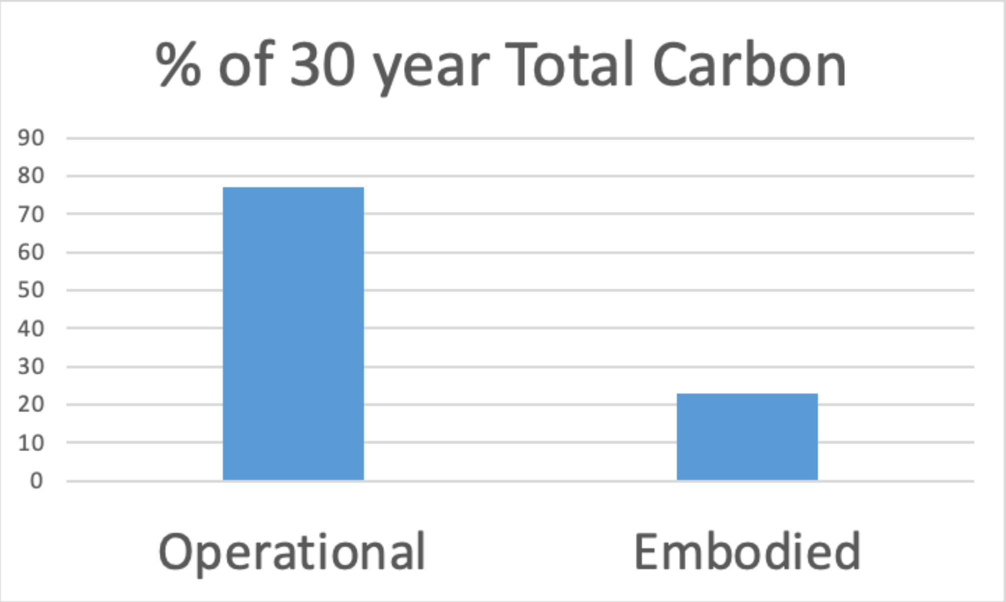
= Reduction target 91Tonnes

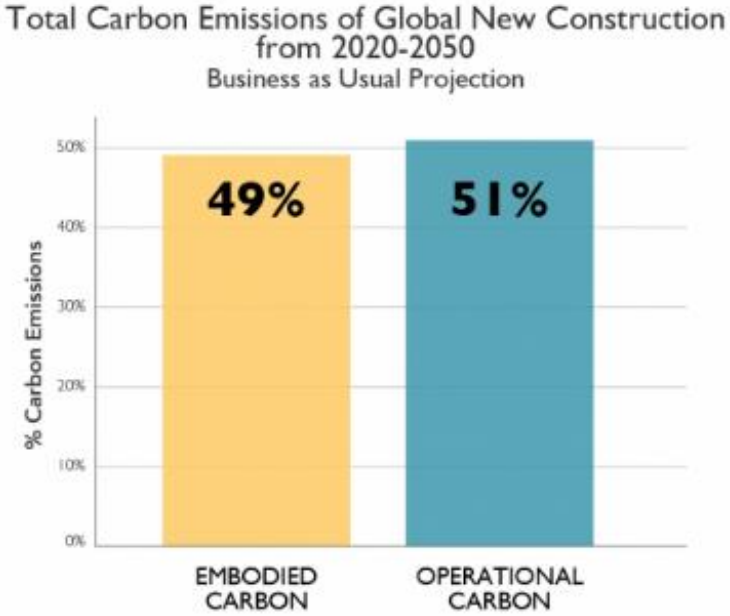


Opportunities in both Operational and Embodied

EEBA

Carbon Reduction Targets





- This ratio of embodied to operation carbon is specific to this house in this location
- This is the average ratio of embodied versus operational carbon globally

Reduction Strategies will vary in each location

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Some Other Resources

Deeper Carbon Emissions: Continuing Discussions

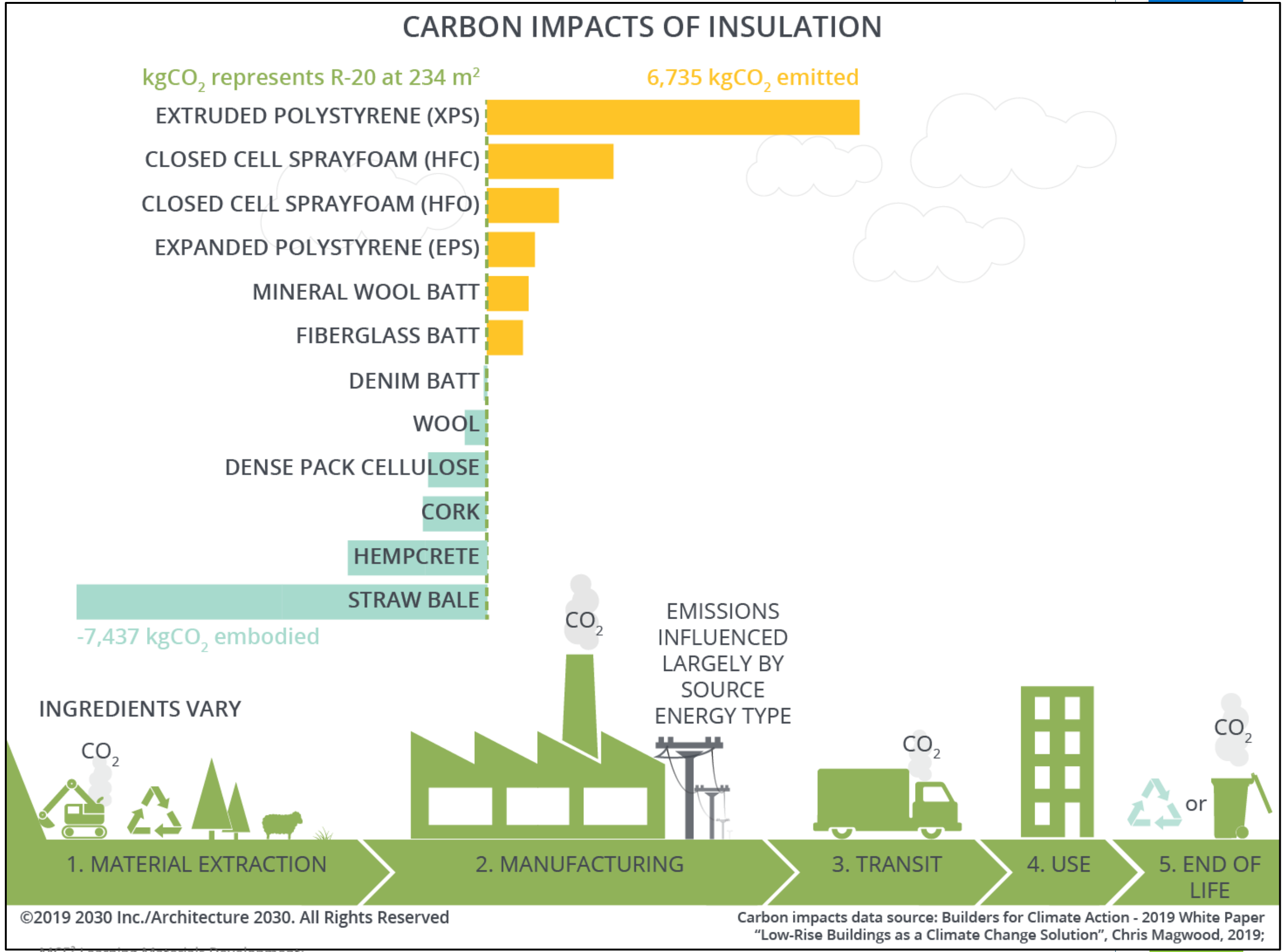
Carbon Smart Materials Palette
By Architecture2030.org
https://materialspalette.org/

Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities (RMI, 2021) – download free report

Carbon Smart Materials Palette

By Architecture 2030.org

- https://materialspalette.org/insulation/
- Example: insulation



Slide and information provided by :

Natural Resources Canada / Ressources naturelles Canada — Canada

LEEP — LOCAL ENERGY EFFICIENCY PARTNERSHIPS

MCE² Learning Materials Development:
Doug McFarlane
douglas.m.mcfarlane@gmail.com
Alternative Energy Technology at NAIT - website

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Design and Material Selection Opportunities to Optimize Carbon Reductions

What's the decision tree?

- The functionality of the product to ensure it meets all design and construction specification requirements
- The magnitude of emissions from specific materials
- The impact on design and aesthetics of the house for market acceptance
- The cost implications
- The impact on warranty/service issues
- The impact on process/cycle times
- Supplier availability

These criteria are similar to the decisions you make every day in the complex world of new home construction

EEBA

Embodied Carbon Impact of Material Changes

3 Top Contributors

Concrete

Cladding - brick

Insulation

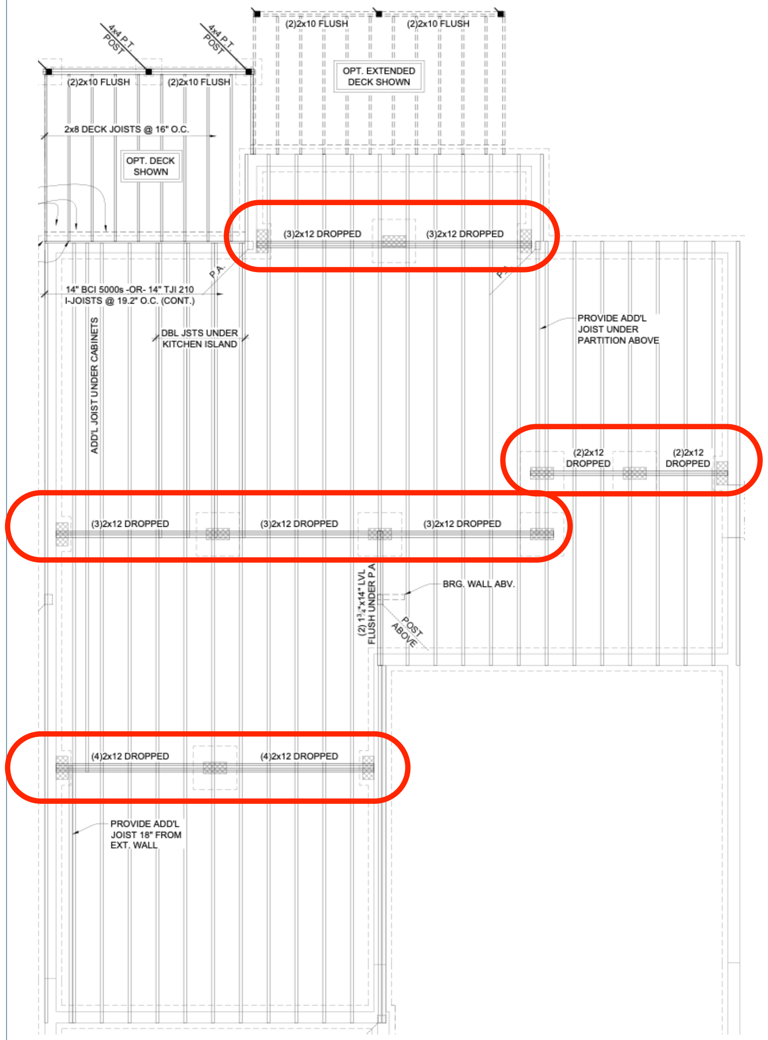
Low Embodied Carbon Materials

- Wood and wood based products store or sequester carbon
- Wood is 50% carbon by weight

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS ($kg\ CO_2e$)	EMISSIONS ($kg\ CO_2e$)	STORAGE ($kg\ CO_2e$)
CELLULOSE INSULATION								
	Cellulose / loose fill / R 3.7/inch / CIMA [Industry Avg | US & CA]	2,699.7	ft^2	100%	☐	-986	452	1,437
	Cellulose / batt / CMS / EcoCell / R 3.6/inch	2,699.7	ft^2	100%	☐	-1,654	452	2,106
	Cellulose / spray applied / R 3.75/inch / International Cellulose Corp. / K-13, ThermoCon	2,699.7	ft^2	100%	☐	-1,949	301	2,251
	Cellulose / dense pack / R 3.7/inch / CIMA [Industry Avg | US & CA]	2,699.7	ft^2	100%	☐	-1,971	904	2,875

- Cellulose based products, such as insulation have negative emissions - they store carbon for the life of the building

Structural Carbon Optimization Example



EEBA House Floor Layout

EEBA House Floor Beam Design

	Steel	LVL	Lumber
Kg CO_2e	652	202	63.9

Courtesy of: https://www.gestimat.ca/projets/1229

Replacing steel beams for the second floor with engineered or dimensional lumber

What other advantages and decision criteria are there?

Wood Use In Construction

Maximizing wood use in both residential and commercial construction could remove an estimated 21 million tons of C02 from the atmosphere annually—equal to taking **4.4 million cars** off the road.

https://www.thinkwood.com/sustainable-architecture-design

Think Wood: Stewards of the Land, Faces of the Forest

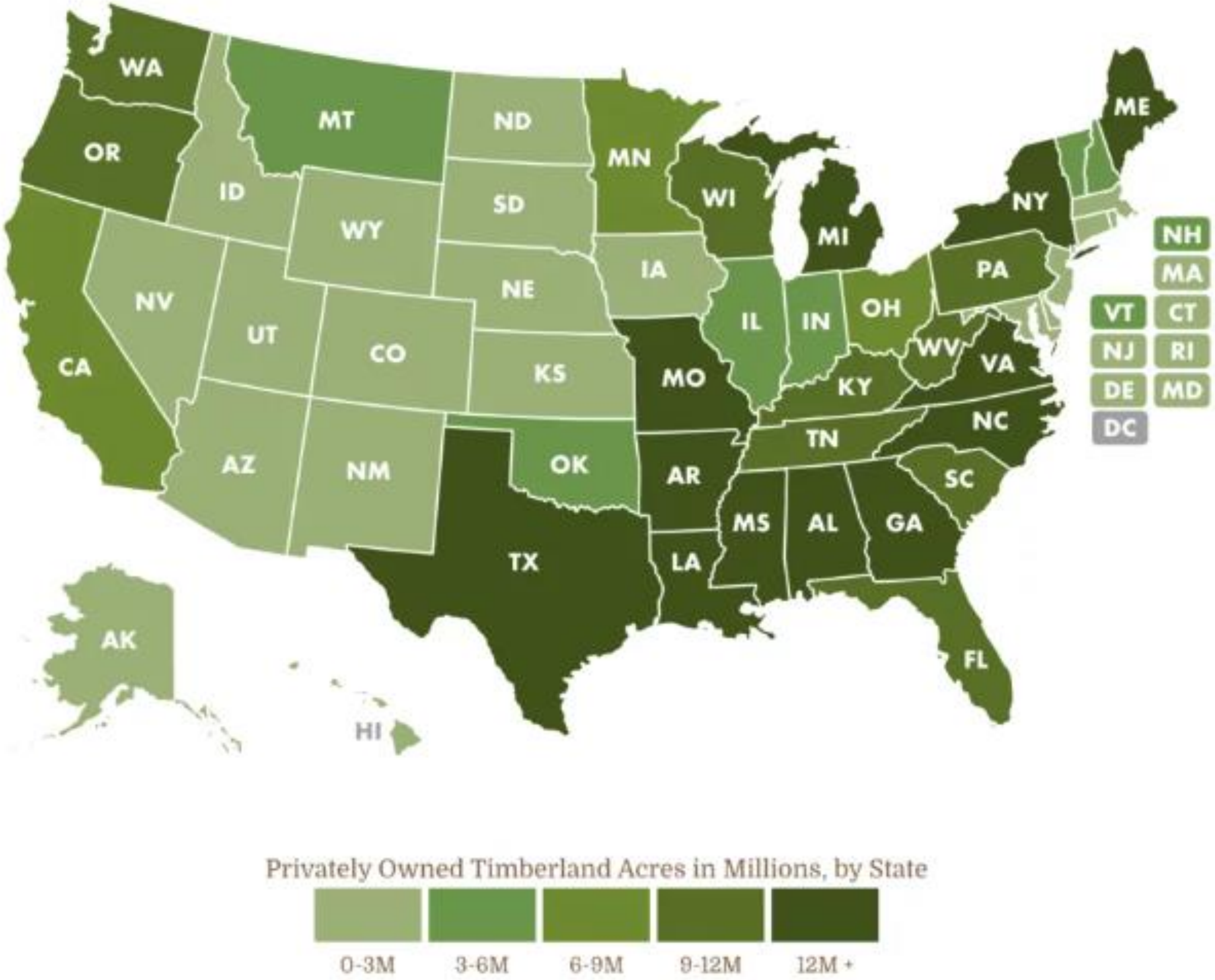
https://www.thinkwood.com/blog/faces-of-the-forest

NATIONAL

PRIVATE ACRES:	351,519,229
PUBLIC ACRES:	151,121,624
NAFO ACRES:	46,868,250

PRIVATE WORKING FORESTS SUPPORT:

- JOBS: 2,465,644
- PAYROLL: $108,032,512,279
- SALES & MANUFACTURING: $284,717,239,692



Think Wood: Wood and Wood-Based is Good

Responsible forest management

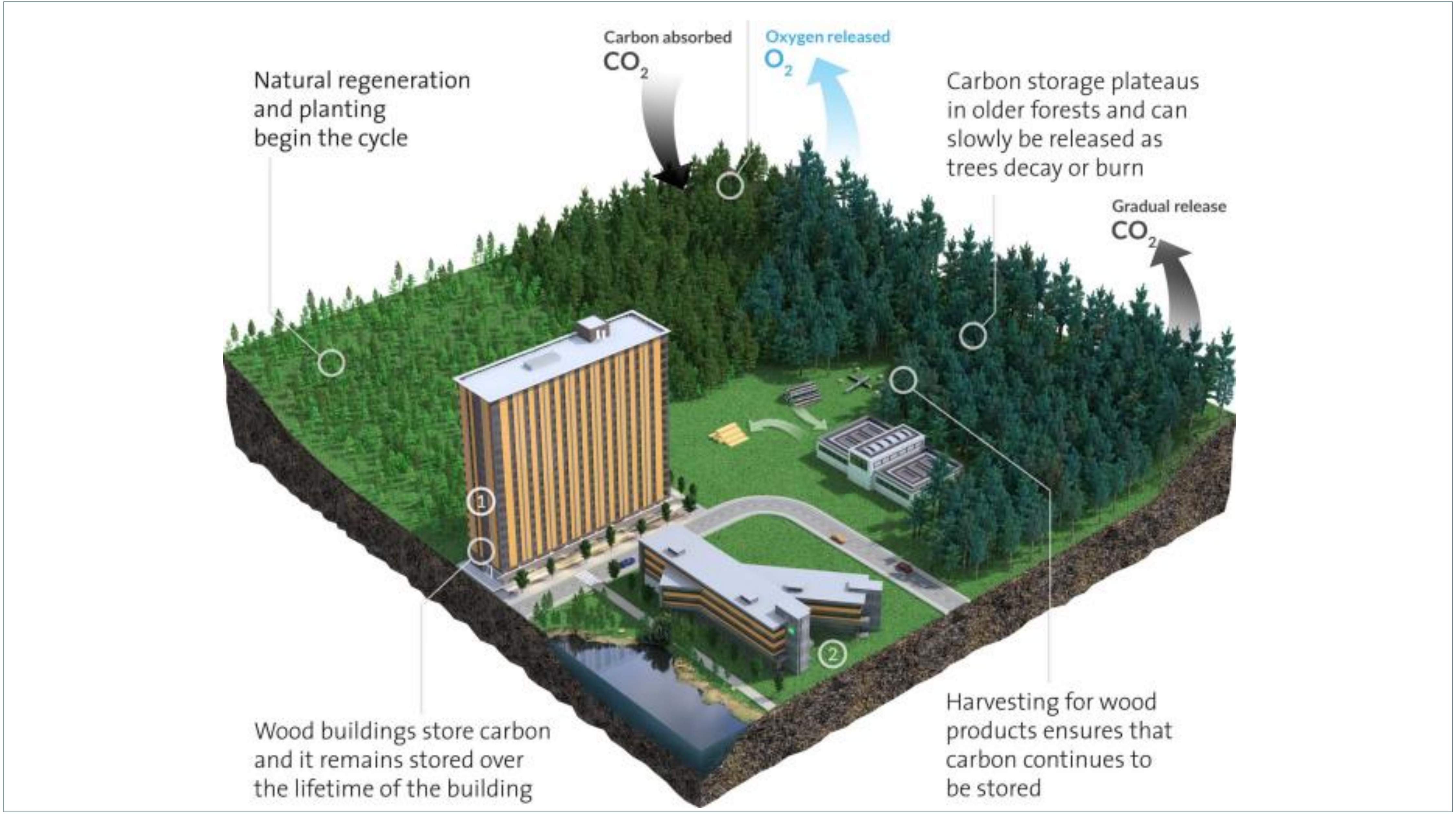
- Grow
- Harvest
- Replant

Creates a reliable, sustainable source of building materials that sequester and store carbon

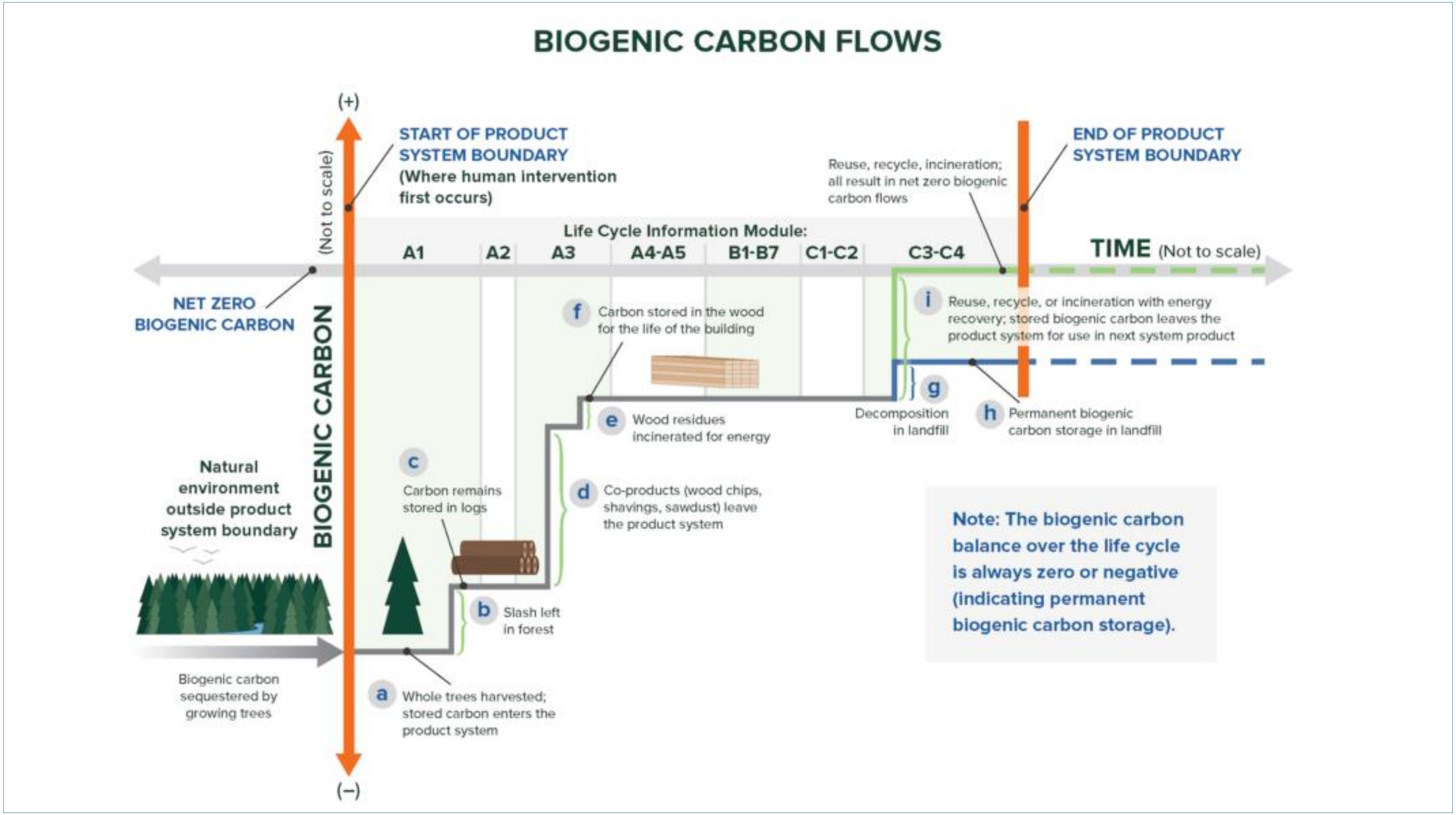
Biogenic Carbon in Wood

Biogenic carbon in wood products refers to carbon sequestered by a tree during its growth that continues to be stored in wood products over their lifetime.

https://www.woodworks.org/resources/woodworks-carbon-calculator/



https://cwc.ca/wp-content/uploads/2019/03/Carbon-Fact-Sheet-May-19-2017.pdf



https://www.woodworks.org/resources/how-to-include-biogenic-carbon-in-an-lca/#:~:text=Biogenic%20carbon%20in%20wood%20products,wood%20products%20over%20their%20lifetime.

Low Embodied Carbon

Wood products are less energy intensive to manufacture than steel or concrete

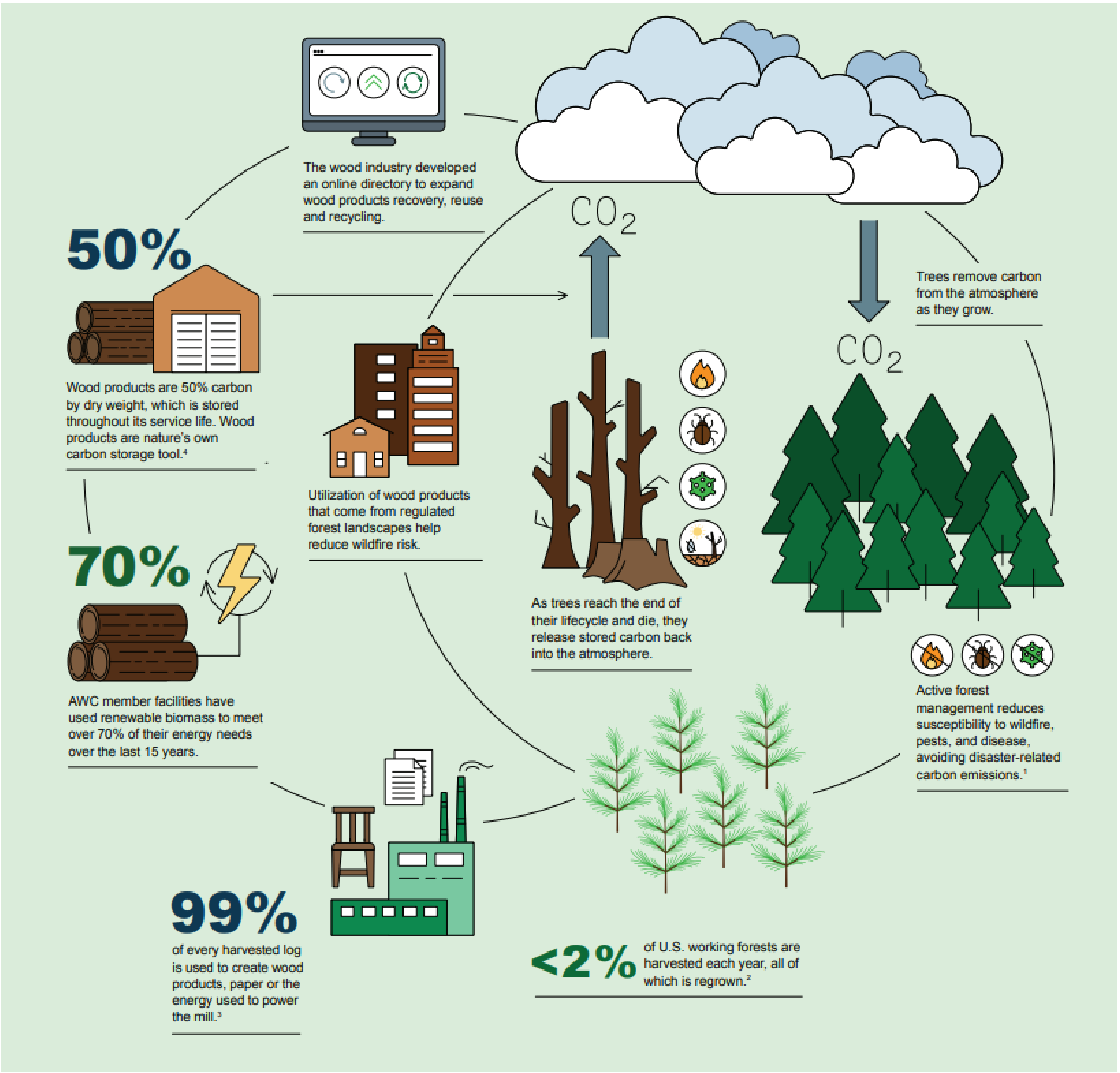
Most of the energy used to manufacture wood products comes from renewable biomass instead of fossil fuels

Wood Buildings Store Carbon

Trees absorb CO2 from the atmosphere as they grow.

They continue to store the carbon when they are manufactured into products

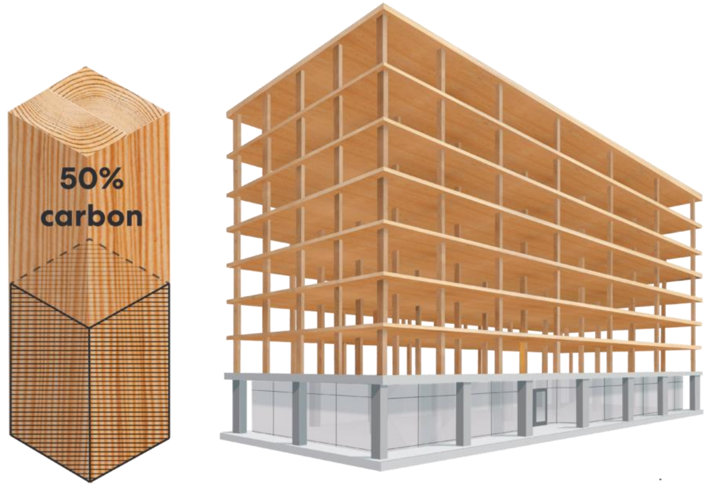
Wood is 50% carbon by dry weight



https://awc.org/issues/wood-product-carbon/

Carbon Storage in Different Wood Products

Species	Density of Wood at 15% MC (lb/ft^3)	Dry Density of Wood (lb/ft^3)	Estimated Carbon Stored (lb/ft^3)	Estimated CO_2 Equivalent (lb/ft^3)
Douglas fir-larch	34.5	30.0	15.0	55.0
Hem-fir	30.7	26.7	13.3	48.9
Spruce pine fir	27.8	24.2	12.1	44.3
Southern yellow pine	36.3	31.6	15.8	57.9



https://www.woodworks.org/resources/calculating-the-carbon-stored-in-wood-products/

Cladding Choices - EEBA Carbon House

Total Material Carbon Emissions (Tonnes CO2e)

Wood siding	54.1	**Best Case**
Vinyl siding	55.8	
Cement Board Siding	62.7	
Stucco	65.9	
Brick	**71.2**	**Base Case**

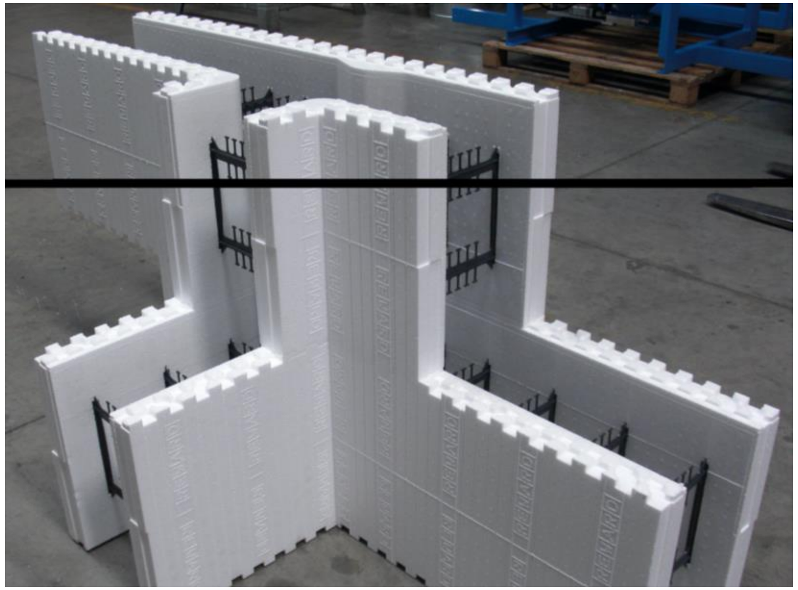
What other decision criteria are there?

A 24% overall reduction by changing to a wood -based cladding in the BEAM tool

4 different claddings on one house

Alternative Wall Structure Choices

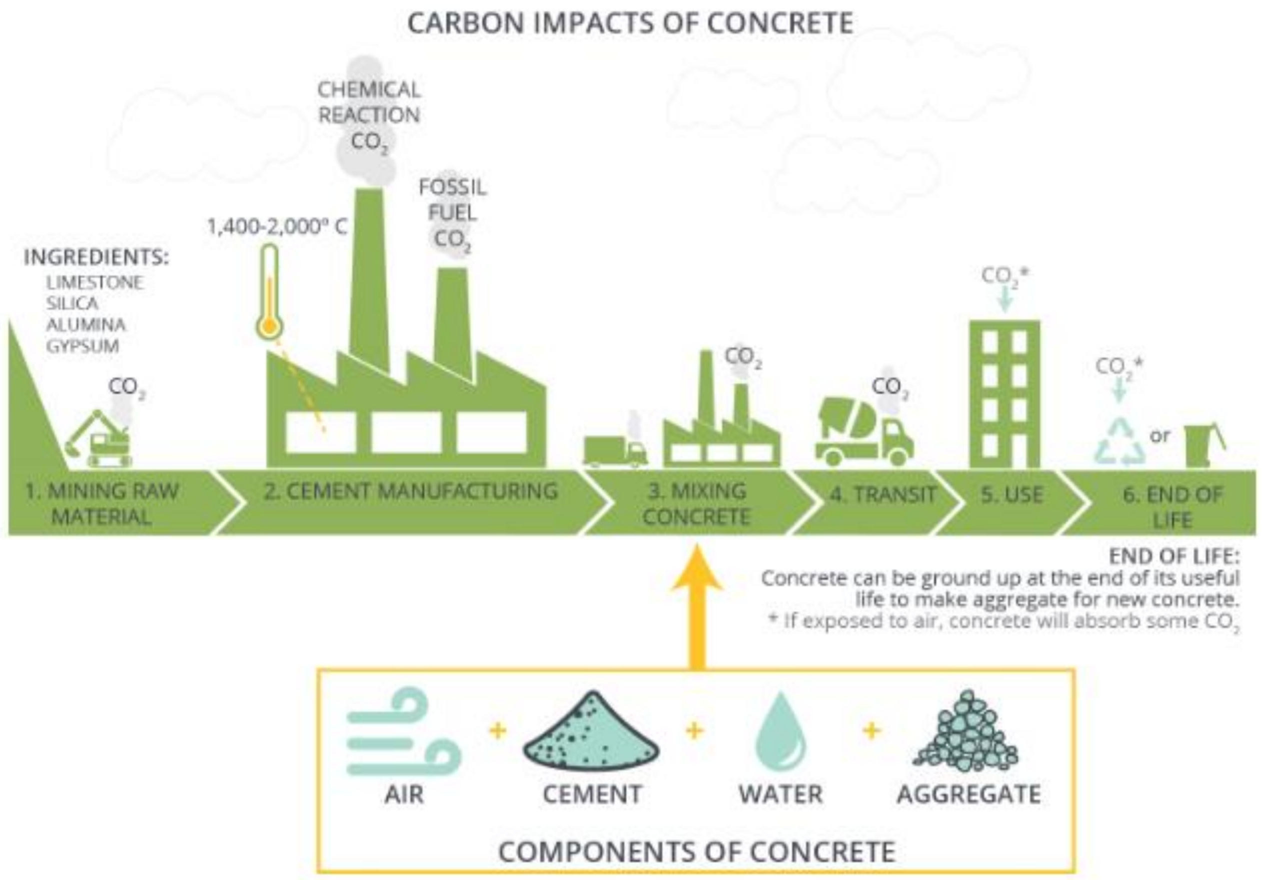
Total Material Carbon Emissions (Tonnes CO2e)		
ICF Basement (R23) only	71.6	
ICF Exterior AG Walls Only (R23)	87.4	
ICF Basement & Ext. AG Walls (R23)	87.9	
SIP Exterior AG Walls (R23)	74.3	
2x6 Framed Ext Walls (R21)	**71.2**	**Base Case**



Evaluate energy efficiency, durability and resiliency of different wall systems in addition to the carbon emission factors

CONCRETE –CEMENT OPTIONS

SCM
Supplemental
Cementitious
Materials (ad-mixture)



CONCRETE –CEMENT OPTIONS WITH SCM

Fossil based-by-products as SCM

Silica Fume

Fly Ash

Blast Furnace Slag
etc

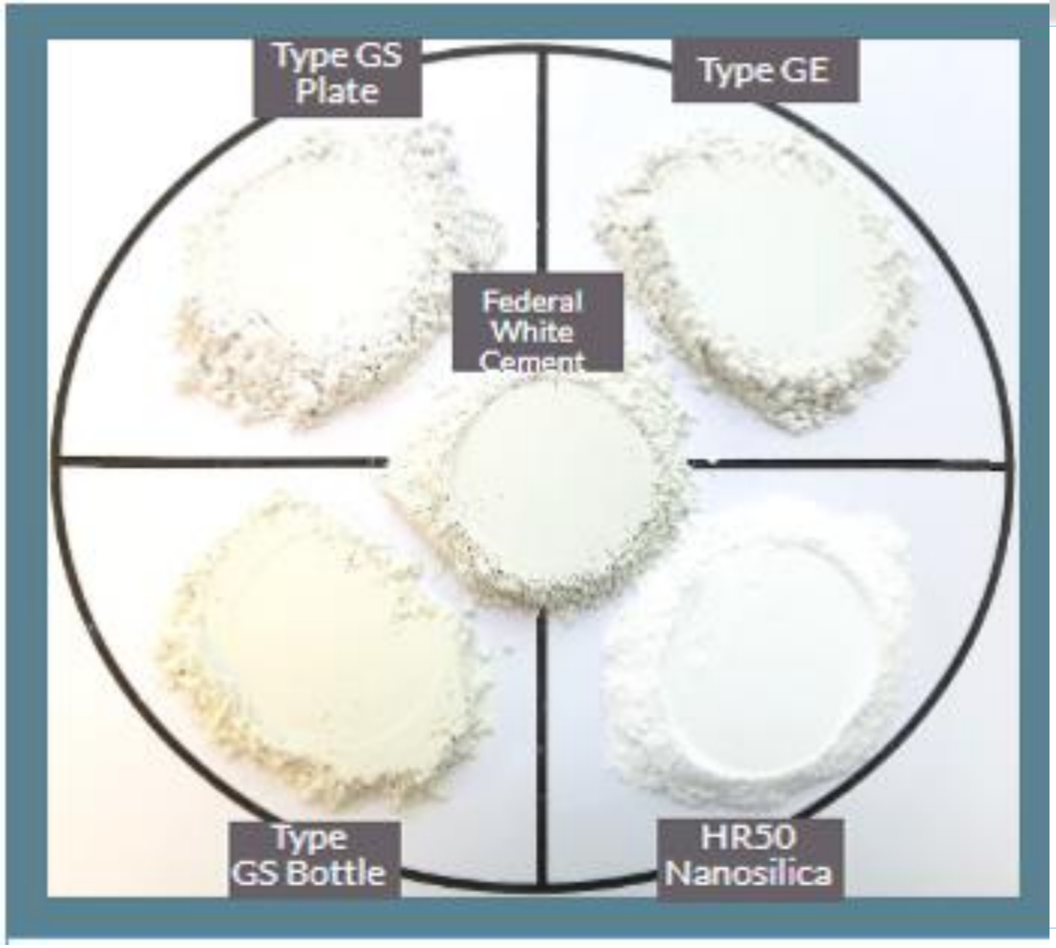
CONCRETE –CEMENT OPTIONS WITH SCM

When possible use non-fossil fuel-based SCMs or cement replacements – Known as **Pozzolans**

Pozzolans are a broad class of siliceous or siliceous and aluminous materials which, in themselves, possess little or no cementitious value but which will, in finely divided form and in the presence of water, react chemically with calcium hydroxide at ordinary temperature to form
compounds possessing cementitious properties.

CONCRETE –CEMENT OPTIONS WITH SCM

Glass Pozzolan*
- Glass Pozzolan is recycled, post-consumer glass that is ground up and used as an SCM, reducing the amount of cement in a concrete mix. Glass pozzolan has been shown to contribute to effective, consistent strength gain and workability.
ASTM 1866



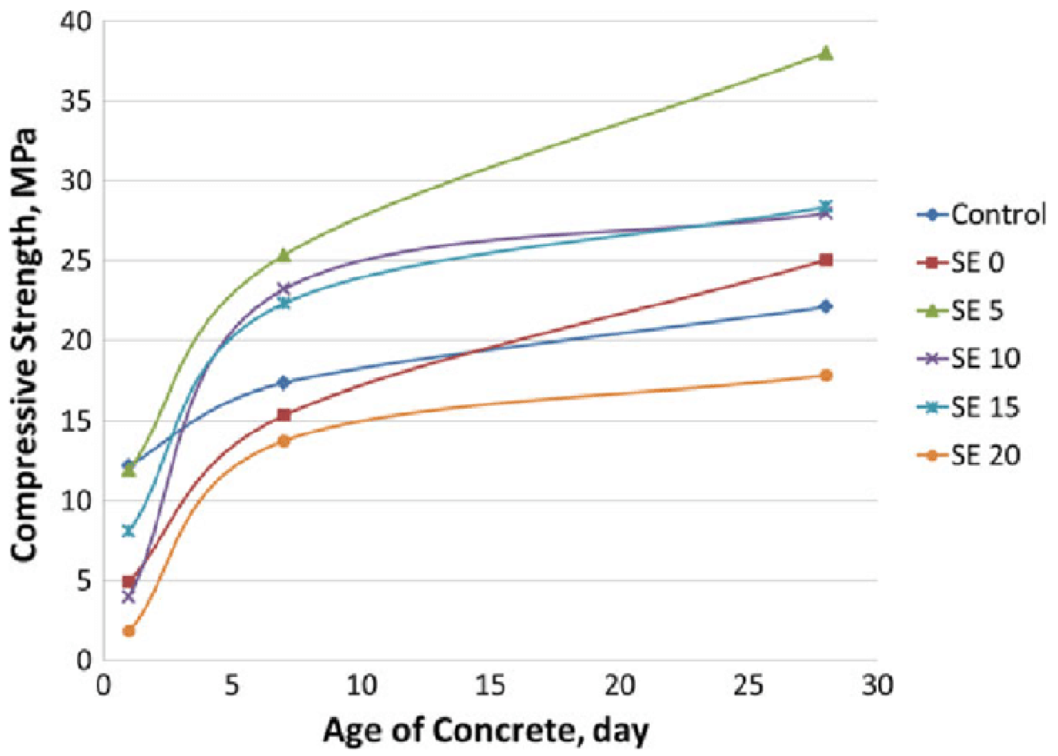
CONCRETE –CEMENT OPTIONS WITH SCM

Rice Husk Ash Concrete
- Rice husks (the hard protective coverings of rice grains) are agricultural byproducts (waste material from rice mill processes), and are made up of approximately 85-90% amorphous silica plus about 5% alumina, making the ash highly pozzolanic*6.

CONCRETE –CEMENT OPTIONS WITH SCM

Substitute cement with supplementary cementitious materials **(SCMs) from non-fossil fuel based sources**

- Consider use of **larger sized aggregate** (e.g. 1" vs ¾" coarse aggregate) where appropriate.
- Typical practice is to define a minimum amount of cement required and/or a maximum allowable amount of SCMs, both of which can result in the inclusion of more cement than necessary. **Instead, specify the required compressive strength at a specific age.**



CONCRETE –CEMENT OPTIONS WITH SCM

Get to know what options are available to suppliers local to the project

- **Not all the options below are available** to all concrete suppliers, as materials in concrete vary significantly depending on local supplies.
- SCM admixtures **can make low-cement concrete that would normally be unworkable much easier to handle** and finish in the field but require well-trained teams at the batch plant and the construction site.
- SCM **may require seasonal adjustment**. E.g. 0-10% in winter and 30%+ in summer. Cold weather application with SCM may limit high-heat hydration/curing therefore requiring forms to remaining place longer

CONCRETE –CEMENT OPTIONS –Increase Lime Use

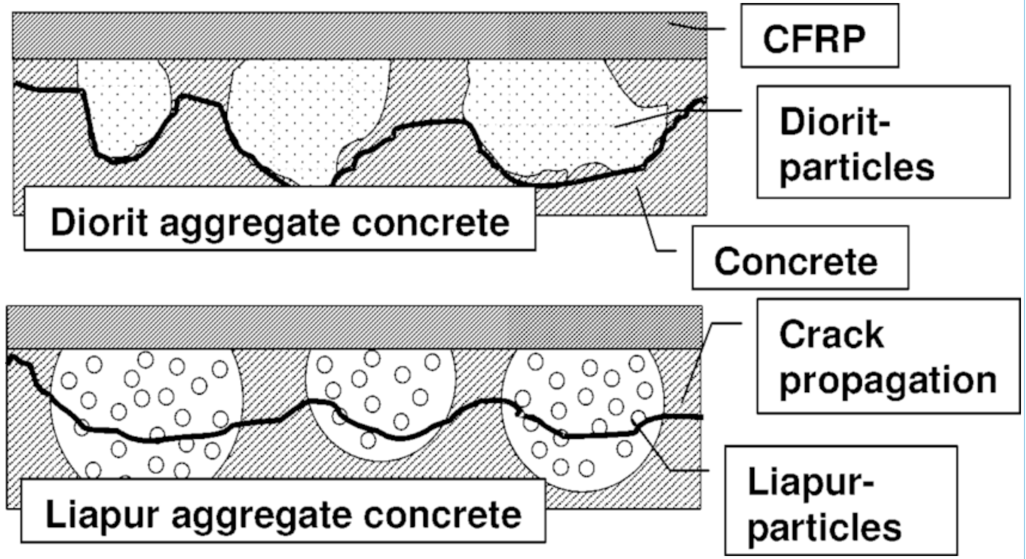
Specify Portland Limestone Cement (PLC) instead of Portland cement

PLC, or type IL cement, is a slightly modified version of Portland cement that can result inreduced embodied carbon by using higher percentages of limestone (5-15% in PLC, compared to the 5% typically used in Portland cement)5. This results in a smaller portion of cement in the mix. Where locally available, specify PLC over typical Portland cement.

CONCRETE –CEMENT OPTIONS -Aggregate

Specify hard, clean, and strong aggregates

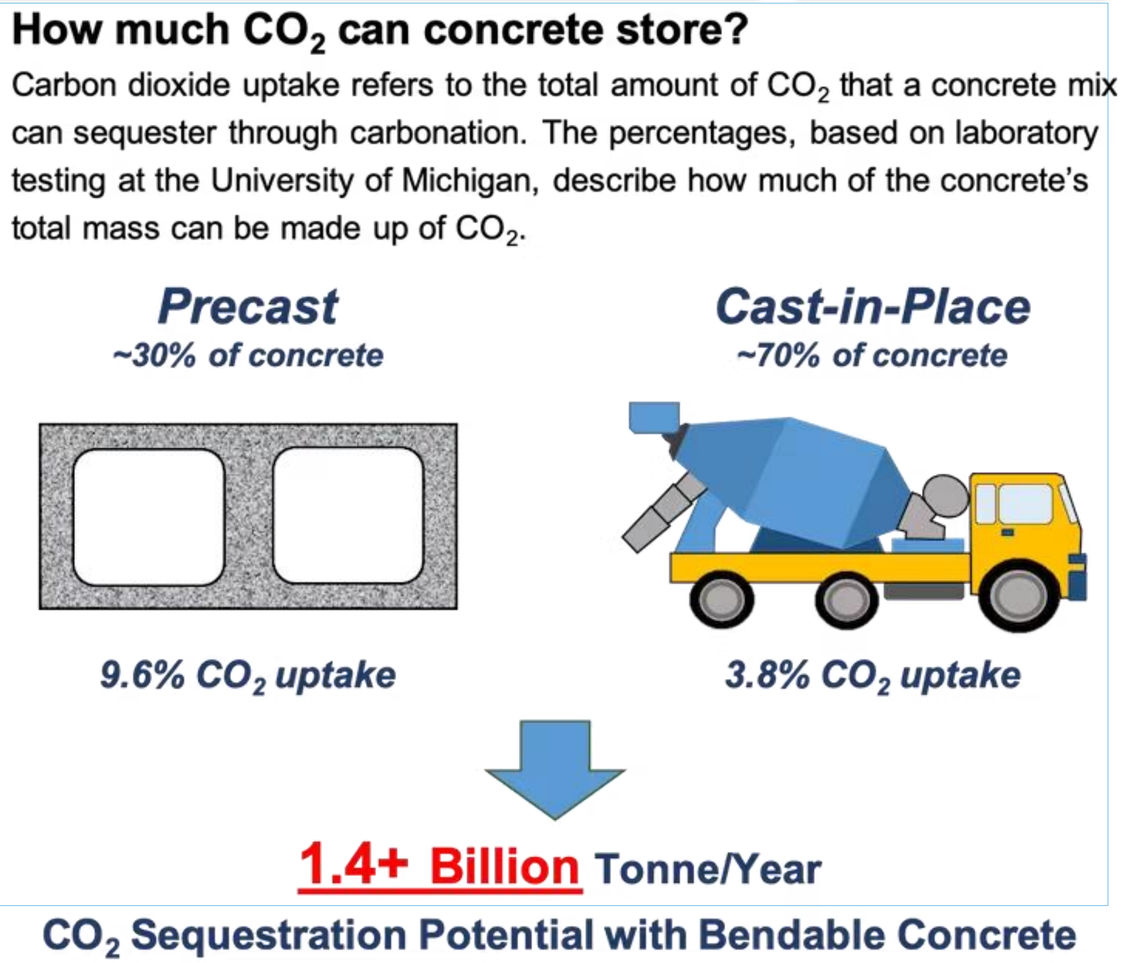
Weak and/or lightweight aggregates often require the addition of more cement to achieve the necessary mix strength. Soft, porous aggregates can also result in weak concrete with low wear resistance, reducing the life-span of the material. **Whenever possible and locally available, use strong aggregates to reduce the required cement quantity** and create concrete with a high resistance to abrasion and a longer life-span.



CONCRETE –CEMENT OPTIONS

Utilize carbon sequestration (CO2 injection)

New technology captures the carbon naturally emitted during the cement manufacturing process and injects it back into the concrete mix during mixing. Encourage concrete suppliers to use carbon sequestration/CO2 injection methods.



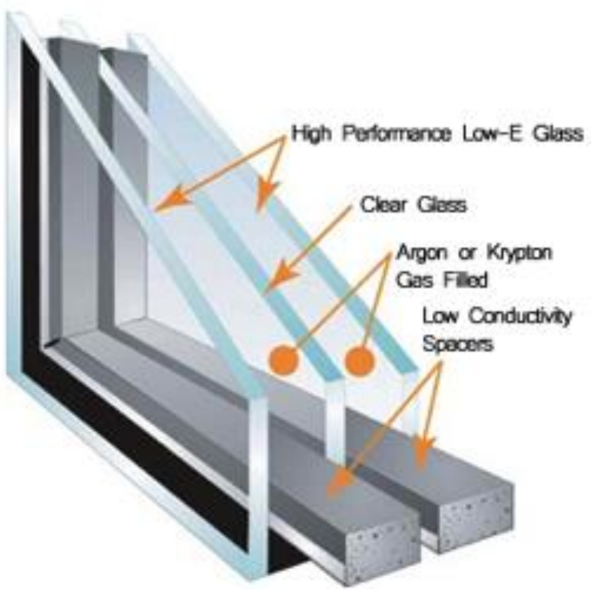
CONCRETE –CEMENT OPTIONS

Consider 56 or later day strength on parts of the project

Strength conformity at 56, 90, 120, or more days, rather than the conventional 28, **could enable an increase in the amount of SCMs replacing cement.** Specify design compressive strengths greater than 28 days whenever possible to allow the maximum use of SCMs**.**

Embodied Carbon Impact of Energy Efficiency Changes

Window Choices - EEBA Carbon House



Glazing	**MMBTUs/yr**	**Operational CO_2e Tonnes/yr**	**Embodied CO_2e Tonnes**
Double, Low E, Argon	108.1	7.82	71.2
Triple, 2 Coats Low E, Argon	103.9	7.55	71.7
Change		- 0.27 Tonnes/yr	+0.5 Tonnes

A 2 year "return" on carbon investment

What other advantages do triple glazed windows offer?

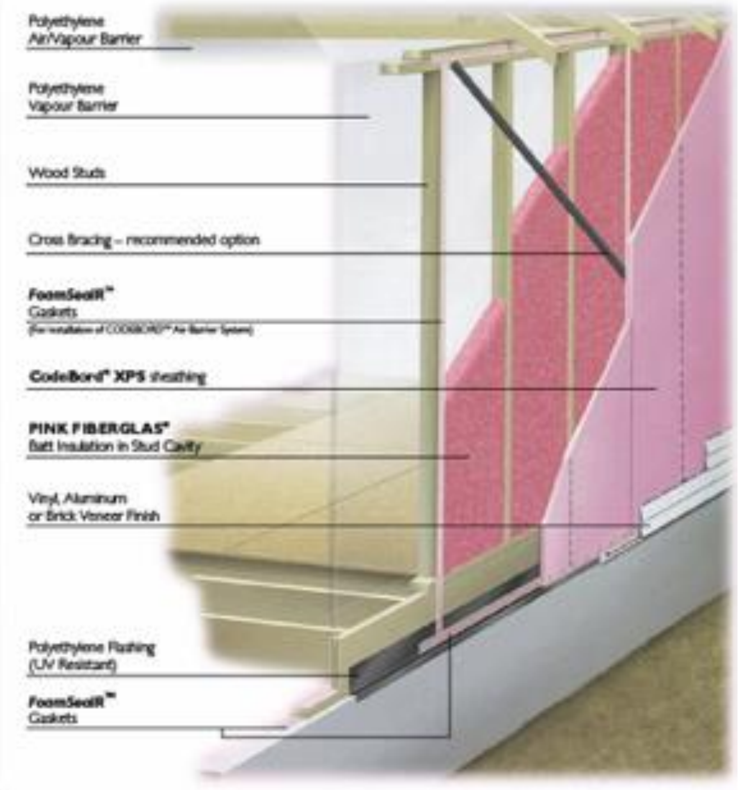
Air Tightness - EEBA Carbon House

Tightness ACH50	**MMBTUs/yr**	**Operational CO_2e Tonnes/yr**	**Embodied CO_2e Tonnes**
3.0	108.1	7.82	71.2
2.0	103.2	7.56	Neglible
1.5	100.9	7.44	Neglible
Change		-0.38 Tonnes/yr	Neglible

Less than one year "return" on carbon investment

What other advantages does airtightness offer?

Exterior Insulation Choices - EEBA Carbon House



Insulated Sheathing	**MMBTUs/yr**	**Operational CO_2e Tonnes/yr**	**Embodied CO_2e Tonnes**
None	108.1	7.82	71.2
R5	103.5	7.57	72.4
R10	100.5	7.41	73.6
Change		-0.41 Tonnes /yr	+2.4 Tonnes

A 6 year “return” on carbon investment

CONTINUOUS INSULATION (R5)

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
CONTINUOUS INSULATION		**R-VALUE**	**5.0**					
XPS FOAM BOARD (LEGACY FORMULAS)								
	XPS foam board / DuPont / Styrofoam / HFC-filled / R 5.6/inch	2,699.7	ft^2	100%	☐	13,428	13,428	0
	XPS foam board / Owens Corning / Foamular 250 / HFC-filled / R 5.0/inch	2,699.7	ft^2	100%	☐	11,154	11,154	0
XPS FOAM BOARD (REDUCED GWP)								
	XPS foam board / DuPont / Styrofoam / Reduced GWP / R 5.6/inch	2,699.7	ft^2	100%	☐	8,061	8,061	0
SPRAY POLYURETHANE FOAM – HIGH DENSITY								
	Spray polyurethane foam - High Density (HFC gas) / R 6.3/inch / SPFA [Industry Avg | US & CA]	2,699.7	ft^2	100%	☐	3,759	3,759	0
	Spray polyurethane foam - High Density (HFO gas) / R 6.5/inch / SPFA [Industry Avg | US & CA]	2,699.7	ft^2	100%	☐	1,093	1,093	0
SPRAY POLYURETHANE FOAM – CLOSED CELL								
	Spray polyurethane foam - Closed Cell (HFC gas) / R 6.6/inch / SPFA [Industry Avg | US & CA]	2,699.7	ft^2	100%	☐	2,907	2,907	0
	Spray polyurethane foam - Closed Cell (HFO gas) / R 6.6/inch / SPFA [Industry Avg | US & CA]	2,699.7	ft^2	100%	☐	919	919	0
	Spray polyurethane foam - Closed Cell (HFO gas) / Huntsman / Heatlok Soya HFO & Heatlok HFO / R 6.5/inch	2,699.7	ft^2	100%	☐	553	553	0
XPS FOAM BOARD								
	XPS foam board / Owens Corning / Foamular NGX 250 / R 5.0/inch	2,699.7	ft^2	100%	☐	1,793	1,793	0
	XPS foam board / R 5.0/inch [BEAM Avg | US & CA]	2,699.7	ft^2	100%	☐	1,083	1,083	0
	XPS foam board / DuPont / Styrofoam ST-100 / R 5.0/inch	2,699.7	ft^2	100%	☑	1,031	1,031	0
	XPS foam board / SOPREMA / SOPRA-XPS / R 5.0/inch	2,699.7	ft^2	100%	☐	425	425	0
MINERAL WOOL BOARD								
	Mineral wool board - heavy density / NAIMA / R 4.2/inch [Industry Avg | N.America]	2,699.7	ft^2	100%	☐	1,802	1,802	0
	Mineral wool board / Rockwool / Comfortboard 80 / R 4.2/inch	2,699.7	ft^2	100%	☐	897	897	0
	Mineral wool board - light density / NAIMA / R 3.7/inch [Industry Avg | N.America]	2,699.7	ft^2	100%	☐	735	735	0
	Mineral wool board / Rockwool / Rockboard 60 / R 4.3/inch	2,699.7	ft^2	100%	☐	573	573	0
HIGH R-VALUE CONTINUOUS INSULATION								
	Vacuum Insulated Panel / Porextherm / Vacupor / R 30/inch	2,699.7	ft^2	100%	☐	1,640	1,640	0

CONTINUOUS INSULATION (R5) Cont'd

CATEGORY	MATERIAL	QUANTITY	UNITS	%	SELECT	NET EMISSIONS (kg CO_2e)	EMISSIONS (kg CO_2e)	STORAGE (kg CO_2e)
EPS FOAM BOARD								
	EPS foam board / R 4.3/inch, Type XV, 60 psi (400 kPa) / EPS Industry Alliance [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	1,718	1,718	0
	EPS foam board / R 4.0/inch avg [BEAM Avg | US & CA]	2,699.7	ft²	100%	☐	1,055	1,055	0
	EPS foam board / R 4.2/inch, Type IX, 25 psi (170 kPa) / EPS Industry Alliance [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	1,054	1,054	0
	EPS foam board / R 4.0/inch, Type II, 15 psi (100 kPa) / EPS Industry Alliance [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	833	833	0
	EPS foam board / R 3.6/inch, Type I, 10 psi (70 kPa) / EPS Industry Alliance [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	616	616	0
EPS FOAM BOARD WITH GRAPHITE								
	EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type IX	2,699.7	ft²	100%	☐	755	755	0
	EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type II, 15 psi (Type 2, 110 kPa)	2,699.7	ft²	100%	☐	610	610	0
POLYISOCYANURATE FOAM BOARD								
	Polyisocyanurate / Wall Boards / R 6.5/inch / PIMA [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	905	905	0
	Polyisocyanurate / Wall Boards / DuPont / Thermax / R 6.5/inch	2,699.7	ft²	100%	☐	528	528	0
	Polyisocyanurate / Wall Boards / Hunter / Xci / R 6.5/inch	2,699.7	ft²	100%	☐	501	501	0
CORK BOARD								
	Cork board insulation / Amorim / Isolamentos / R4/inch	2,699.7	ft²	100%	☐	-1,509	657	2,166
WOOD FIBER BOARD								
	Wood fiber board / GUTEX / Multi-Therm / R 3.6/inch, 40, 60, 80, 100, 120, 140, 160, 180, 200 mm	2,699.7	ft²	100%	☐	-958	970	1,929
	Wood fiber board / Steico / Special Dry / R 3.6/inch, 40, 120, 140, 160, 180, 200 mm	2,699.7	ft²	100%	☐	-1,520	419	1,939
	Wood fiber board / Pavatex / Pavatherm / R 3.4/inch	2,699.7	ft²	100%	☐	-1,826	921	2,748
	Wood fiber board / R 2.7/inch / NAFA [Industry Avg | US & CA]	2,699.7	ft²	100%	☐	-2,279	2,349	4,627

Exterior Insulation Choices - EEBA Carbon House

Continuous Insulation Material Carbon Emissions	
Insulation Type	**Net Emissions (kg CO2e)**
EPS Foam Board	1718
Mineral Wool Board	897
XPS Foam Board	1031
Legacy XPS Foam Board	13428
Wood Fiber Board	**-958**

There is significant differences in the embodied carbon of exterior insulation
Some can ever store carbon - what decision criteria will you consider?

Cavity Insulation Choices - EEBA Carbon House

Cavity Insulation Material Carbon Emissions	
Insulation Type	**Net Emissions (kg CO2e)**
High Density Spray Foam (HFO)	4592
Closed Cell Spray Foam (HFO)	3859
Open Cell Spray Foam	1317
Mineral Wool Batt	1580
Fiberglass Batt	430
Cellulose	**-936**

Some can even store carbon

There is significant differences in the embodied carbon of Cavity Insulation

Carbon Smart Attributes

Concrete

- Less Cement = Less Carbon
- Consider different concrete mixes (Fly Ash/Slag)

Insulate

- Insulate with biogenic materials that naturally sequester carbon
- Consider blown-in instead of rigid and spray foams

Reduce, Reuse, Recycle

- Specify reclaimed & salvaged products
- Design for longevity, repair, and maintenance

Reducing the Carbon Impact of Concrete

- Use less concrete
  - Smaller homes, no basement, optimize footing & wall thickness
- Switch to alternative structural components - wood is good
- Use Supplementary Cementitious Materials **(SCMs)** - Fly ash
  - 80% of concrete's carbon impact comes from the production of cement
- Use local materials and suppliers that are using low carbon fuels
- New carbon dioxide injection technologies are being researched

https://civilengineersforum.com/fly-ash-in-concrete-advantages-disadvantages/

PCA
Portland Cement Association

PCA member companies are committed to achieving carbon neutrality across the cement and concrete value chain by 2050.

AT THE CEMENT PLANT

- Increase the use of decarbonated raw materials
- Decrease the use of traditional fossil fuels by 5X
- Increase the use of alternative fuels
- Push efficiency and decrease energy intensity for one metric ton of clinker
- Utilize carbon capture to avoid the release of CO_2 emissions
- Reduce clinker production emissions

OPTIMIZING THE DESIGN AND CONSTRUCTION OF THE BUILT ENVIRONMENT

- Lower concrete manufacturing emissions to zero at the plant
- Transition to zero emission fleets
- Optimize concrete mixes
- Reduce overdesign

PRODUCTION: AT THE CEMENT PLANT	
Replace raw materials with decarbonated materials	Using decarbonated materials eliminates CO_2 emissions from processing traditional raw materials, like limestone.
Use alternative fuels	Replacing traditional fossil fuels with biomass and waste-derived fuels lowers greenhouse gas (GHG) emissions and keeps materials out of landfills.
Continue efficiency improvements	Increasing energy efficiency reduces the amount of CO_2 emitted for each ton of product.
Implement carbon capture, utilization, and storage (CCUS) technology	CCUS directly avoids a significant portion of cement manufacturing emissions.
Promote new cement mixes	Creating new cements using existing and even alternative materials reduces emissions from mining for new materials, while optimizing the amount of clinker used ensures emissions correspond to necessary production.
Increase use of portland-limestone cement (PLC)	As an existing lower-carbon blend, universal acceptance of PLC will reduce clinker consumption and decrease emissions.
CONSTRUCTION: DESIGNING AND BUILDING	
Optimize concrete mixes	Considering the specific needs of the construction project and using only the materials necessary, avoiding excess emissions.
Use renewable fuels	Switching to solar, wind and other renewable sources of energy directly reduces emissions from other energy sources.
Increase the use of recycled materials	Diverting these materials from landfills.
Avoid overdesign and leverage construction technologies	Designing for the specific needs of the construction project reduces unnecessary overproduction and emissions; incorporating just-in-time deliveries.
Educate design and construction community	Improve design and specifications to be more performance oriented which will permit innovation in cement and concrete manufacturing. Encourage the use of advanced technologies to improve structural performance, energy efficiency, resiliency, and carbon sequestration.
EVERYDAY: CONCRETE INFRASTRUCTURE IN USE	
Incentivize energy efficient buildings	Increasing buildings' energy efficiency can cut energy use and resulting emissions from heating and cooling.
Reduce vehicle emissions by improving fuel efficiency	Because of its rigidity, concrete pavements enhance the fuel efficiency of vehicles driving over them, reducing vehicle emissions.
Decreased maintenance	Due to their durability, concrete structures (buildings, pavements, bridges, dams, etc.) last longer and require less frequent maintenance.
Recycling	Concrete in place can be 100% recycled, limiting the use of raw materials and production emissions.
Carbonation	Every exposed concrete surface absorbs CO_2 and over the course of its service life, a building can reabsorb 10% of cement and concrete production emissions.

Materials Matter

The same building can have very different Material Carbon Emissions (MCE)

High MCE

Total Embodied Carbon
198 kg CO_2e

- High contents of cement mix
- XPS & Closed cell spray foam
- Brick cladding
- Steel interior framing
- Vinyl windows
- Tile & Carpet flooring
- Clay tile roofing

Typical MCE

Total Embodied Carbon
137 kg CO_2e

- Average carbon concrete
- Fiberglass insulation
- Brick cladding
- Wood & TJI interior framing
- Vinyl Windows
- Engineered Wood & Vinyl flooring
- Asphalt shingle roofing

Current/Low MCE

Total Embodied Carbon
91 kg CO_2e

- Concrete with SCM contents
- XPS HFC Closed cell spray foam & blowing agents
- Fiberglass batts & Mineral wool insulation
- Brick and Fiber cement siding
- Wood interior framing

Proposed MCE

Total Embodied Carbon
32 kg CO_2e

- Concrete with high SCM contents
- HFO Closed cell spray foam & blowing agents
- Mineral wool insulation
- Brick and Fiber cement cladding
- Wood interior framing

Can we get to a ZERO Carbon House?

Chicago Base House

Low or Negative Carbon Upgrades:

- Concrete with 35% SCMs for footings, slabs
- Treated wood foundation or Hempcrete
- Wood frame walls with straw bale insulation
- Straw attic insulation
- Wood-frame floor structure
- Wood wool interior wall finish
- All electric heat & DHW
- A “clean” fuel source - solar

SECTION	CATEGORY	NET EMISSIONS ($kg\ CO_2e$)	CARBON EMISSIONS ($kg\ CO_2e$)	CARBON STORAGE ($kg\ CO_2e$)
BEAM	BUILDERS FOR CLIMATE ACTION	-9,096	29,215	38,312

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The Challenges….

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Low Carbon /Carbon Materials: The Building Science Challenges

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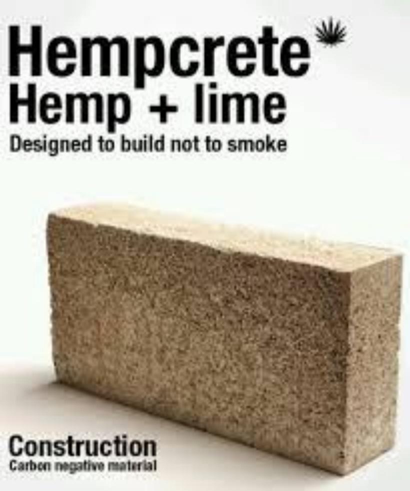
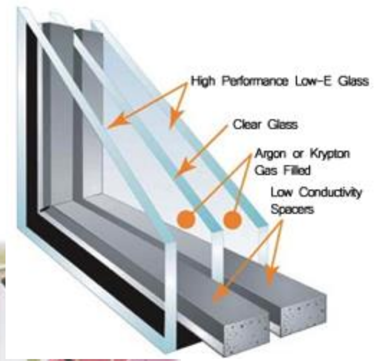
Carbon Reduction is complex building science undertaking



Choices, Alternatives & Options



Opportunities

OR Risks?

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Material Options: Regional Options Do Exist.

SCM
Supplemental
Cementitious
Substitute

- Slag
- Fly Ash
- Lime?
- Other….

Can impact
- Cold weather application
- Limit “heat development “ and set-time

Table 7. Comparison of possible GWP factors for 25 MPa concrete in Canada
*Total GWP for concrete only, does not include rebar or mesh

Concrete Mix	GWP Factor kg CO_2e/m^3	Emissions from 503 samples, kg CO_2e	Percentage change from benchmark
CRMCA - 0-25 MPa, Canadian Benchmark Avg.	**305**	**4,269,344***	
Butler Concrete N254	124	1,738,469	-59%
LaFarge ECOPact RMXUG35A3A8M	170	2,383,385	-44%
CRMCA Mix #19 - 0-25 MPa, 35-50% Slag, GUL	214	3,000,260	-30%
CRMCA Mix #18 - 0-25 MPa, 35-50% Slag, GU	234	3,280,660	-23%
CRMCA Mix #10 - 0-25 MPa, 30-40% Fly Ash, GU	250	3,50,478	-18%
CRMCA Mix #12 - 0-25 MPa, 25-34% Slag, GU	268	3,757,337	-12%
CRMCA Mix #6 - 0-25 MPa, 15-29% Fly Ash, GU	283	3,967,635	-7%
CRMCA Mix #1 - 0-25 MPa, 0-14% FA/SL, GU	327	4,584,512	+7%
EC3 Avg. for 107 Canadian 25 MPa concrete EPDs	390	5,467,766	+28%
EC3 Conservative estimate for Canadian 25 MPa	507	7,108,096	+66%
LaFarge RMXK925A21F	610	8,552,147	+100%

https://www.buildersforclimateaction.org/report---embarc-report.html

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Material Options: Regional Options Do Exist.

Insulation Options

- New formulas are already changing the mix
- Reference the products actual EPD vs industry averages
- EPD need to be frequently UPDATED

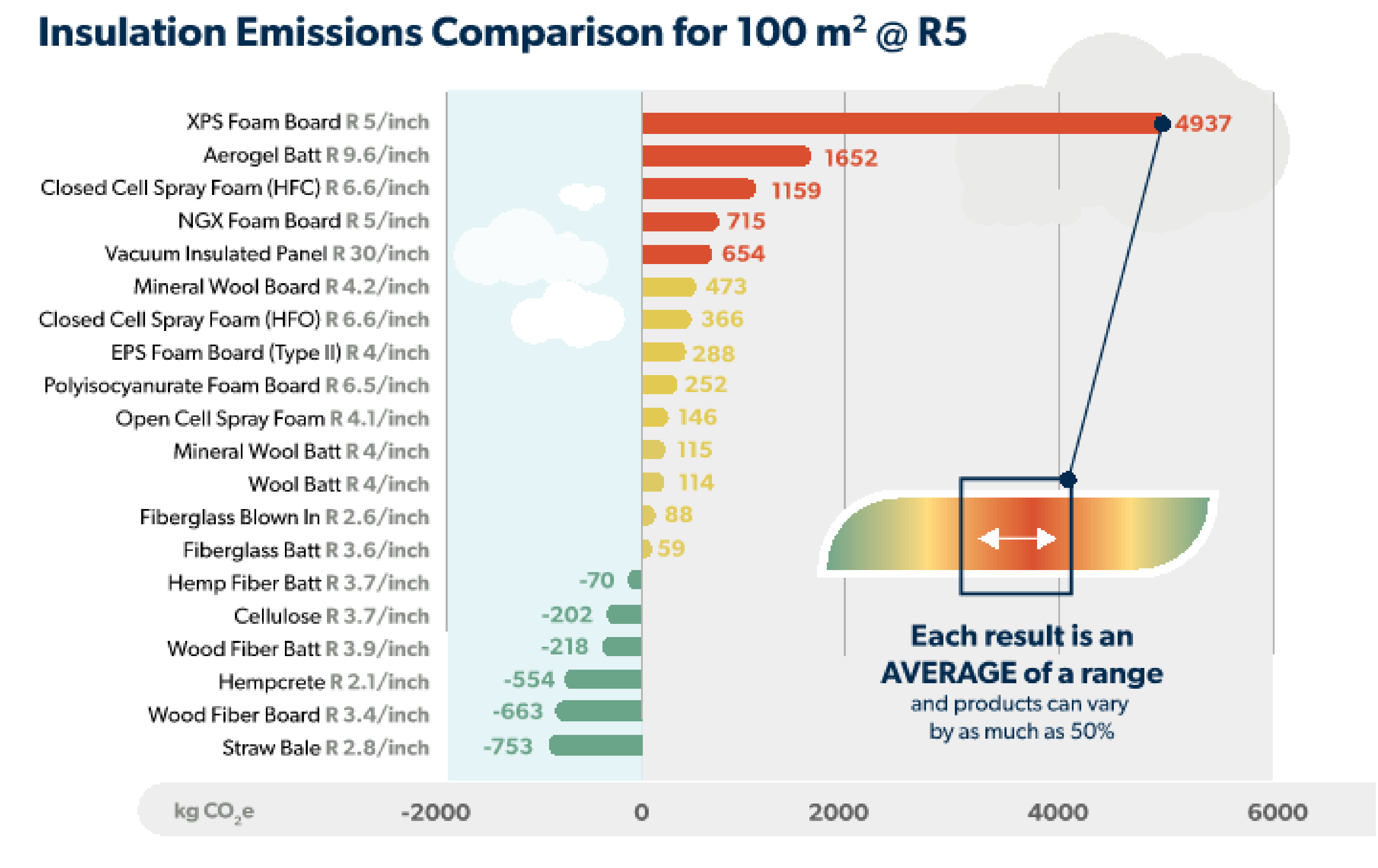

Figure 11. Range of net emissions for different insulation types from BEAM software.

https://www.buildersforclimateaction.org/report---embarc-report.html

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Carbon Reduction is complex building science undertaking

Natural , carbon storing, construction materials

Wonderful opportunity to invest in future , today.

- This said, we better get some things right because….
  - ❑ Water /moisture interaction?
  - ❑ Porous materials or Hygrophobic?
  - ❑ Durability under variable moisture RH conditions and temperatures?

IF WE DO-

- ….Better be water management experts(better than we do today…)
- ….Better be air tight masters (interstitial condensation)
- …Better be more careful at controlling dew points and hygrothermal performance of enclosure
- …Better start controlling interior relative humidity(summer and winter) better than we do now

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Carbon Reduction is complex building science undertaking

EC and HVAC : What about the systems ?

- EC = Materials. 2020 Swiss studies suggest

  15% to 36% of total building EC

- ODP Ozone Depletion Potential / GWP

  Global Warming Potential = “refrigerants”

- LOW to ZERO ODP are here….(R410A)
- LOW GWP -**CO2 based systems are coming**
- We need to know more…

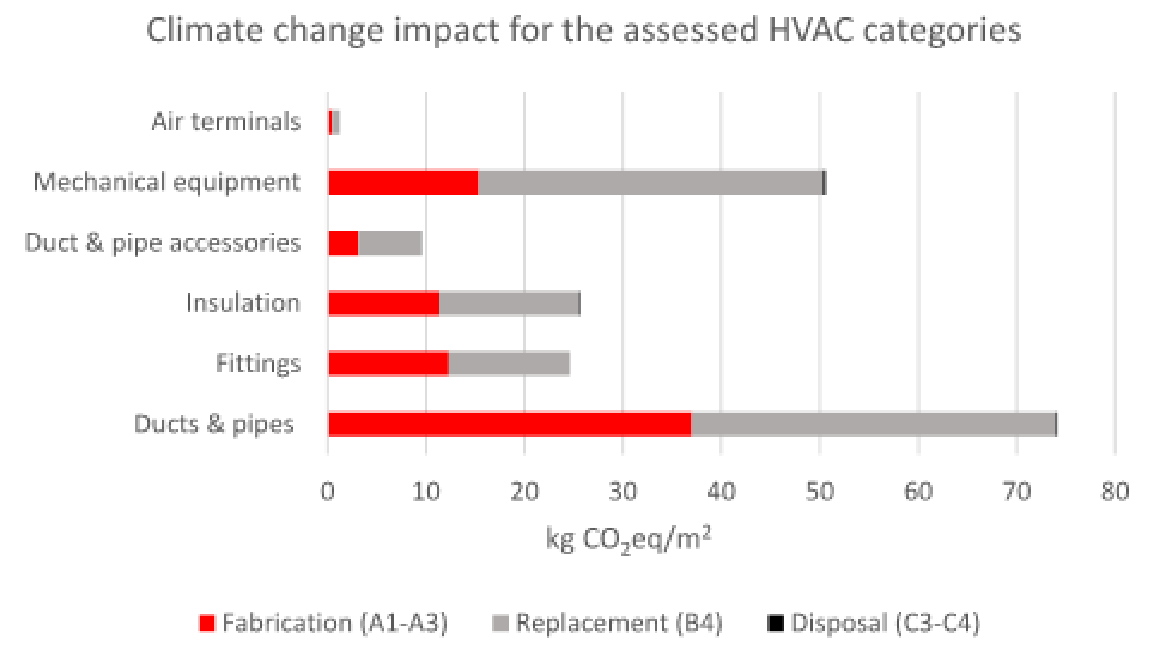

Figure 4. Climate change impact results for the assessed HVAC categories in kgCO_2eq/m².

Detailed Assessment of Embodied Carbon of HVAC Systems for a New Oce Building Based on BIM

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Carbon Reduction is complex building science undertaking

EC and EXISTING HOMES

Potential for positive impact with existing housing could equal OR exceed impact potential on new housing

Reusing empty homes could make an initial saving of 35 tonnes of carbon dioxide (CO2) per property by removing the need for the energy locked into new build materials and construction.

UK study found that the construction of a **new house generated 50 tonnes of CO2, but the renovation of an existing house emitted only 15 tonnes**

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Carbon Reduction is complex building science undertaking

Renewables and Carbon

- For multicrystalline-silicon systems (i.e. solar panels), it currently takes 4 years to achieve EPBT(energy pay back total) according to the U.S. Department of Energy. Since solar panels last for 20 to 30+ years, a single solar panel can generate **more than four or five times the energy used to produce**.
- China – where a growing portion of solar panels are made – has set regulations for manufacturers to recycle at least 98.5% of silicon tetrachloride waste. Moreover, scientists at the National Renewable Energy Laboratory, a division of the U.S. Department of Energy, are experimenting with **alternative production methods**
- **We still need to understand this better….**

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CASE STUDY

Applying BEAM

A Case Study

Carbon Emissions

BEAM Tool

A Sample Analysis

Single Detached

Cz 6

ON

Operational Carbon Emissions (30 Years)	Material Carbon Emissions (Upfront)	Carbon Use Intensity (30 Years)
101.41 tonnes CO2e	55.36 tonnes CO2e	156.77 tonnes CO2e

52% < Carbon Emissions Reduction

Scenario 1: Exisiting Home - Total Carbon Emissions (30 Year Lifespan)

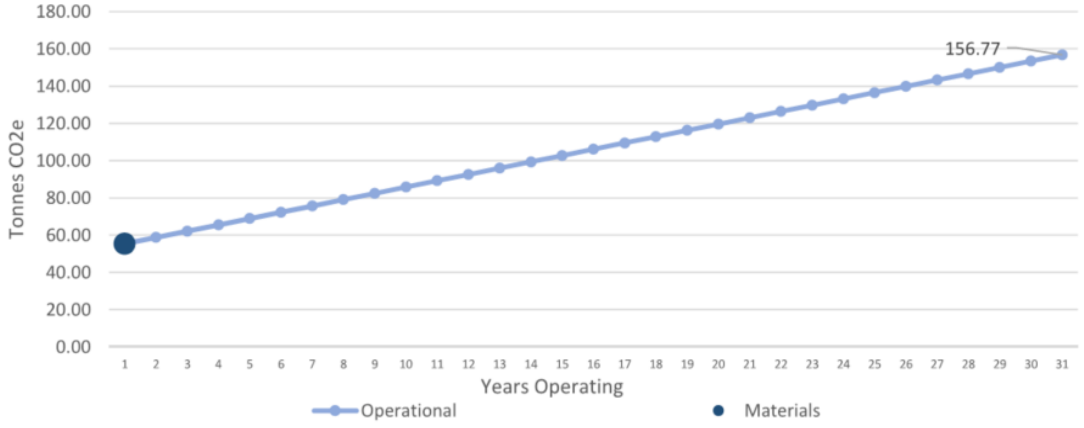
Operational Carbon Emissions (30 Years)	Material Carbon Emissions (Upfront)	Carbon Use Intensity (30 Years)
101.41 tonnes CO_2e	55.36 tonnes CO_2e	156.77 tonnes CO_2e

Material Carbon Emissions (tonnes CO_2e)*

*Carbon Intensity factor based from Natural Resources Canada & BFCA (2021) 'ACHIEVING REAL NET-ZERO EMISSION HOMES.

**Average MCE for same house typology from EMBARC report

Total Tonnes of CO_2e Emitted Over 30 Years

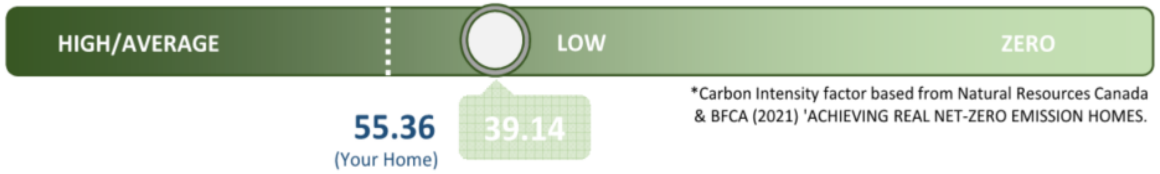


Scenario 2: Low Carbon - Total Carbon Emissions (30 Year Lifespan)

Modeled with an Air Source Heat Pump, NGX 250 XPS Insulation and 30-40% Fly Ash Concrete

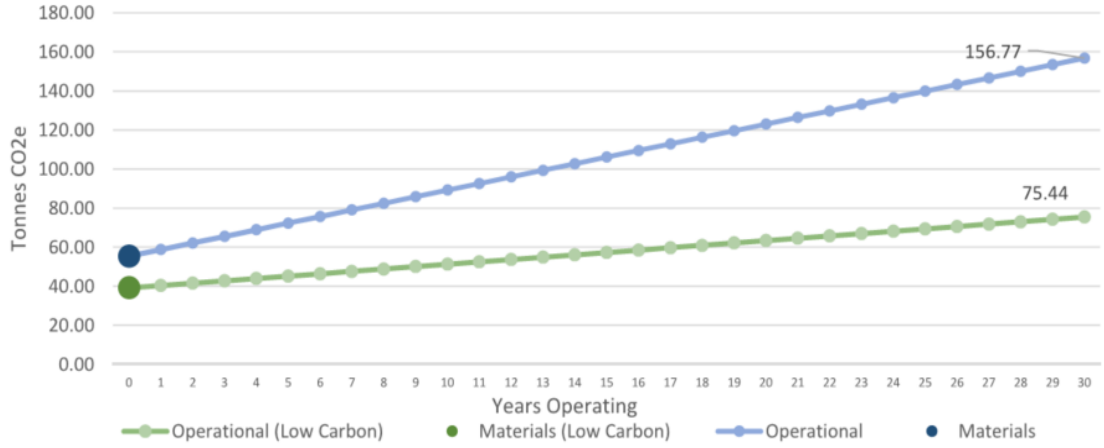
Operational Carbon Emissions (30 Years)	Material Carbon Emissions (Upfront)	Carbon Use Intensity (30 Years)
36.30 tonnes CO_2e	39.14 tonnes CO_2e	75.44 tonnes CO_2e

Material Carbon Emissions (tonnes CO_2e)*



*Carbon Intensity factor based from Natural Resources Canada & BFCA (2021) 'ACHIEVING REAL NET-ZERO EMISSION HOMES.

Total Tonnes of CO_2e Emitted Over 30 Years



Embodied Carbon : Top 3

BEAM TOOL

A Sample Analy

Single Detachec

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ON

Carbon Emissions Reduction

1	Average Insulation	Carbon Smart Insulation	-15.1 Tonnes CO2e
2	Concrete - Average Mix	Concrete - 30 - 40% Fly Ash	-2.9 Tonnes CO2e
3	Average Fiber Cement Siding	Low Carbon Fiber Cement Siding	-1.9 Tonnes CO2e

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Operational Carbon Reduction Opportunities

BEAM TOOL

A Sample Analys

Single Detached

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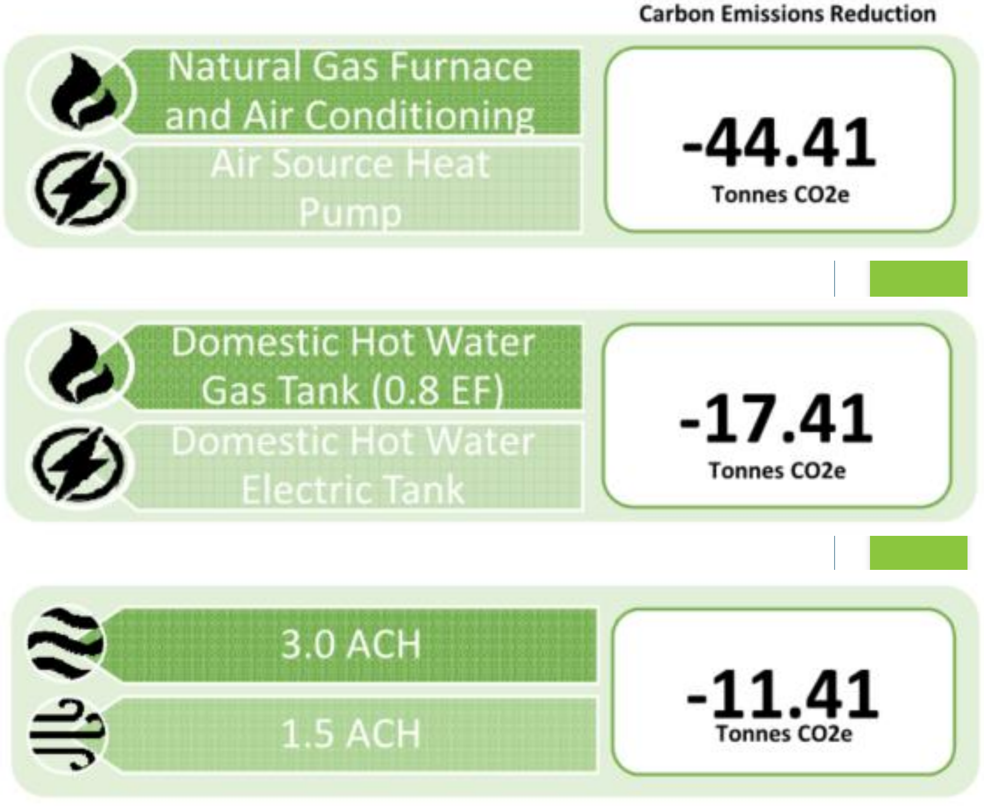
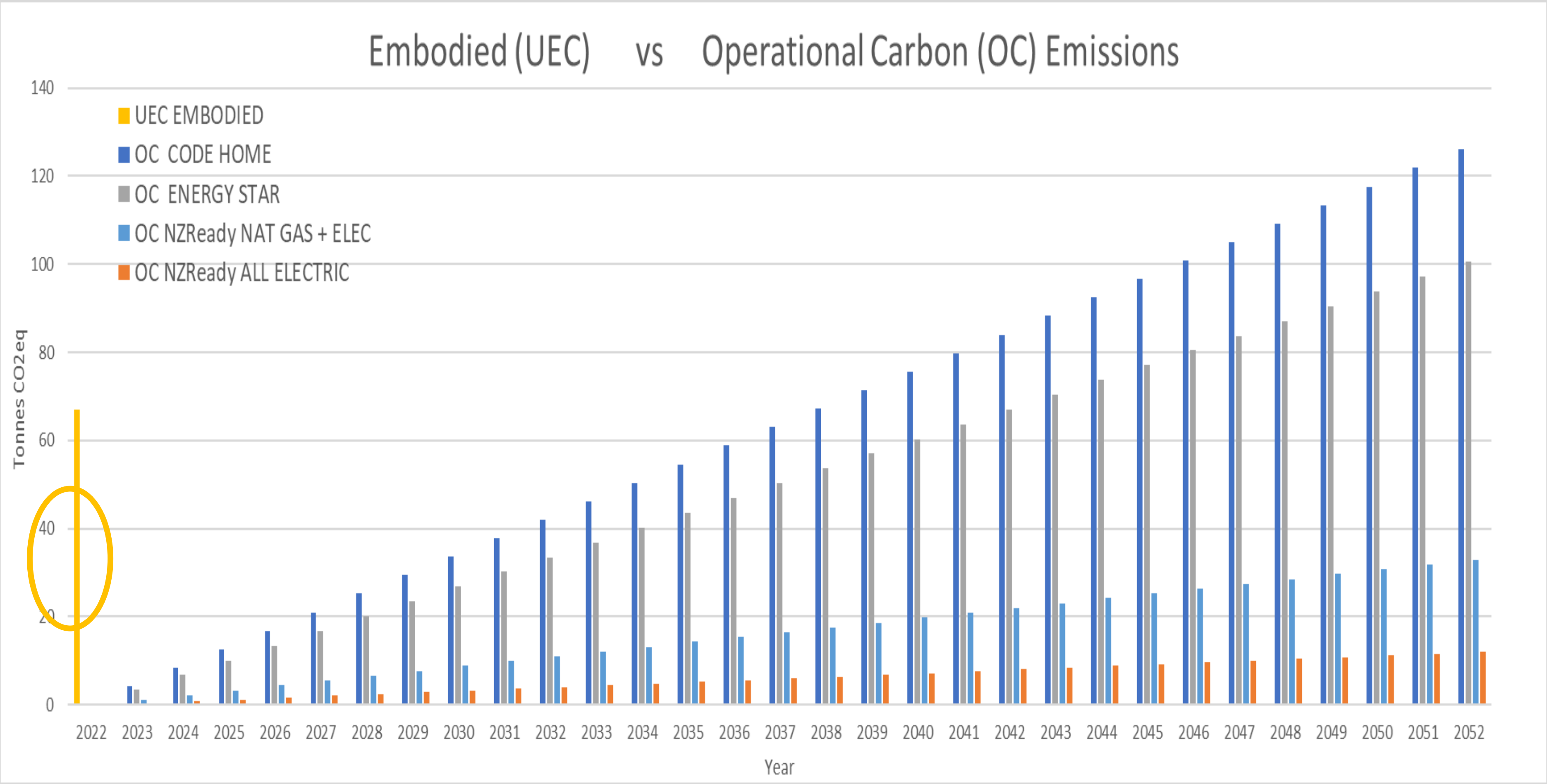
1

2

3



30 year impact of a 2300sqft, Single Detached Home, Zone 6 ON: Ontario Grid



UEC: 70t

2018 CODE: 127t

ESNH: 100t

NZR NG+Elec: 32t

NZR ALL Elec: 12t

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LOW OR ZERO CARBON PROGRAMS AND BENCHMARKS

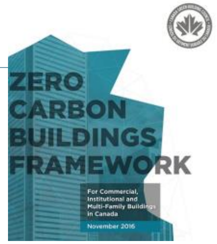
- LEED v4.1 (website)
- CaGBC/USGBC – Zero Carbon Building Standard v2
  - https://www.cagbc.org/zerocarbon
  - Not applicable to houses, small buildings < 3 storeys
- International Living Future Institute (ILFI) Zero Carbon Standard v1
  - https://www2.living-future.org/zero-carbon-standard
- Operational carbon-related codes (energy efficiency):
  - In BC: Energy Step Code (2017) – website
  - Coming soon: Tiered National Energy Code for Buildings (NECB)

LEED™ Building Life - Cycle Impact Reduction

- Leadership in Energy and Environmental Design (LEED) v4.1 – Website
- Administered by the Canada Green Building Council (CaGBC)
- Most widely used green building rating system in the world

LEED CRITERIA AND CREDITS

- Whole-building LCA: Up to 4 points (link)
  - 4 points: minimum 20% reduction from "baseline" in GWP and at least 10% reduction in at least two other environmental categories
- Building product disclosure and optimization – environmental product declarations: 2 points (link)
  - Select at least 20 products from manufacturers that have EPDs for their products



Zero Carbon Building Standard, v2

		ZCB-Design v2 One-time certification for new buildings and major renovations	ZCB-Performance v2 Annual certification for existing buildings
Carbon	Zero carbon balance	Model zero carbon balance	Achieve zero carbon balance
	Embodied carbon	Report embodied carbon	Offset embodied carbon
	Refrigerants	Report total quantity	Offset any leaks
	RECs and carbon offsets	Provide quote	Provide proof of purchase
	Onsite combustion	Provide transition plan	Update plan every 5 years
Energy	Energy efficiency	Meet one of three approaches	Report EUI
	Peak demand	Report seasonal peaks	Report seasonal peaks
	Airtightness	Report and justify modelled value	Conduct testing if ZCB-Design v2 certified
Impact and Innovation		Apply two strategies	No requirement

Figure 2 – Summary of Key Zero Carbon Building Requirements

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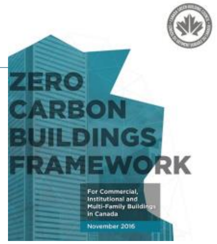

Zero Carbon Building Standard, v2

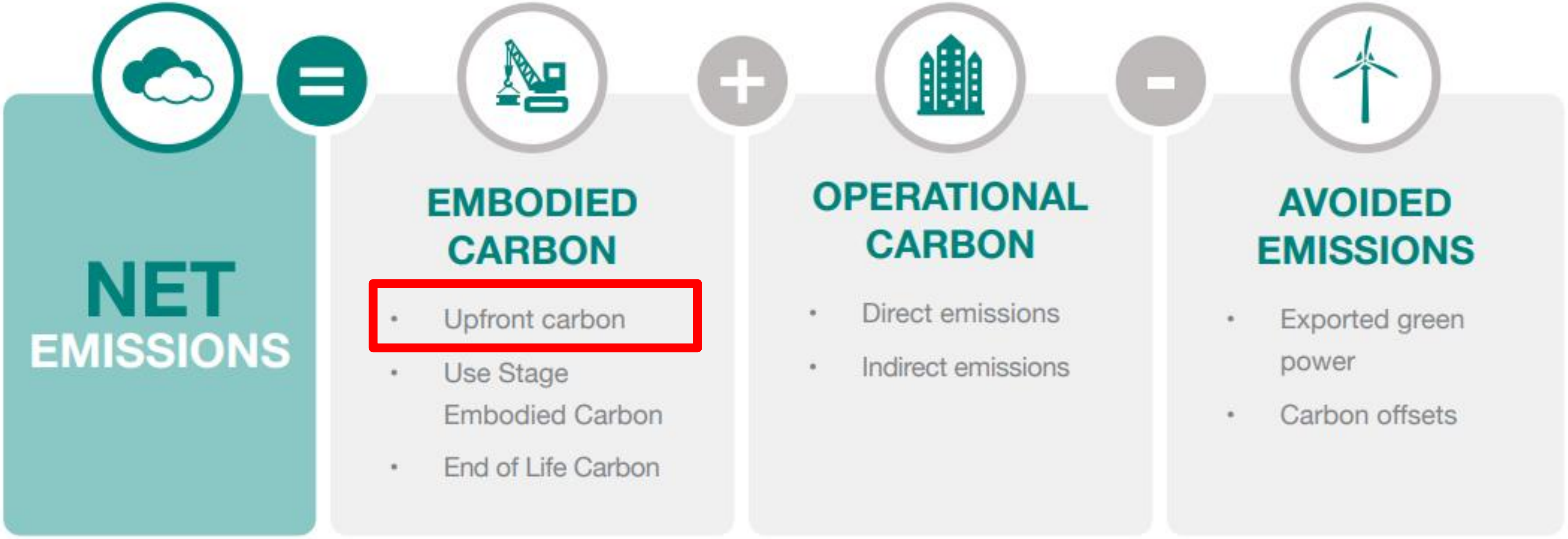

Figure 3 – Calculating a Zero Carbon Balance

TELL US…

What Volunteer Programs are you familiar with?

1. Living Building Challenge
2. LEED v4.1
3. CaGBC/USGBC – Zero Carbon Building Standard v2
4. Other: ?

Next Steps

Class exercise to discuss barriers to:

1. *Changing designs*
2. *Changing suppliers*
3. *Changing processes*
4. *Changing Fuels*

Small groups come up with ideas and timelines for moving past the barriers

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Barriers to Overcome

Upgrade	Design	Suppliers / Trades	Cost	Ideas to Overcome
Concrete				
Cladding				
Insulation				
Windows				
HVAC & Solar				
Other				

Carbon Smart Attributes Summary

Electrify

- Electricity has the lowest operating carbon of all fuels
- Consider investing in electric based appliances and mechanicals

Reduce Energy Consumption

- Reduce operating energy requirements
- Consider long term effects and using renewable sources

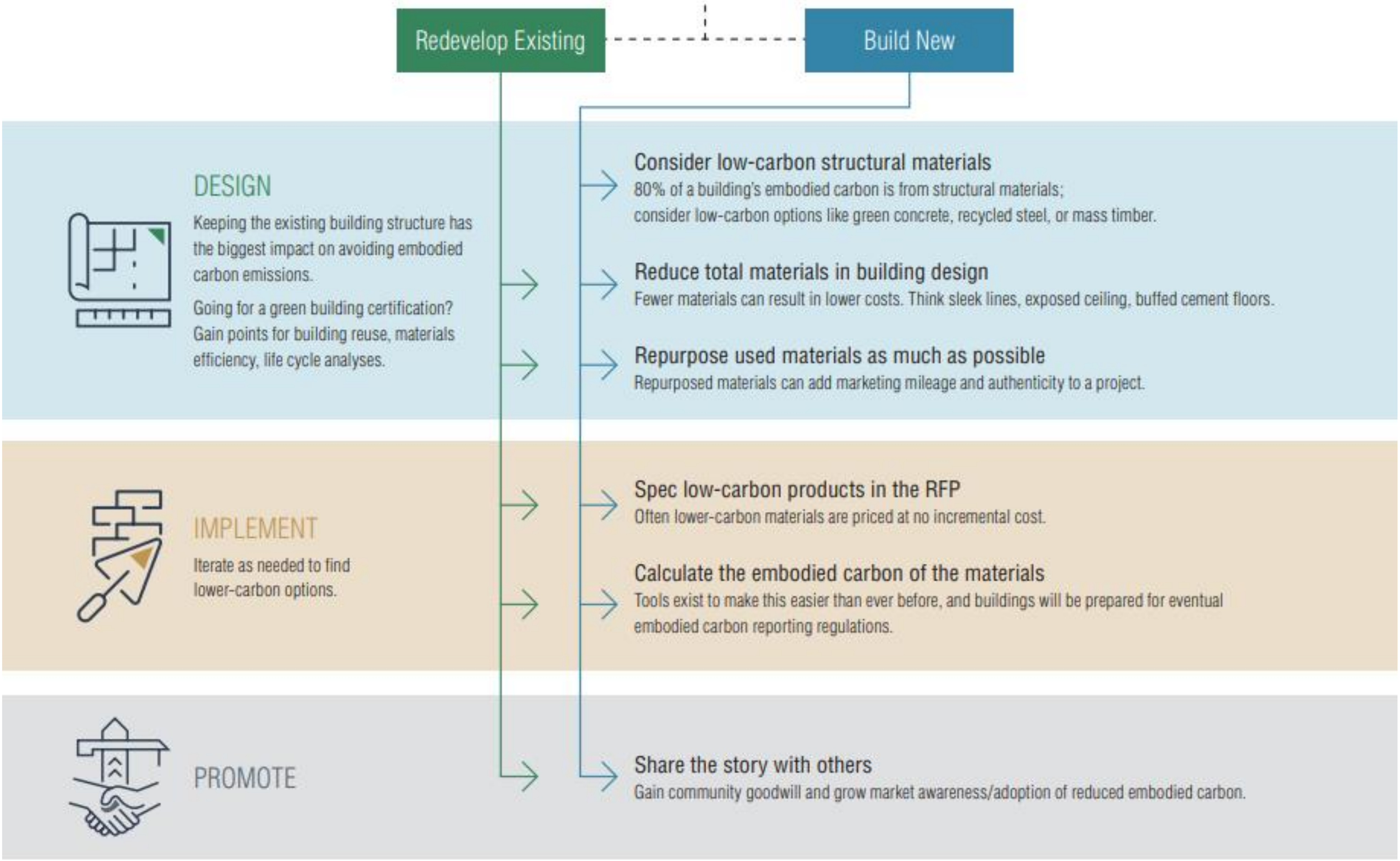
Measure

- Reduce how much waste is created during construction
- Design for longevity, repair, and maintenance

Next Steps

1. Select a carbon analysis tool
2. Perform an operational carbon analysis of current builder packages
3. Contact suppliers and request EPDs
4. Set 1, 3 & 7 year goals to work towards Net Zero carbon emissions

Pathway for Developers to Reduce Embodied Carbon:



4. Set 1, 3 & 7 year goals to work towards Net Zero carbon emissions

Upgrade	1 year	3 years	7 years	Why?	Actions to Take
Concrete					
Cladding					
Insulation					
Windows					
HVAC & Solar					
Other					

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SOFTWOOD
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These are just place holders for whatever logo is to be used.

Thank you and any final questions

NET ZERO CARBON
BUILDING PROFESSIONAL

Thank You for participating in this workshop along the path of achieving the
EEBA NET ZERO Carbon Building Professional designation

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