Integrative Carbon Building

embodied carbon, net positive carbon, and the new carbon architecture

AIA Learning Objectives:

1. Participants will become familiar with the data demonstrating the positive impact that choosing low-embodied-carbon building materials and methods has on global carbon levels.

2. They will understand where in the building the biggest impacts can be made towards low-carbon or carbon-positive buildings.

3. Participants will develop a practical toolkit of low-carbon and carbon-positive materials and assembly options to use on their next project.

4. They will be able to integrate and implement embodied-carbon awareness into their practice, helping to positively alter the course of our field and its role in global climate resilience.

Carbon in the atmosphere is a problem

Imagine this bathtub…
We're filling it much faster than it's being emptied.

Production of building materials is a significant contributor…

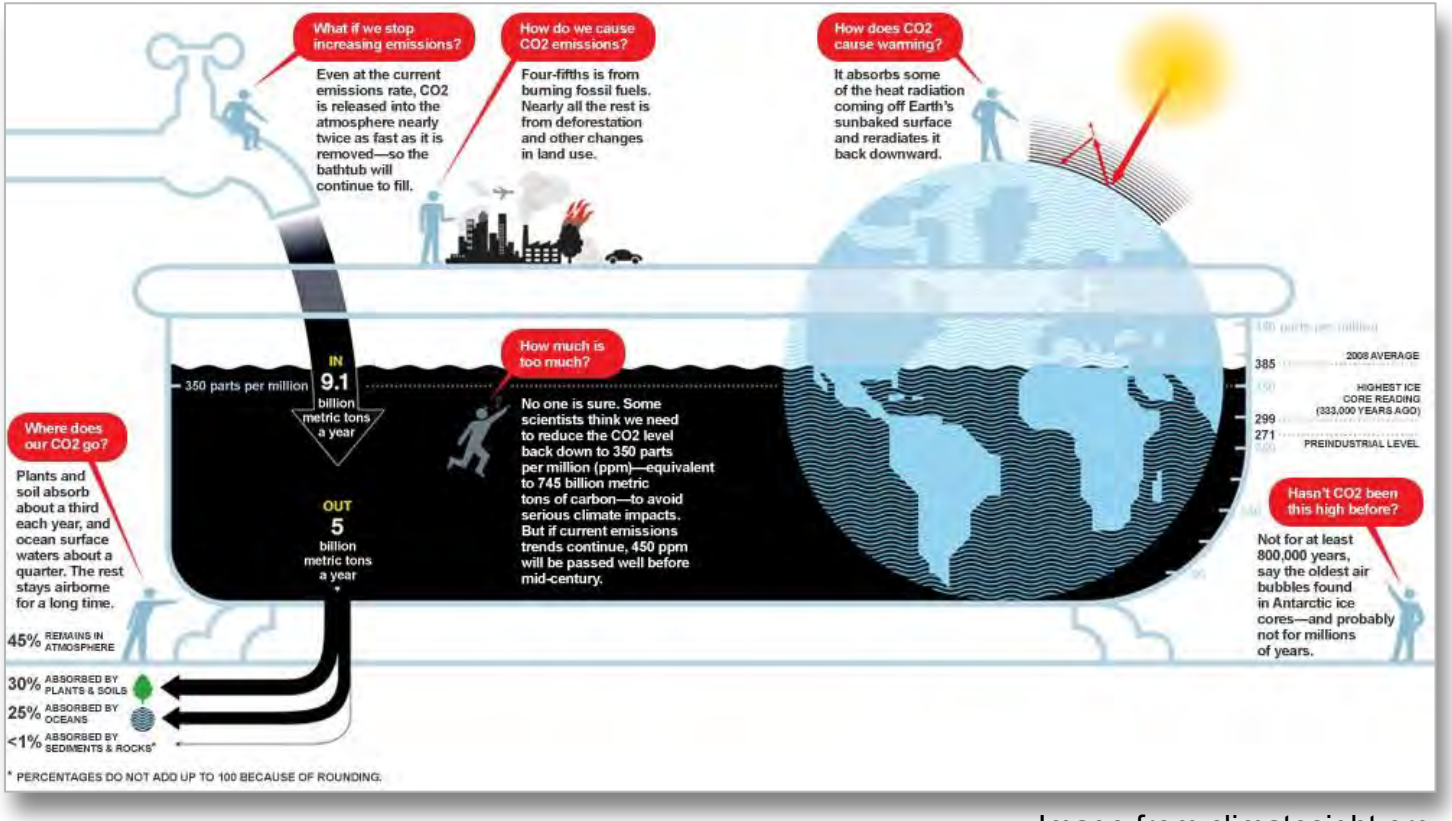
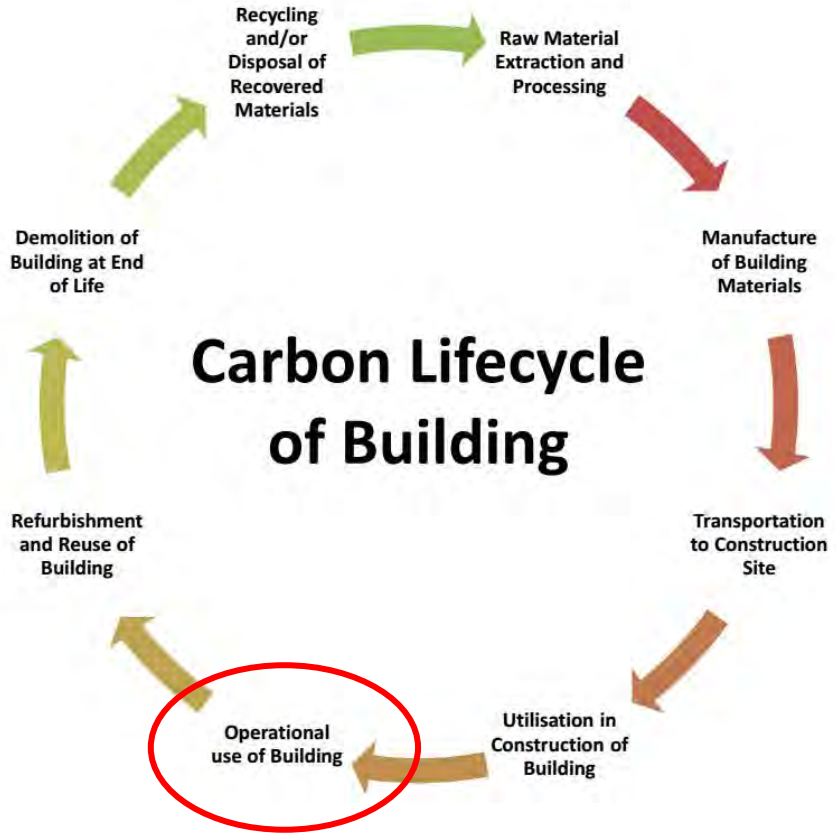
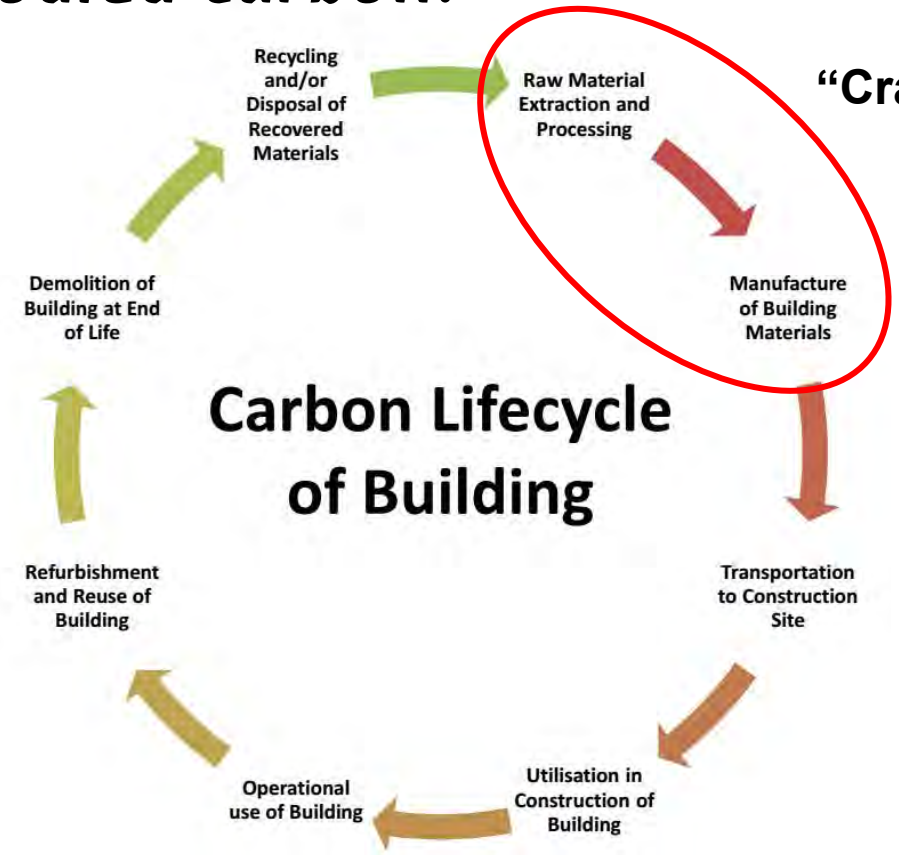


Image from climatesight.org

Whole Life Carbon of Buildings



What is *embodied carbon*?

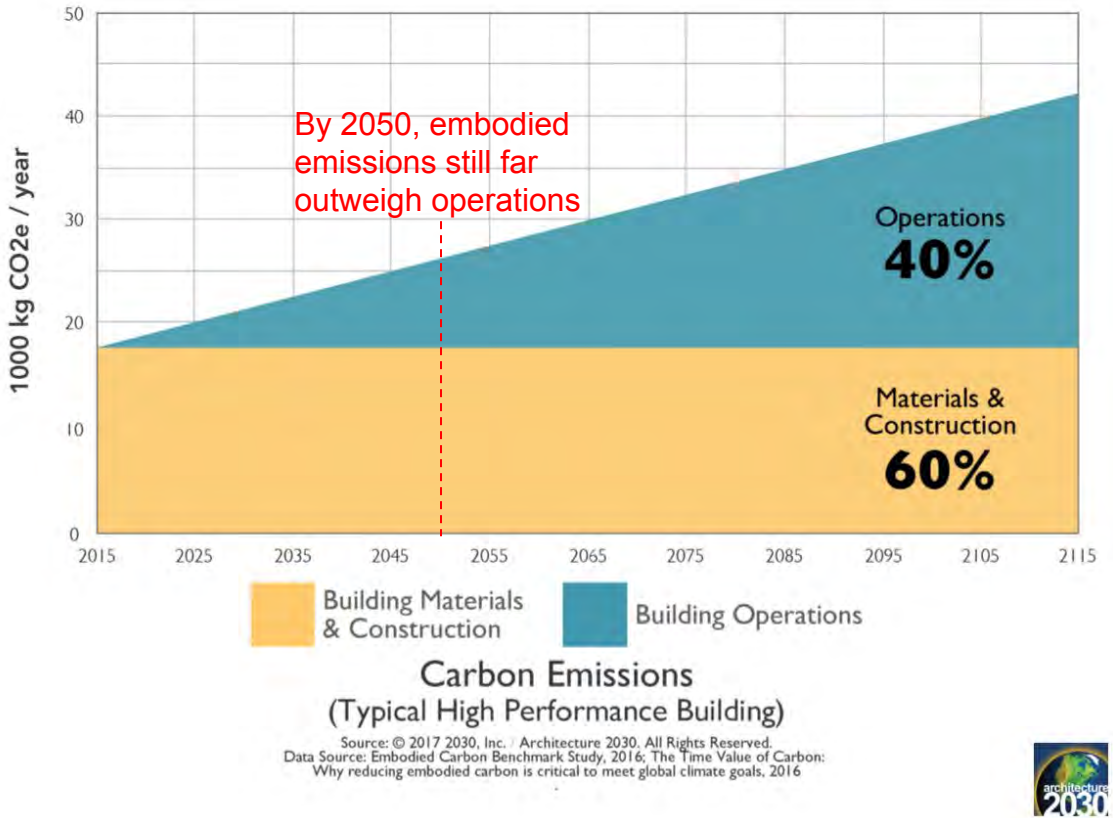


“Cradle to gate”

Why does embodied carbon matter?

Embodied emissions are large, and immediate.

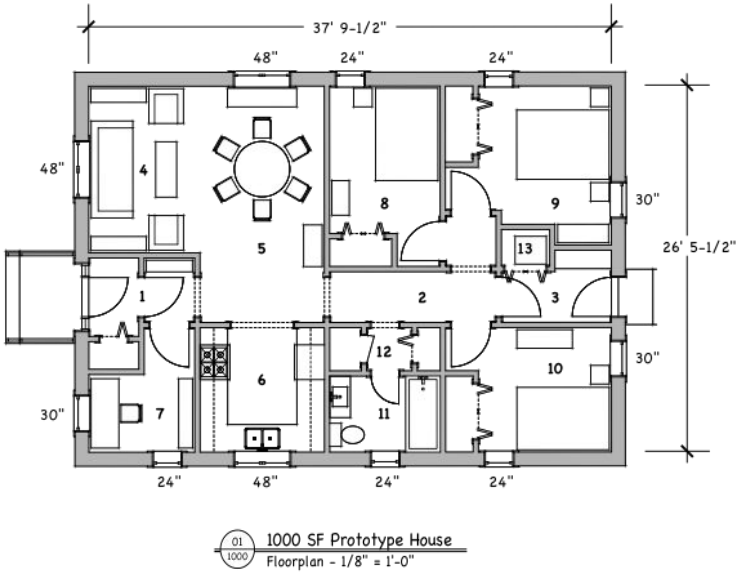
Although operational emissions may eventually outweigh embodied emissions, the initial value of embodied emissions will be the most significant impact until well after 2050.



Measuring embodied carbon

Modeling a 1,000 square foot home with basement foundation built to current Ontario Building Code standards...

Data comes from Environmental Product Declarations where available, and from Inventory of Carbon and Energy V.2 when no EPD available.



EPD

CERTIFIED

EPD Transparency Summary

COMPANY NAME: **American Wood Council**
Canadian Wood Council

PRODUCT TYPE: **Wood Products**

PRODUCT NAME: North American Cellulosic Fiberboard

PRODUCT DEFINITION: Cellulosic fiberboard is manufactured by thermo-mechanically reducing wood chips to fibers, combining the fibers with water and additives, forming the slurry into a mat, drying it with rollers to remove water, and trimming to specified dimensions.

PRODUCT CATEGORY RULE (PCR): **North American Structural and Architectural Wood Products**, PFInnovations Version 2 (UN CPC 31, NAICS 321), 18 June, 2015

CERTIFICATION PERIOD

DECLARATION NUMBER

LIFECYCLE IMPACT CATEGORIES

ATMOSPHERE			WATER		EARTH	
Global Warming Potential	**Ozone Depletion Potential**	**Photochemical Ozone Creation Potential**	**Acidification Potential**	**Eutrophication Potential**	**Depletion of Abiotic Resources (Elements)**	**Depletion of Abiotic Resources (Fossil Fuels)**
TRACI	285.06 kg CO2 eq.	0.00 kg CFC-11 eq.	20.64 kg O3 eq.	2.82 kg SO2 eq.	0.07 kg N eq.	0.32 kg	5858.43 MJ
LCI						

UL

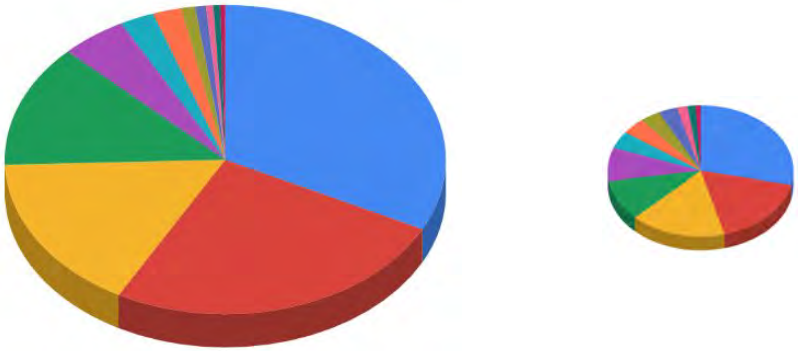
Environment

Adding it up...

High Embodied Carbon

Asphalt shingles	1646
Trusses & decking	350
HDSF roof ins.R-38	21335
Drywall ceiling	329
Carpet & tile flooring	1384
Drywall interior	245
Floor framing & decking	674
Vinyl windows	522
Brick cladding	3177
Frame walls w/HDSF R-26	10825
HDSF basement ins.	16846
Concrete basement & slab	8463

Total CO_2e 65,796



Low Embodied Carbon

825	Steel roofing
350	Trusses & decking
72	Cellulose roof ins. R-38
339	ReWall ceiling
151	Wood & clay floor
287	ReWall interior
674	Floor framing & decking
272	Al. clad wood windows
116	Wood siding
1364	Frame walls w/cellulose
1434	Hempcrete & perlite
2334	Watershed blocks & hempcrete & earth slab

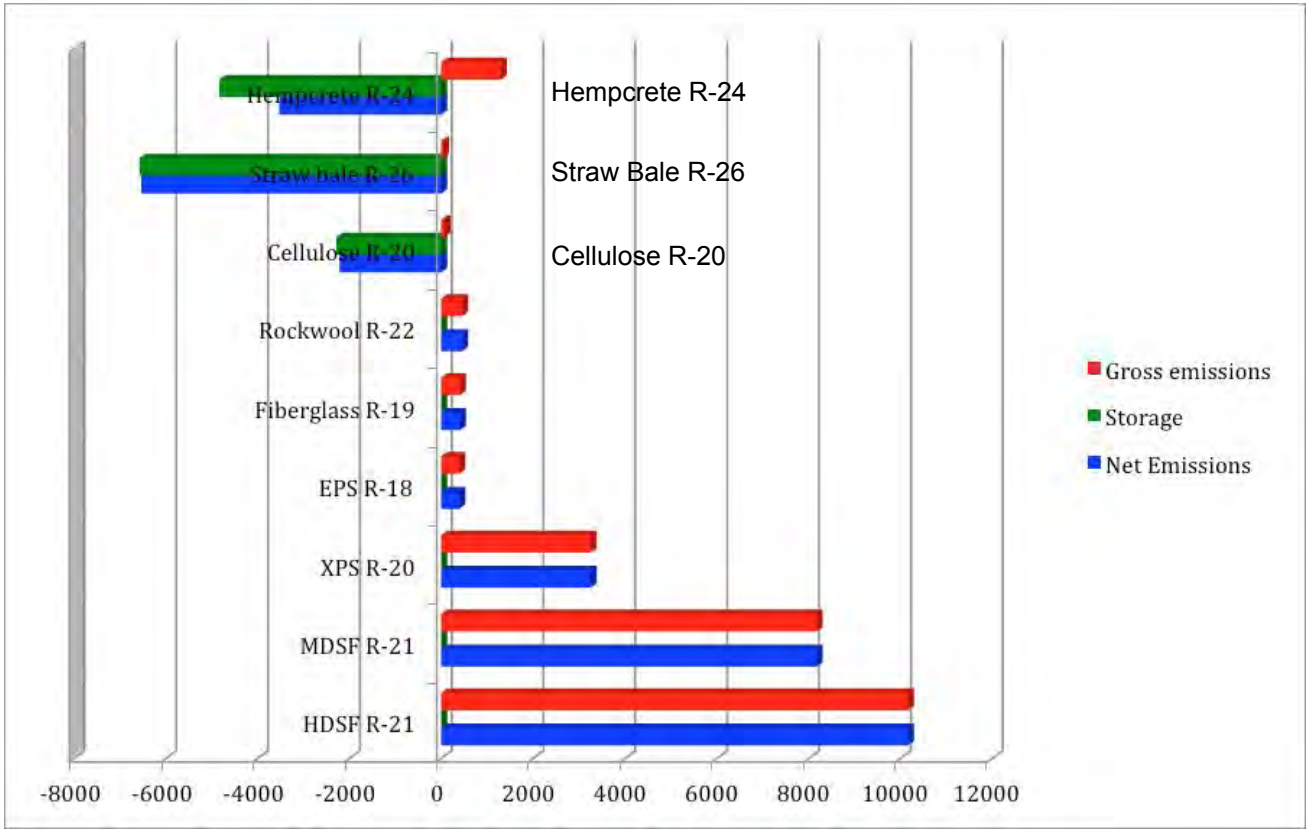
8,218 Total CO_2e

Carbon storage: *Our secret weapon*

Plant-based materials not only have low embodied carbon...

They also store a significant amount of carbon in the material for the life of the building...

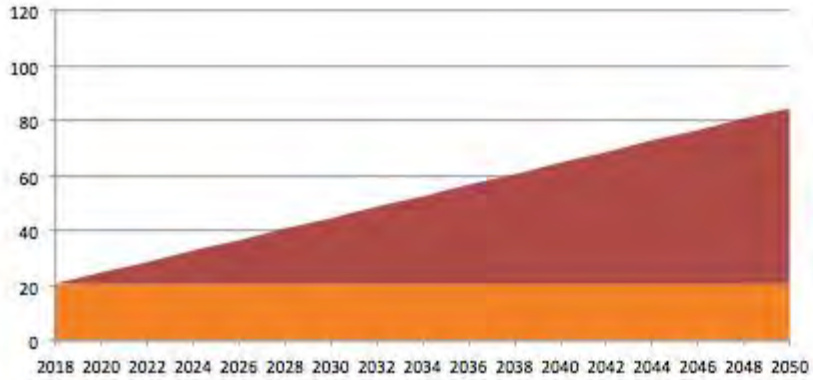
Carbon positive!



Total Carbon Impact Modeling Scenarios

*Not modeling for *any* wood storage

	Scen. 1 *Baseline*	**Scen. 2** *Net Zero High Foam*	**Scen. 3** *Natural Building w/ Gas*	**Scen. 4** *Baseline ASHP*	**Scen. 5** *High Foam w/ ASHP*	**Scen. 6** *Best Case*	**Scen. 7** *Low Carbon Code-Comp.*
Perform Level	Typical Code - 3/3/10/20/24/38	High Perform. - 1/5/20/30/40/60	High Perform. - 1/5/20/30/40/60	Typical Code - 3/3/10/20/24/38	High Perform. - 1/5/20/30/40/60	High Perform. - 1/5/20/30/40/60	High Perform. - 1/5/20/30/40/60
Material Type	Standard - 20.8 tons CO2e	High Embodied Carbon - 90.3 tons	Low Embodied Carbon - -10.5 tons	Standard - 20.8 tonnes CO2e	High Embodied Carbon - 90.3 tons	Low Embodied Carbon - -10.5 tons	Low Emb. Carbon - Code-Comp. -2.2 tons
Heating Fuel / System	Natural Gas, 95% AFUE Condensing Boiler	Natural Gas, 95% AFUE Condensing Boiler	Natural Gas, 95% AFUE Condensing Boiler	Air-Source Mini-Split Heat Pump 2.5 COP	Air-Source Mini-Split Heat Pump 2.5 COP	Air-Source Mini-Split Heat Pump 2.5 COP	Air-Source Mini-Split Heat Pump 2.5 COP



Ontario typical code build

R-10/20/24/38

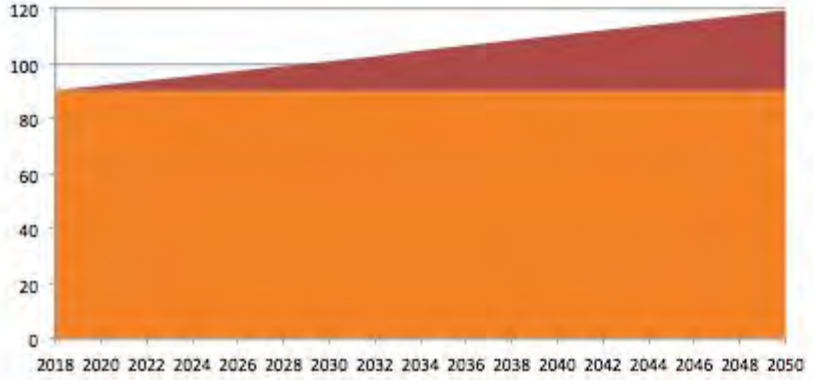
EC = 20.8 tons CO2e

Nat. gas heat = 2.0 tons/yr

84.8 tons @ 2050 total emissions

Scenario 1

Baseline



Ontario high performance build

R-20/30/40/60

EC = 90.3 tons CO2e

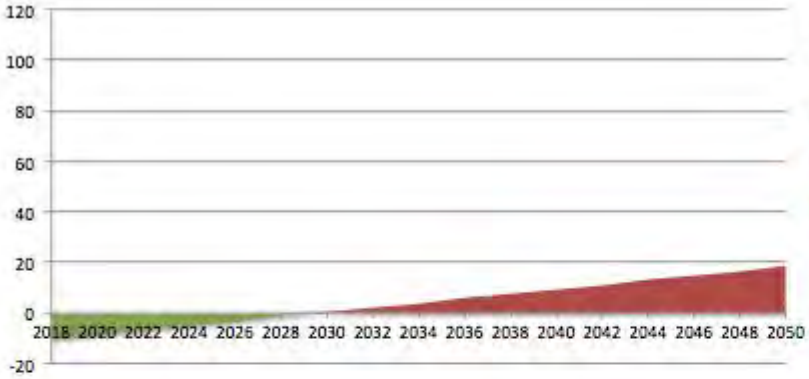
Nat. gas heat = 0.9 tons/yr

118.8 tons @ 2050 total emissions

Scenario 2

Net Zero

High Foam



Ontario high perf. natural build

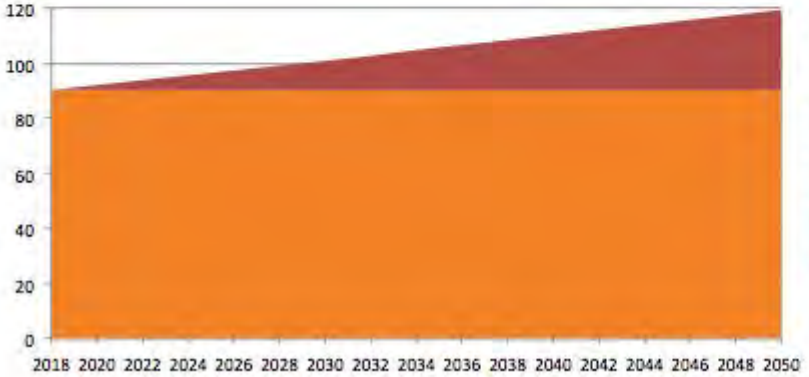
R-20/30/40/60

EC = -10.5 tons CO2e

Nat. gas heat = 0.9 tons/yr

18.3 tons @ 2050

Scenario 3
Natural Building w/ Nat. Gas



Ontario high performance build

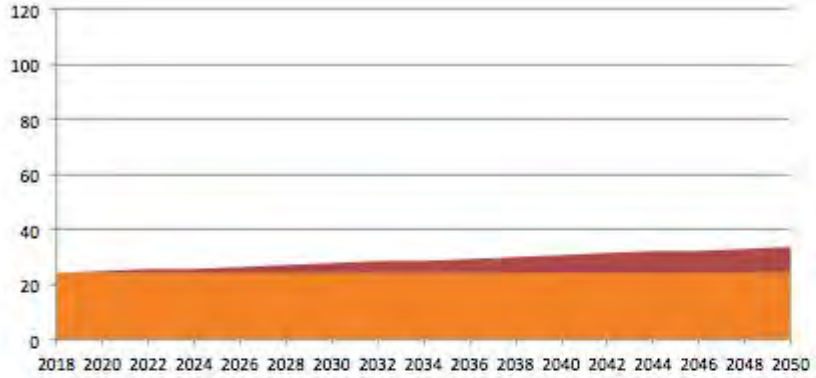
R-20/30/40/60

EC = 90.3 tons CO2e

Nat. gas heat = 0.9 tons/yr

118.8 tons @ 2050 total emissions

Scenario 2
Net Zero High Foam



Ontario typical code build

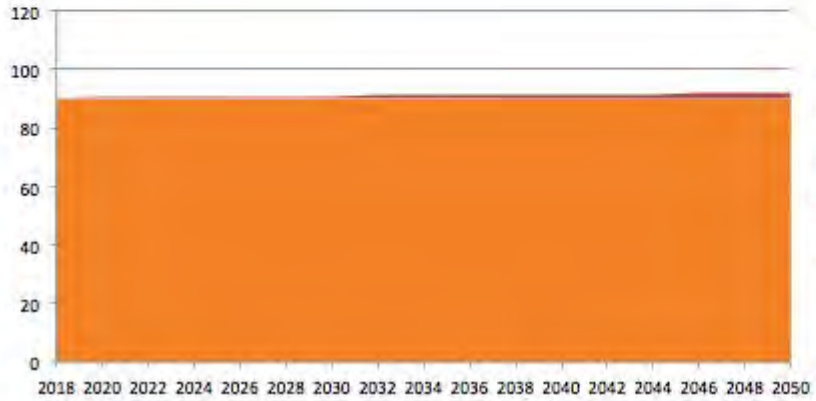
R-10/20/24/38

EC = 20.8 tons CO2e

Heat pump (COP2.5)= 0.3 tons/yr

33.7 tons @ 2050 total emissions

Scenario 4
Baseline with Heat Pump



Ontario high performance build

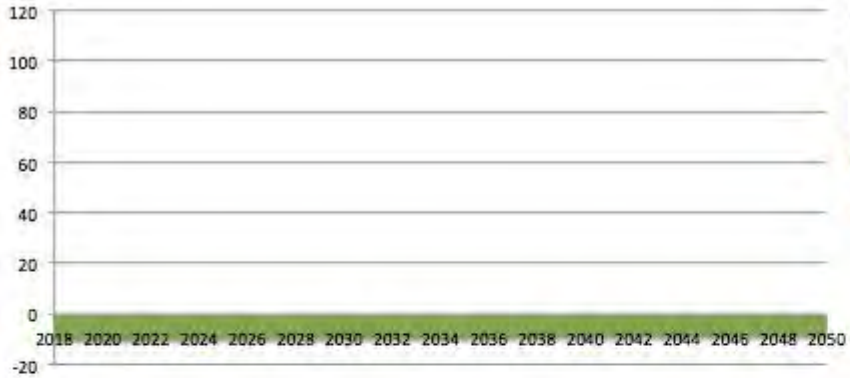
R-20/30/40/60

EC = 90.3 tons CO2e

Heat pump = 0.1 tons/yr

91.9 tons @ 2050 total emissions

Scenario 5
High Foam with Heat Pump



Ontario high perf. natural build

R-20/30/40/60

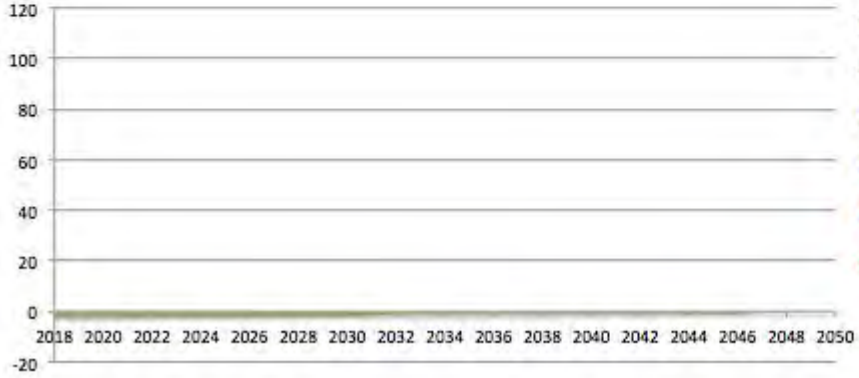
EC = -10.5 tons CO2e

Heat pump = 0.1 tons/yr

-8.9 tons @ 2050

Scenario 6

Best Case



Ontario low carbon conventional materials

R-20/30/40/60

EC = -2.2 tons CO2e

Heat pump = 0.1 tons/yr

-0.6 tons @ 2050

Scenario 7

Low Emb. Carbon Code-Compliant

What does this mean?

U.S. & Canadian single family residential building in 2016:

179,600,000 m^2

High carbon building: **127.2 million tons of CO_2 emissions**

Carbon storing building: **0 net CO_2 emissions**

7.8 million tons of CO_2 stored*

135 million tons of CO_2 averted

That's the equivalent of taking 38 coal-fired power plants offline!**

**no carbon storage attributed to wood products*
***500MW plant with 3.5 million tons of CO2 emissions*

Twelve Building Materials For a Changing Climate

- Insulation
  - Wood fiberboard sheathing
  - Cellulose cavity fill
  - Ag fiber cavity fill, panel
  - Mycelium panel
- Finishes
  - Clay/lime paint
  - Earthen and cork floors
  - Plaster air barrier/enclosure skin
- Structure
  - 100% recycled structural wall panels
  - Advanced concrete technologies
  - Multi-story mass-timber construction

Wood Fiberboard Sheathing

- Direct replacement for foam or mineral board in above-grade applications
- Range of thicknesses; T&G edging
- Vapor permeable, moisture durable
- R-4/inch using high recycled content
- Low toxicity, non-chemical
- Examples: Gutex, MSL SonoClimat, Steico

Cellulose Insulation

- Existing supply chain, trade support, market presence, testing data, etc.
- Loose fill, dense-pack, open-cavity
- All-borate formulations available
- Fire and moisture durable
- R-3.2 - 3.7/in.
- Examples: Igloo, GreenFiber All-Borate

Credit: Bill Hulstrunk

Straw Bale Construction

- Custom R-40 - 50 hybrid wall systems for high-performance cold-climates
- Air-tight, vapor permeable, durable interior plaster finish
- Short-cycle crop = max. C storage
- Straw installs into dried-in enclosure
- Standard framing, exterior detailing for easy integration to conventional construction

Straw Bale & Carbon Storing Panels

Hempcrete Construction

- Cast or spray insulation - R-3/in
- Flexible install, cures hard
- Ultra-low CO2e / C-negative
- Moisture-durable, vapor open
- Fire retardant, no chemicals
- Floors, walls, roofs, foundations

Mycelium Insulation Board

- Mushroom insulation board panel, uses waste biofibers as medium
- ~ R-3/in, moisture durable
- Good compressive strength
- Naturally fire-resistant
- Standard panel sizes, 3 thicknesses
- Example: Ecovative Design

Credit: Ecovative Design, Inc.

Natural Paints, Washes, Stains

- Non-petroleum, low-impact finishes
- True no-VOC bases, pigments
- No TiO2 = lower carbon
- Wide range of color, texture
- Most are easy to make for DIYers
- Examples: BioShield, Kreidezeit, Auro

Credit: www.bioshieldpaint.com

Earthen Floors

- Low carbon replacement for Portland-based concrete slab, or thin layer over subfloor
- Wide range of color, texture
- Examples: Claylin

Cork Floors

- Regenerative bio-based product: harvested from live trees; R-3/inch
- Click, floating, glue-down; tile or plank
- Wide range of color, texture
- Examples: US Floors, Nova

Credit: www.calibamboo.com

Clay and/or Lime Plasters

- Air-tight - achieve < 0.6 ACH50
- Hygric buffer, manages humidity
- Liquid-applied flexible application
- Ultra durable - 1+” solid masonry
- Inspectable and repairable - no hidden membranes , simple repairs
- Fireproof, no VOCs
- Examples: American Clay, LimeStrong

Wood Structures

- Dramatic carbon reduction compared to steel, concrete
- Old post-and-beam, new CLT
- 18-story commercial construction; taller structures in design
- Two-hour fire ratings
- Domestic manufacturing
- Examples: SmartLam, Structurlam

Credit: blog.weyerhaeuser.com

Advanced Concrete Solutions

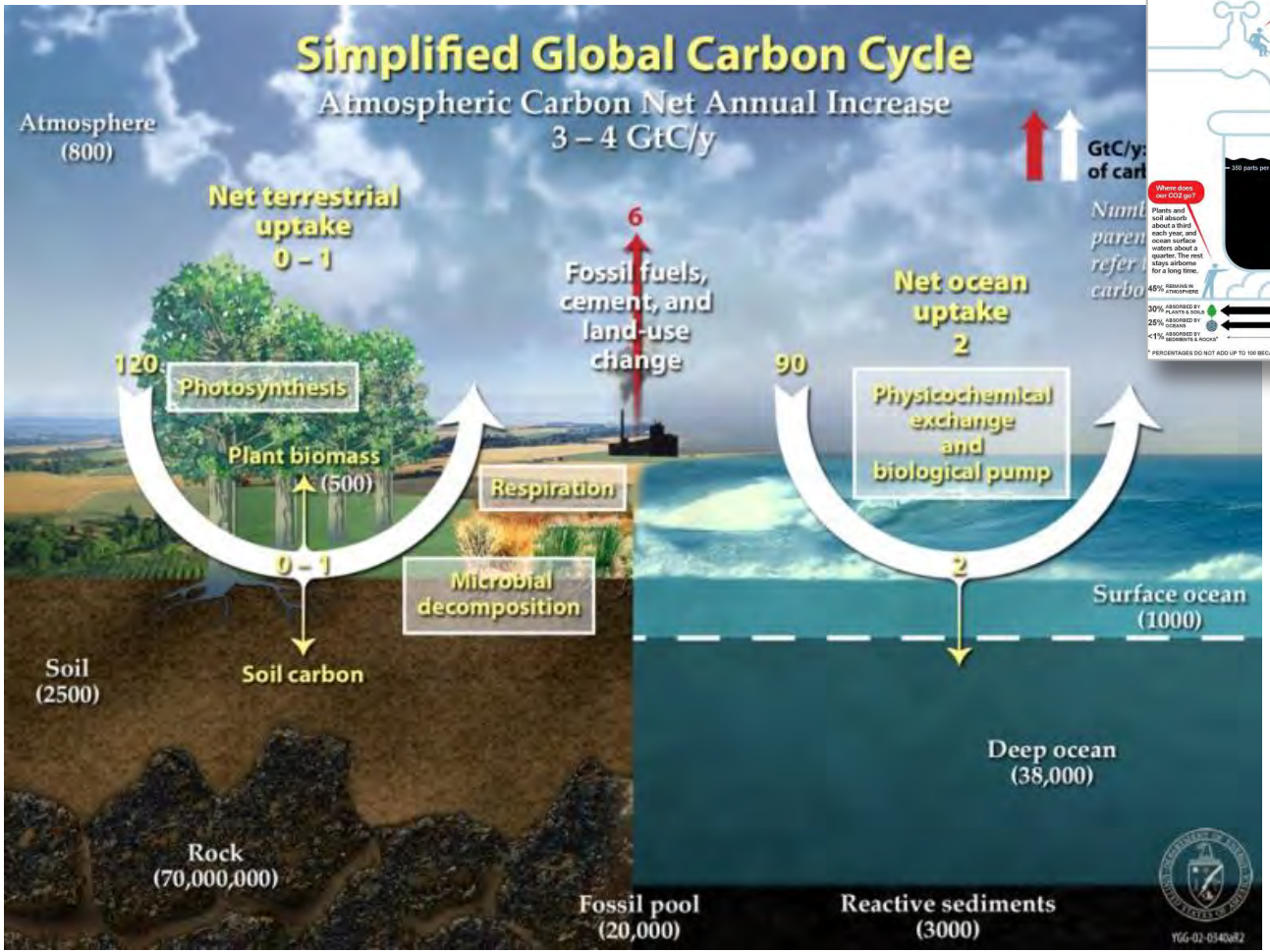
- Dramatic C reduction compared to standard Portland concrete (SPC)
- Most approaches can be applied in current manufacturing
- Bio-cements use microorganisms to harden concrete
- Carbon capturing cements use CO2 from energy production
- Pozzolonic lime, geo-polymerized concretes, modified SPC
- Examples: CarbiCrete, CarbonCure, bioMASON, Blue Planet

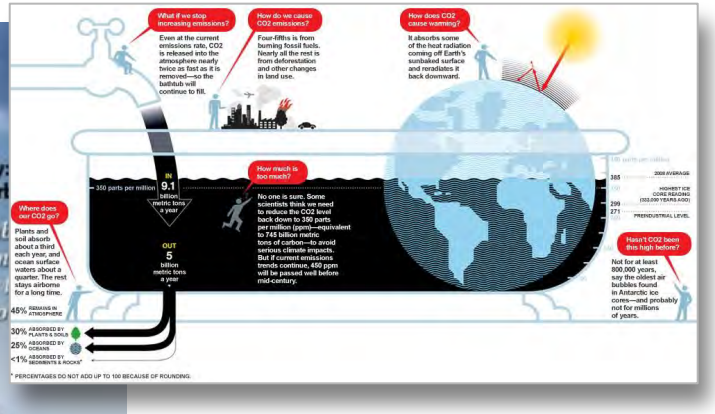
Credit: www.blueplanet-ltd.com

Recycled Structural Panels

- 100% recycled/recyclable panel from beverage containers (paper)
- Fully structural, VOC-free
- Air/vapor/water barrier
- Fire and mold resistant
- R-2/in, acoustic insulator
- Example: ReWALL

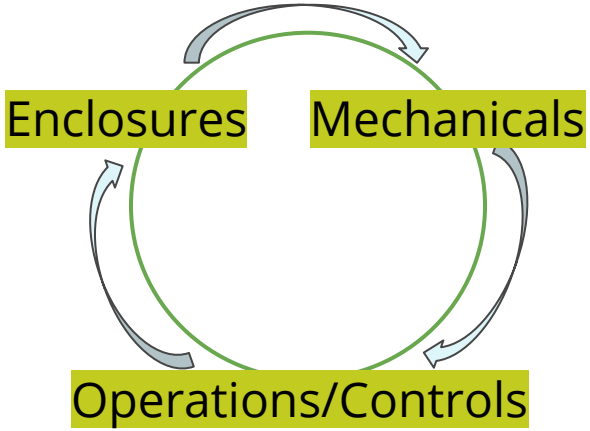
Credit: www.rewallmaterials.com


Simplified Global Carbon Cycle
Atmospheric Carbon Net Annual Increase
3 – 4 GtC/y
Atmosphere
(800)
Net terrestrial
uptake
0 – 1
6
Fossil fuels,
cement, and
land-use
change
Net ocean
uptake
2
120
Photosynthesis
90
Physicochemical
exchange
and
biological pump
Plant biomass
(500)
Respiration
0 – 1
Microbial
decomposition
2
Surface ocean
(1000)
Soil
(2500)
Soil carbon
Deep ocean
(38,000)
Rock
(70,000,000)
Fossil pool
(20,000)
Reactive sediments
(3000)

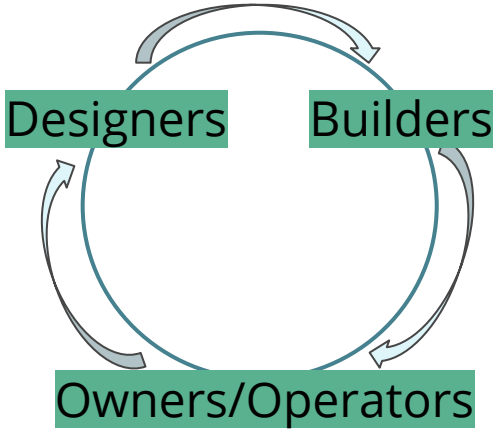

What if we stop increasing emissions?
Even at the current emissions rate, CO2 is released into the atmosphere nearly twice as fast as it is removed—so the bathtub will continue to fill.
How do we cause CO2 emissions?
Four-fifths is from burning fossil fuels. Nearly all the rest is from deforestation and other changes in land use.
How does CO2 cause warming?
It absorbs some of the heat radiation coming off Earth's sunbaked surface and reradiates it back downward.
How much is too much?
No one is sure. Some scientists think we need to reduce the CO2 level back down to 350 parts per million (ppm)—equivalent to 745 billion metric tons of carbon—to avoid serious climate impacts. But if current emissions trends continue, 400 ppm will be passed well before mid-century.
Where does our CO2 go?
Plants and soil absorb about a third each year, and ocean surface waters about a quarter. The rest stays airborne for a long time.
Has it CO2 been this high before?
Not for at least 800,000 years, say the oldest air bubbles found in Antarctic ice cores—and probably not for millions of years.
* PERCENTAGES DO NOT ADD UP TO 100 BECAUSE OF ROUNDING.

Systems Thinking: Buildings and Context

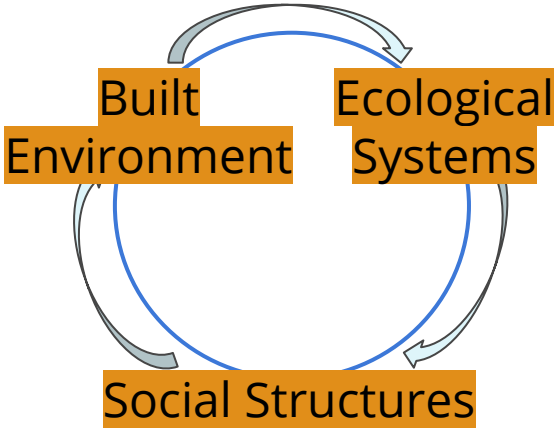
Buildings as a System



Integrated Project Delivery



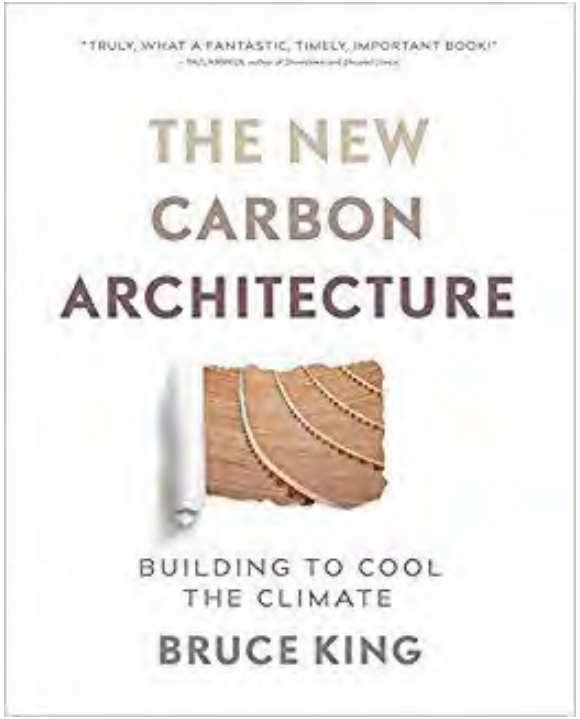
Buildings within a System



“How” Matters!

Chris Magwood - Endeavour Centre - chris@endeavourcentre.org
Ace McArleton - New Frameworks - ace@newframeworks.com
Jacob Deva Racusin - New Frameworks - jacob@newframeworks.com

New Frameworks



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