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.

The Joy of Decarbonization

Navigating choices between operational and embodied carbon

EDC 2023

Dan Wildenhaus

Sr Technical Manager – Decarbonization Training and Consulting Services

Center for Energy and Environment

CEE's nonprofit mission

The Center for Energy and Environment discovers and deploys the most effective energy solutions that strengthen the economy and improve the environment.

We provide practical energy solutions for homes, businesses, and communities.

WE STAND FOR

- ✓Collaboration
- ✓Expertise
- ✓Science
- ✓Community
- ✓Integrity
- ✓Equity

Center for Energy and Environment

At our core

PROGRAMS

We cut energy waste and improve comfort in homes, buildings, and communities.

RESEARCH

We identify cost-effective, efficient technologies through analysis, modeling, and engagement.

CONSULTING

We help building owners and entire communities achieve long-term, energy-saving solutions.

LENDING

We empower people to make upgrades on energy efficiency and comfort in homes or businesses.

POLICY

We strive for high-impact, pragmatic solutions guided by a public interest ethic.

MARKET TRANSFORMATION

We accelerate adoption of promising technologies through early market engagement.

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Our Annual Impact

56

Gigawatt Hours of Electricity Saved

8,400

Homes and Businesses Served

$22.7M

Million Loaned for Improvements

55 Million

Pounds of CO2 in Avoided First-Year Emissions (2020)

$5.6M

Saved in First-Year Energy Costs

19,330

Dekatherms Saved in MN Homes & Businesses

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Who's in the room?

Builders?

Trades?

Programs Implementers?

Weatherization Assistance Staff?

Utilities?

Researchers?

Educators?

Local Government?

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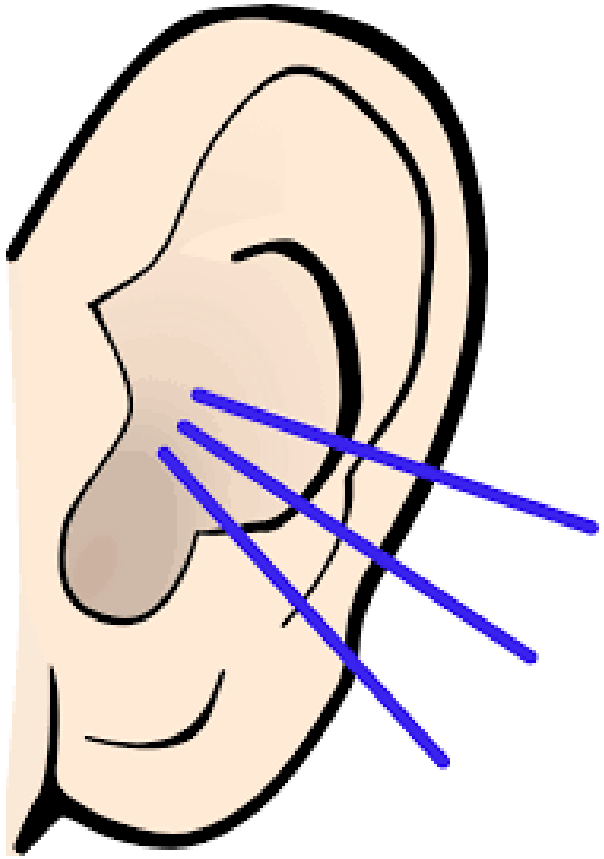
What do you want to get out of today?



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Why care?

- ESG reporting
- Government and utility commitments
- Justifying funding for federal (and state) incentives
- Some of your clients care!!

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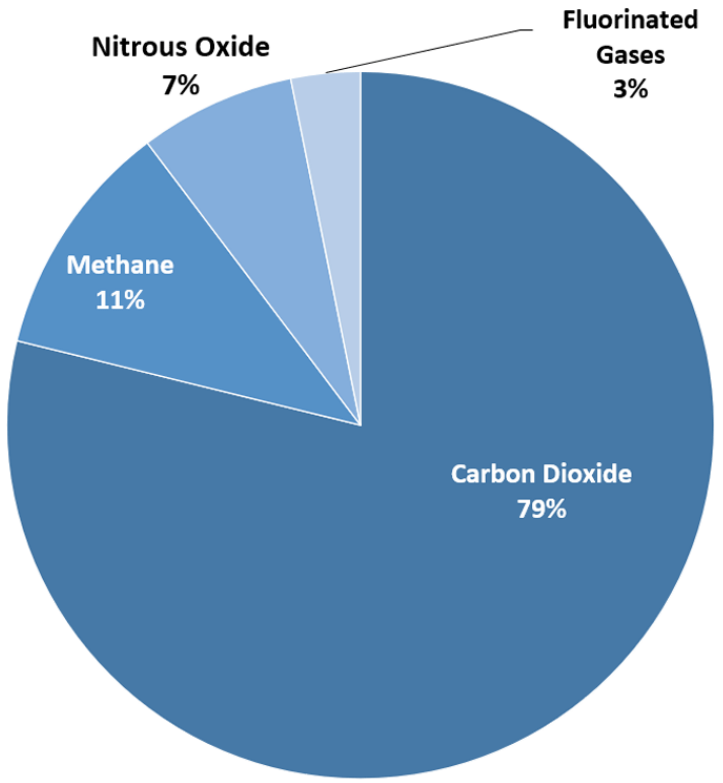
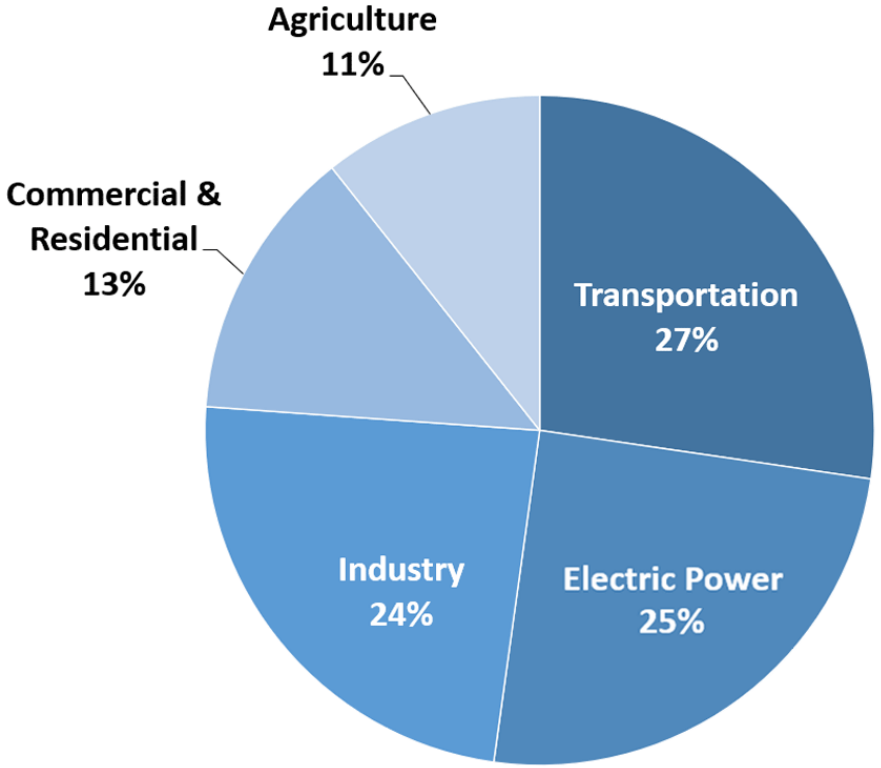
What factors into “decarbonization?”

Overview of U.S. Greenhouse Gas Emissions in 2020



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

Sources of U.S. Greenhouse Gas Emissions in 2020



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

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

What do we measure?

Technically, we're measuring Global Warming Potential, in CO2 equivalent.

Nationally and Globally, its Million Metric Tons (MMT). Statewide and per project, it's Kilograms of CO2 eq. (1 MMT = 1,000 kg)

To make it fun, we also look at tonnes, tons, lbs and more!!

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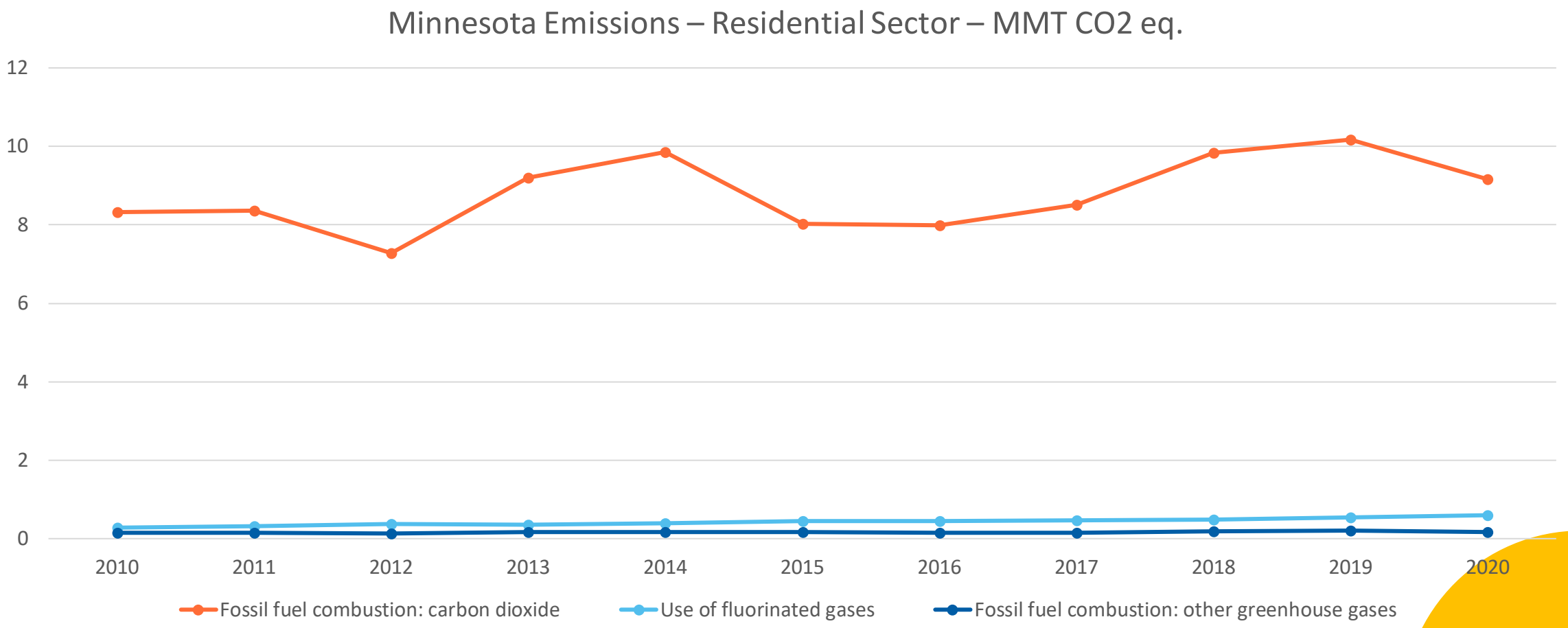
Why Carbon Dioxide?



https://cfpub.epa.gov/ghgdata/inventoryexplorer/#residential/entiresector/allgas/category/all

Responsible Decarbonization and Beneficial Electrification

Goal of Beneficial Electrification: transition from carbon intensive fossil fuels to less carbon intensive electric or hybrid alternatives

- Net reduction in lifetime carbon emissions
- Net reduction in source energy use
- Net reduction or maintenance in fuel-neutral customer energy costs
- No increase in coincident peak electricity demand

Beneficial Electrification is a component of Decarbonization

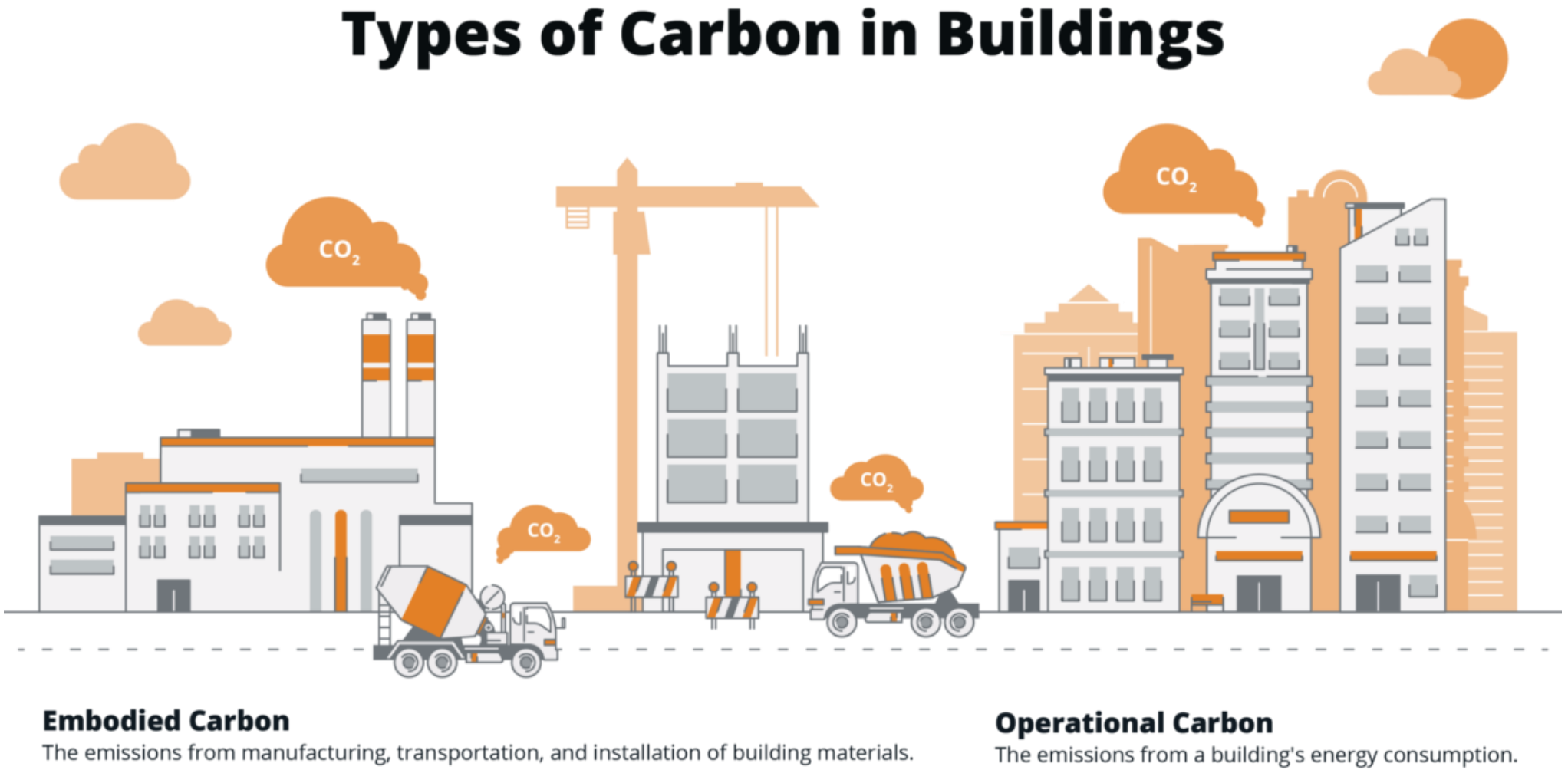
Big Picture Strategies

Carbon equivalents

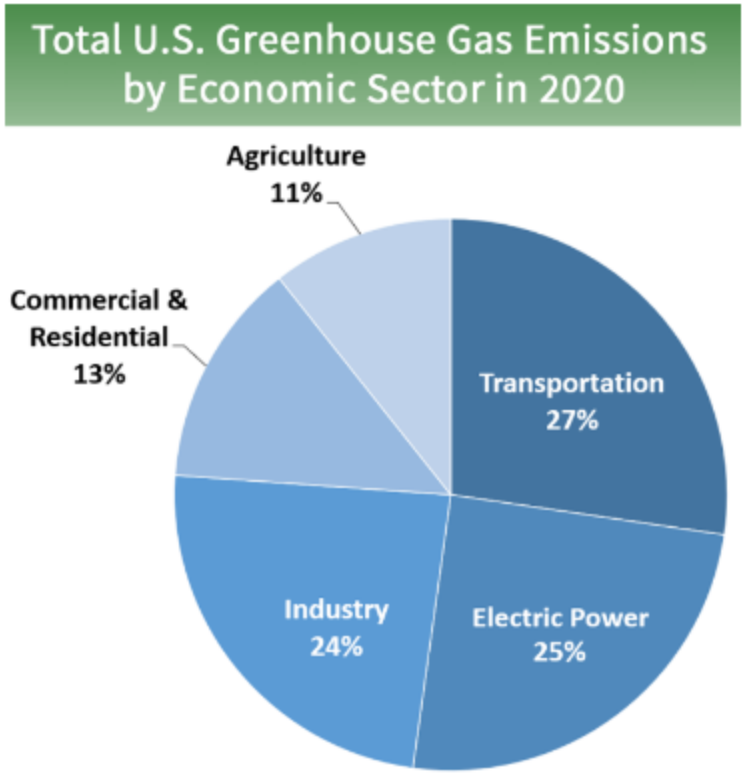
- Natural gas = 1 mmBtu = 10 therms = 5.3 MMT CO2 eq or 6.3 acres of US Forest
- Home heating oil = 1 mmBtu = 10 therms = 7.14 gallons of HHO2 = 7.4 MMT CO2 eq or 8.8 acres of US Forest
- Propane = 1 mmBtu = 10 therms = 10.9 gallons of propane = 6.3 MMT CO2 eq or 7.5 acres of US Forest
- Electricity = 293 kWh = 1 mmBtu = 0.127 MMT CO2 eq or 0.15 acres of US Forest
- Refrigerants = 4.05 kg of R410A = 8,456 MMT CO2 or 10,050 acres of US Forest

https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results
https://www.infraserv.com/en/services/facility-management/expertise/f-gas/gwp-calculator/?amount=4.05&cryogen=2088

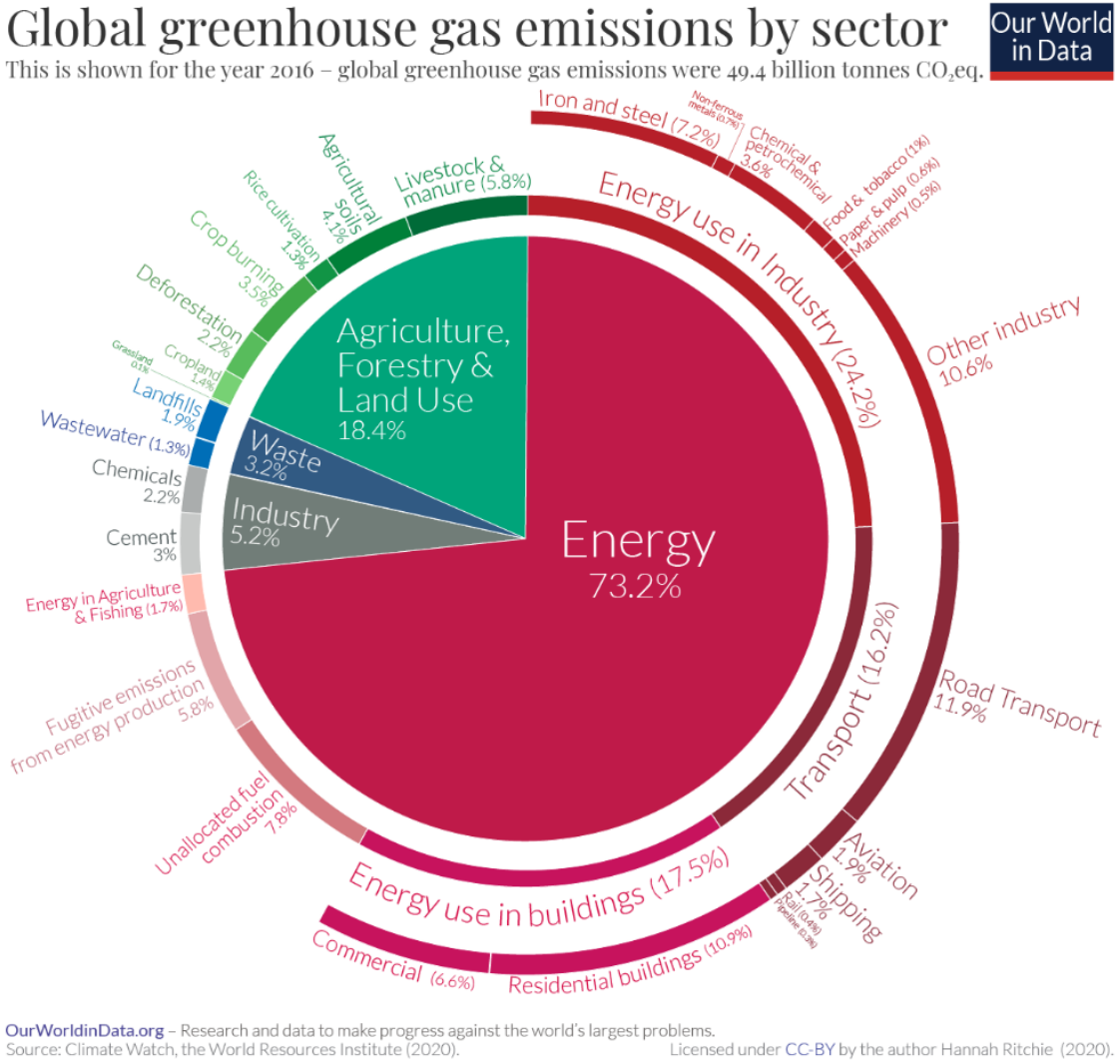
Big Picture Strategies



Why buildings?



Total Emissions in 2020 = 5,981 Million Metric Tons of CO2 equivalent. Percentages may not add up to 100% due to independent rounding.



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Operational vs Embodied Carbon

- ***Operational Carbon:*** *The amount of carbon emitted during the operational or in-use phase of a building. This includes the use, management, and maintenance of a product or structure.*

- ***Embodied Carbon:*** *The amount of carbon emitted during the making of a building. This includes extraction of raw materials, manufacture and refinement of materials, transport, the building phase of the product or structure, and the deconstruction and disposal of materials at the end of life.*

https://spot.ul.com/blog/embodied-vs-operational-carbon/#:~:text=Operational%20Carbon%3A%20The%20amount%20of,for%2028%25%20of%20global%20GHG.

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The Concept

Decision Tree Idea

You could always just use tools…

- EPA Greenhouse Gas Equivalencies Calculator - Calculations and References
- BEAM Tool
- EC3 Tool
- Cove Tool - Embodied Carbon
- Cove Tool - Operational Carbon
- EPA Greenhouse Gas Equivalencies Calculator
- RESNET approved modeling tools
  - RESNET Carbon Index - Standard 301-2019 Addendum D - 2022

A different way!

Decision Tree

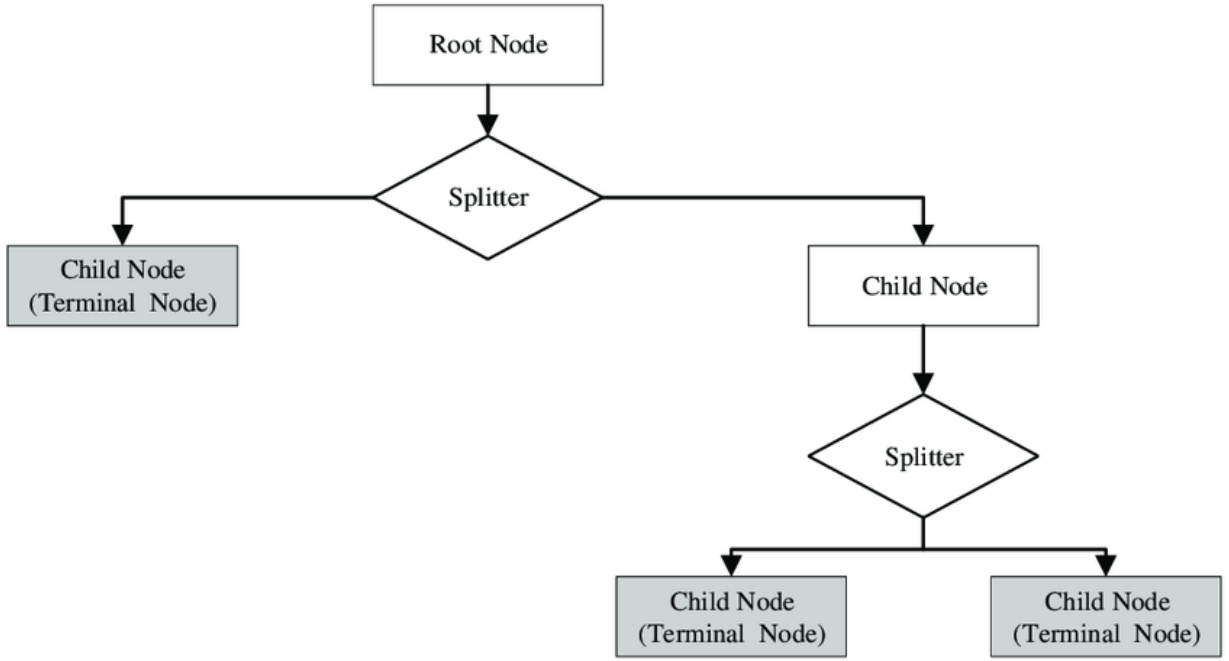
New Construction vs Retrofit

Fuel Type

Operational vs Embodied

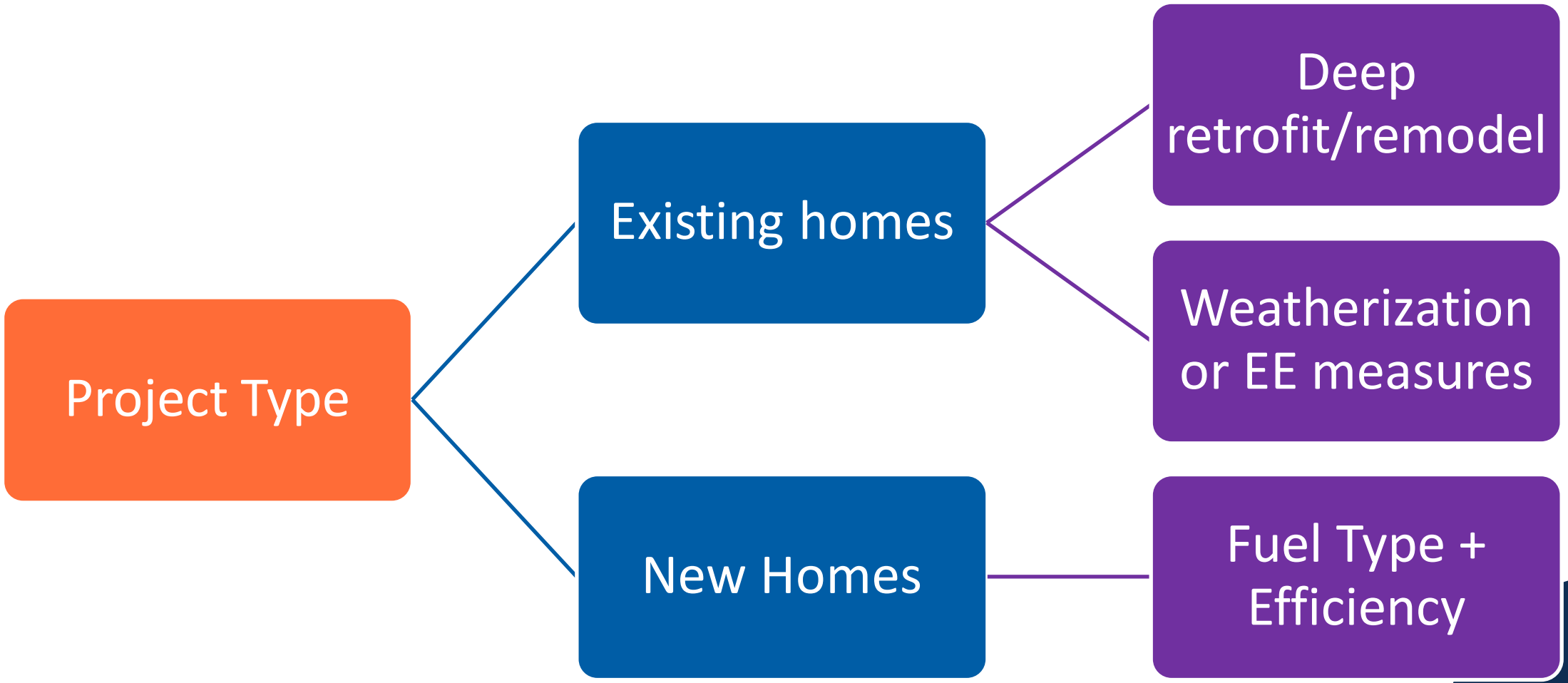
Typical Materials Impacts

Typical Efficiency Impacts



Can we use a simple decision tree to determine where to focus first?

To start


Project Type
Existing homes
New Homes
Deep retrofit/remodel
Weatherization or EE measures
Fuel Type + Efficiency

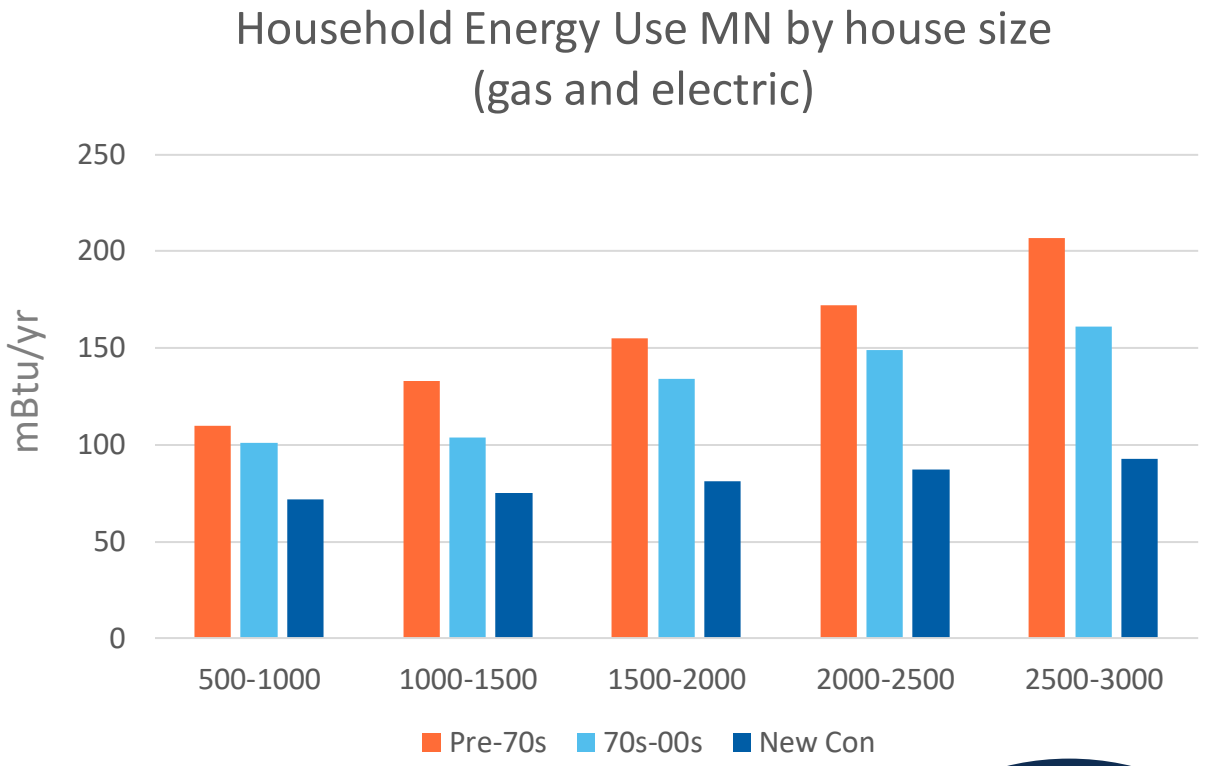
New Construction

In Minnesota, ~80% of new homes are built to use Natural Gas for space and water heat.

~90% of new homes have air conditioners.

Average projected energy use of average new home 87 mmBtu/yr

Average projected energy use of 50-year-old home is 155 mmBtu/yr



https://larrybakerlab.cfans.umn.edu/research-themes/drivers-household-energy-conservation

https://mn.gov/commerce-stat/pdfs/mn-energy-data-dashboard.pdf

https://mn.gov/commerce-stat/pdfs/mn-energy-efficiency-potential-study.pdf

HEAT PUMPS DELIVER 50% MORE HEAT

For the same amount of wellhead gas.

NATURAL GAS FURNACE

100 units of input energy at gas wellhead

Transmission & distribution losses, 5% or 5 units

Gas furnace, 95% AFUE, or 5 unit losses

90 Units of heat delivered into a gas house

50% MORE HEAT DELIVERED INTO HEAT PUMP HOMES

HEAT PUMP, CENTRALLY DUCTED (NATURAL GAS FURNACE REPLACEMENT)

100 units of input energy at gas wellhead

50% electric generation losses, or 50 units

Transmission & distribution losses 5%, or 3 units

47 units of electricity input. Heat pump COP=2.9 (Season avg.)

136 Units of heat delivered into a HP house

sagewell℠

www.sagewell.com

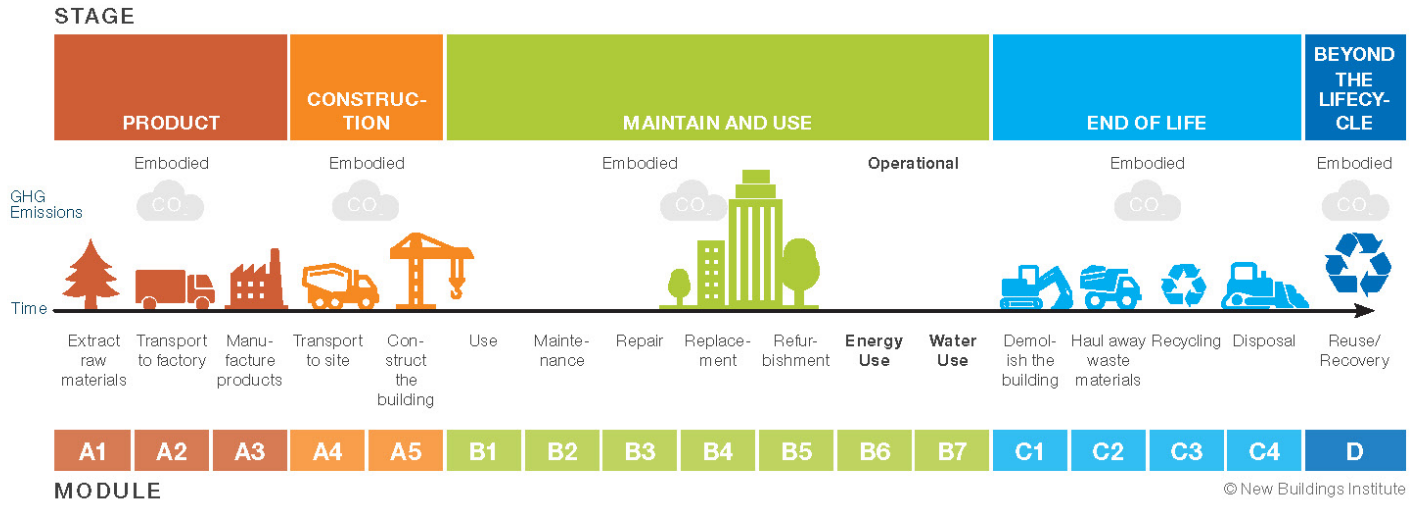
Embodied Carbon in New Construction

Focus area

- Most calculations look at modules A1-A5
- These are one-time contributions, looked at over a “lifetime” using a life cycle assessment.
- LCCAs often use 50 years as a home life (many people prefer 100)

Biggest picture

FIGURE 1: LIFECYCLE STAGES
Data source: BS EN 15978:2011



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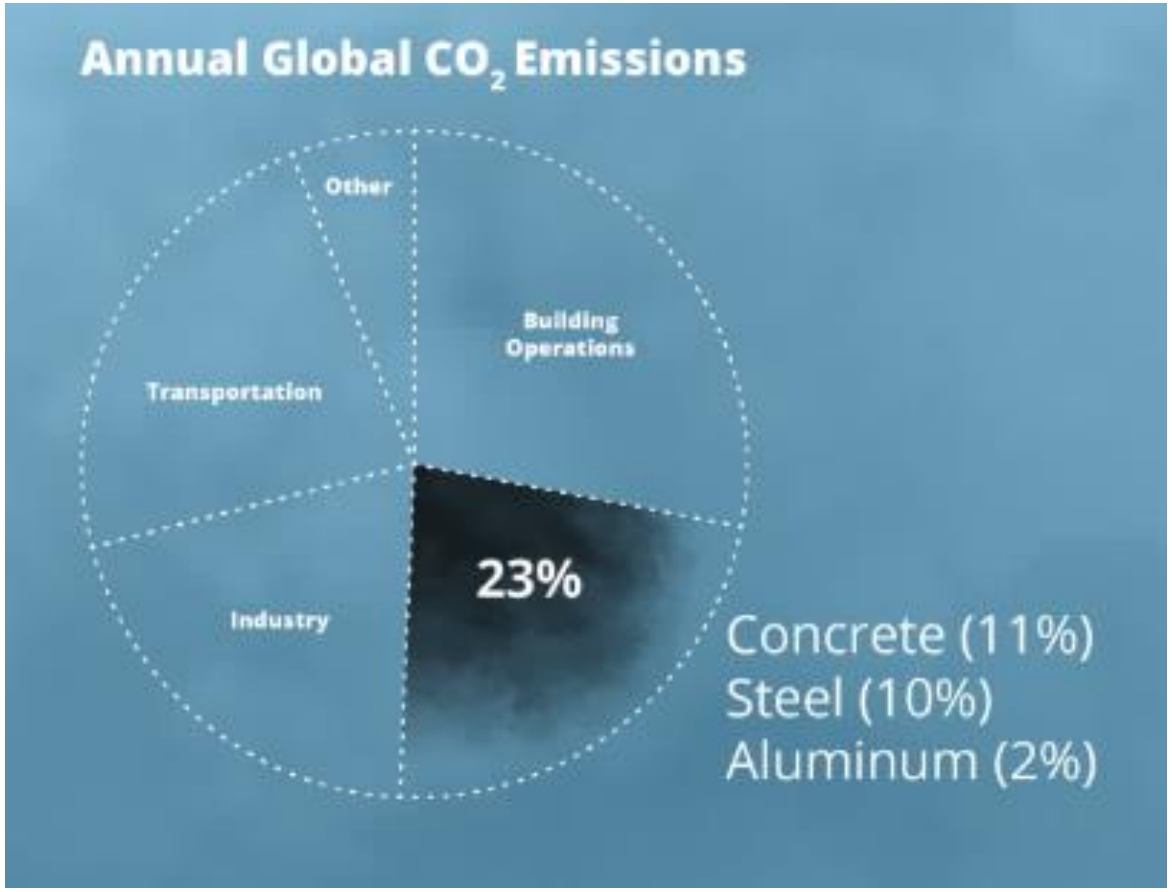
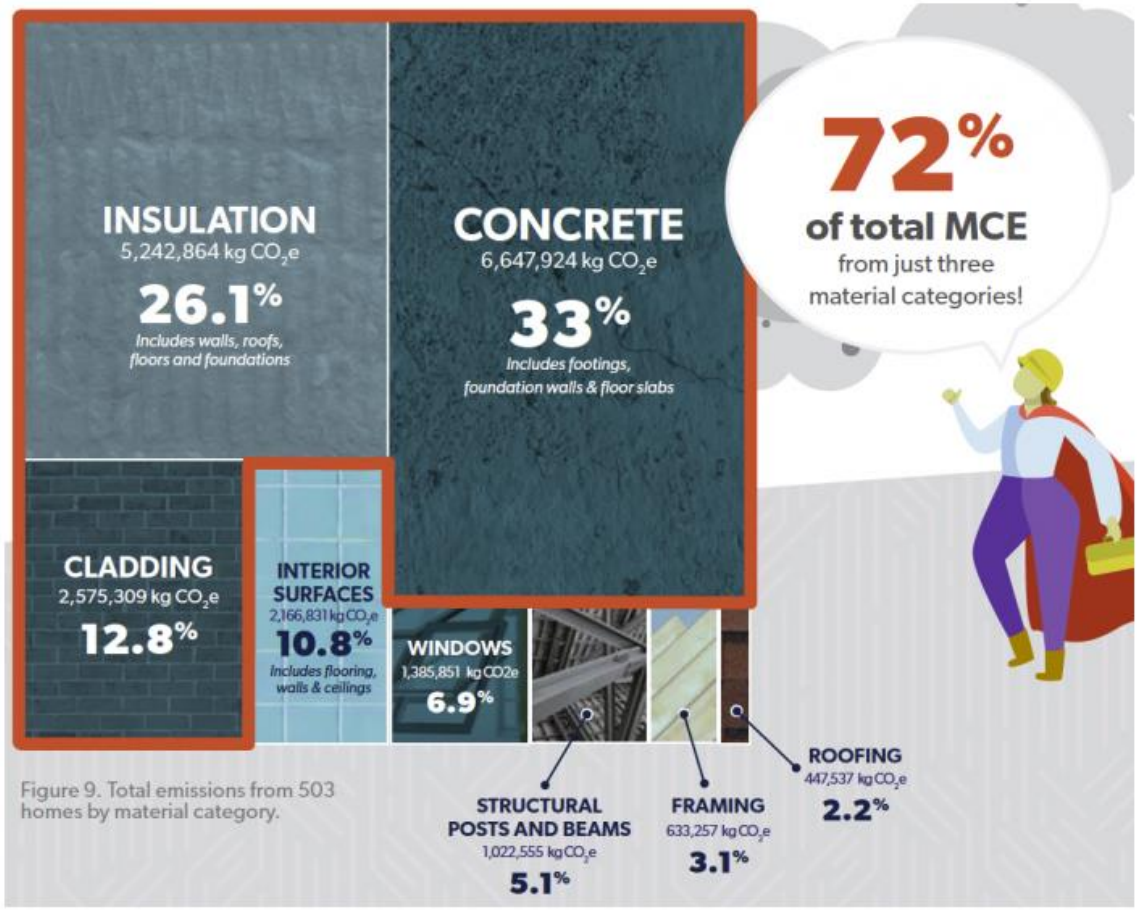
Embodied Carbon heavy weights

Top contributors overall



Top contributors in Res New Con



Average home contributions based on Canadian studies

Average over multiple studies = 39.5 tonnes of CO_2 equivalent is built in.

By focusing on top five to ten contributors and switching to best readily available on the market products, showed an improvement down to 18

Embodied vs Operational Carbon – Res New Con

Embodied carbon

- 39.5 tonnes CO2e

Over a 50-year life, the gas heated home would produce 230 tonnes (167 if efficient)

The dual fuel home would produce 180 tonnes

An ASHP home would produce 120 tonnes (84 if efficienct)

Operational carbon

- 4.6 tonnes per year for Gas homes
- 3.2 tonnes per year for dual fuel
- 2.4 tonnes per year for ASHP house

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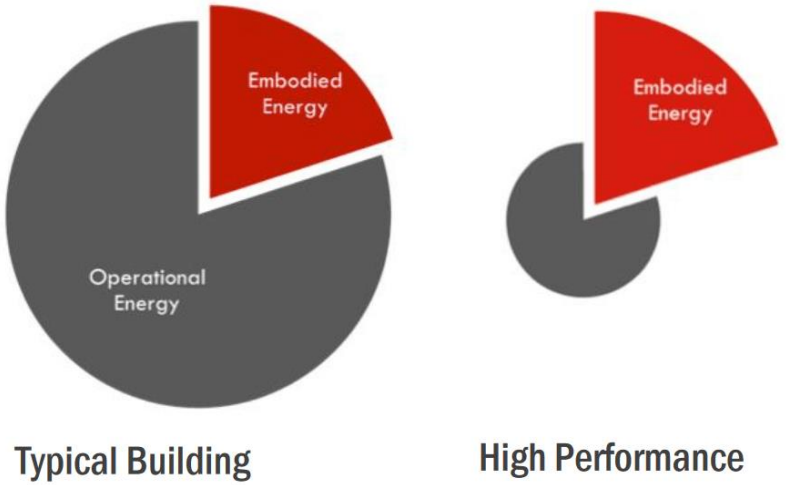
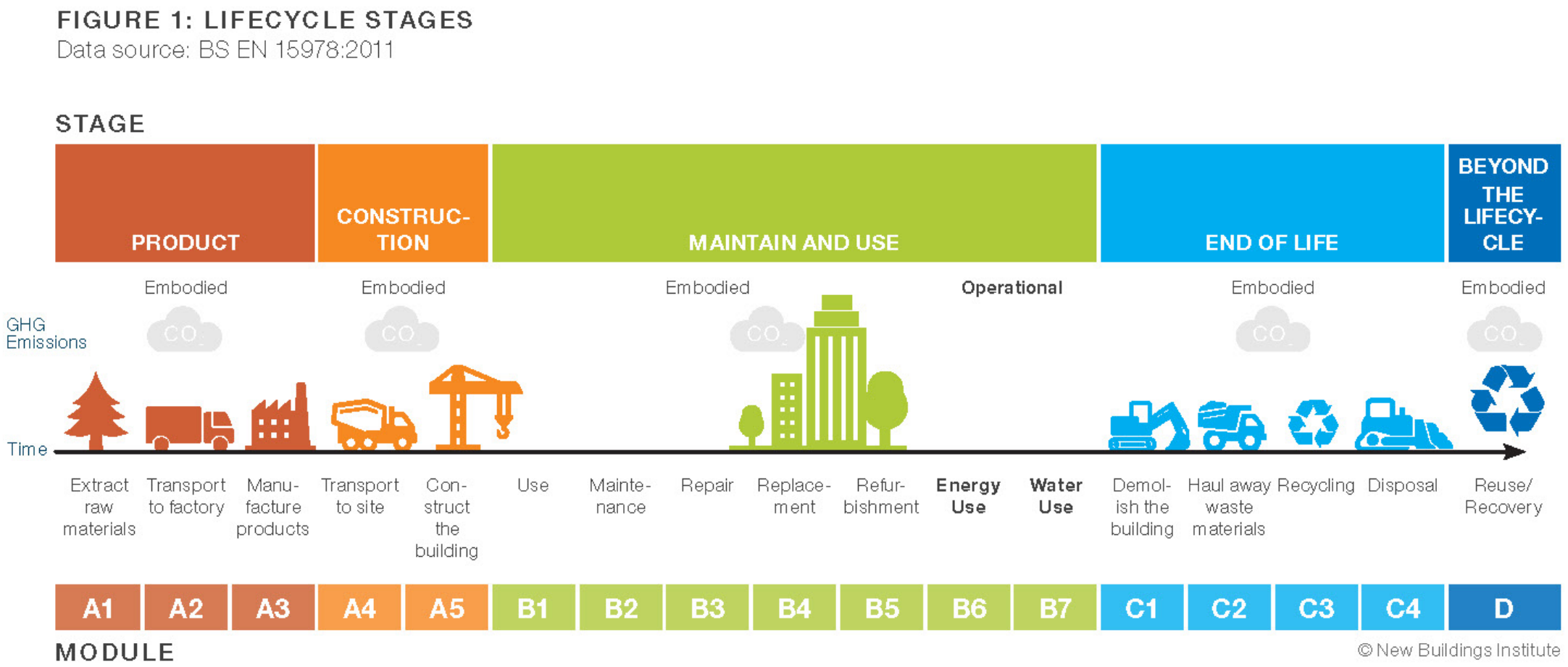
To wrap

- Embodied carbon is very important in new homes
- BUT, a gas heated home will outproduce the embodied carbon in about 8 years or double it over the lifetime!
- So, choice 1 = Fuel Choice
- Choice 2 = Use better concrete, better insulation, and better cladding, surfaces and windows
- Note, electric heat pump homes with a cleaner grid, more efficient equipment, and lower GWP refrigerants will further make the carbon choice easier.
- Note 2, advancing codes will further reduce overall operational carbon



What about existing homes?



Average MN home is 43 years old

Embodied carbon to overcome in existing homes

- Remaining from the 39.5 tonnes, over 50 years, we have 5.53 tonnes left to overcome.
- Add in an additional 5 tonnes for the maintenance, repair, upgrades, etc…
- 10.53 tonnes of embodied carbon to overcome

Biggest contributors to embodied carbon in retrofits

- **Insulation**
  - Cladding and surfaces
  - Windows
  - Equipment
  - Roofing
  - Concrete

Insulation has both the highest embodied carbon content and is also the most installed retrofit measure in Wx and Home Performance

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New embodied carbon added during retrofit

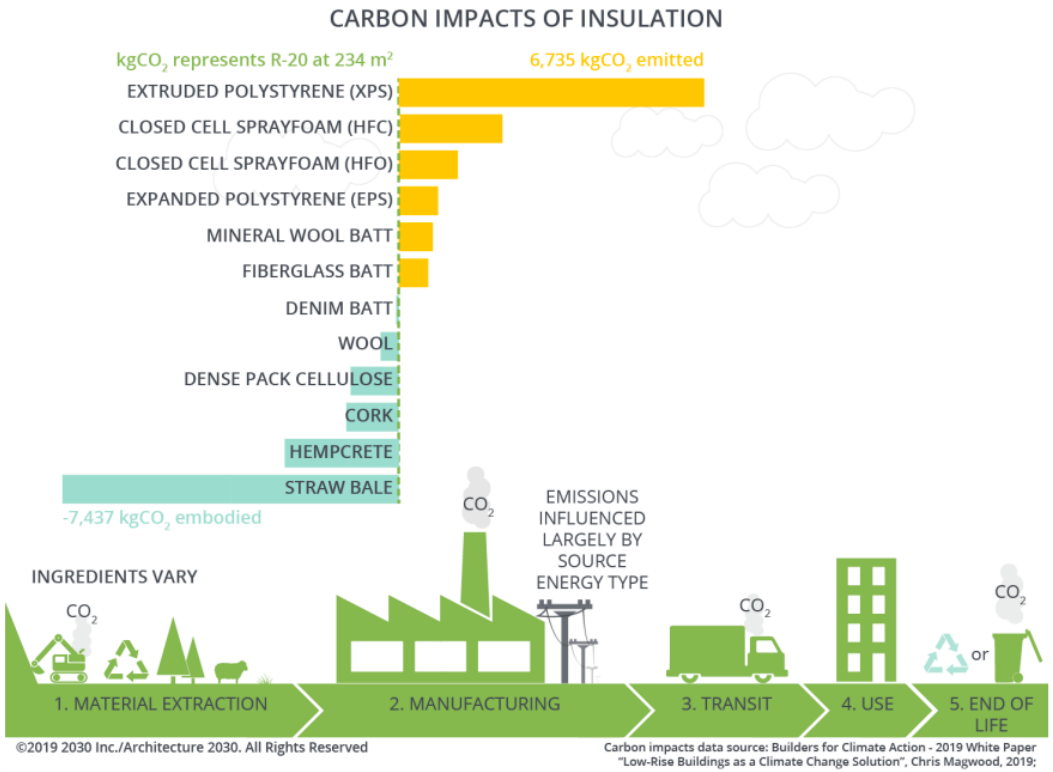
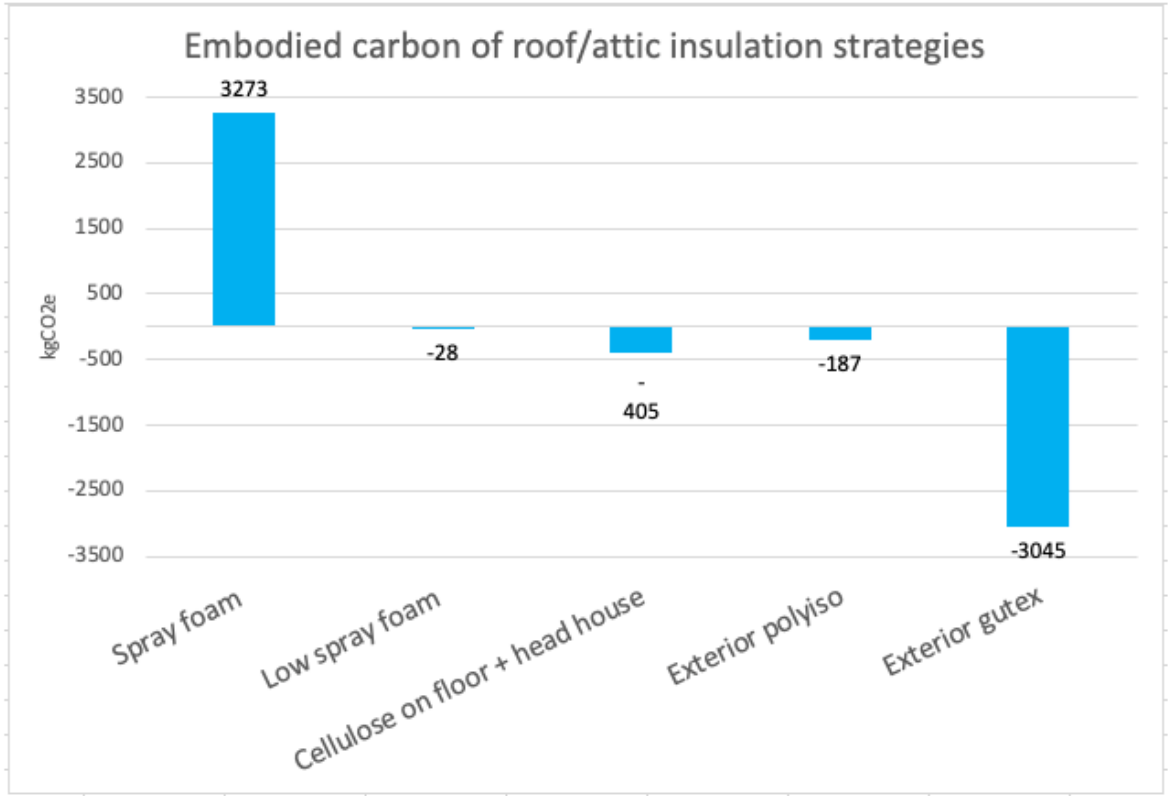


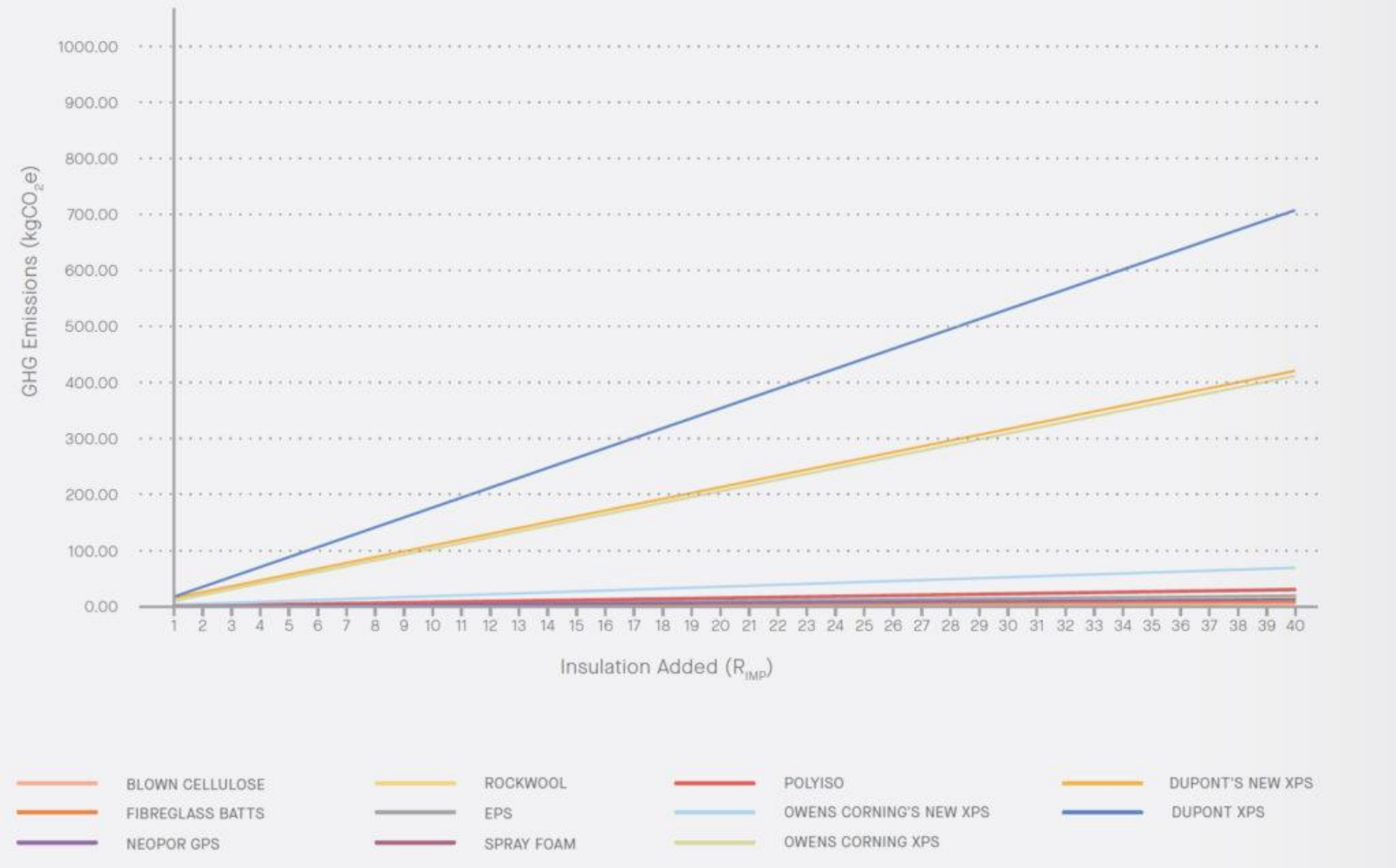
Figure 2. Carbon impact of insulation

Source: Architecture 2030. https://materialspalette.org/insulation



This chart shows the embodied carbon of several options for insulating the attic floor or the roof. Chart courtesy Byggmeister.

How much you add and what type matters!



Contribution of new materials at time of retrofit

- ~ 4 tonnes from insulation (half as much added in a retrofit as in a new home)
- ~ 0.5 tonnes from equipment replacement
- ~ 1 tonne from other materials

- Adding up:
- Embodied carbon for existing project
  - Existing 10.53
  - Adding in Wx 5.5
  - Adding in HP upgrade only 0.5
- Wx project 16.03
- HP upgrade only 11.03

Operational Carbon in EXISTING Homes in MN - estimated

Gas heated homes

- Carbon produced for gas heated homes is an estimate 6.9 to 11.6 tonnes or ~15,000 to ~25,600 lbs of CO2 per year for a 50-year-old home
- Average will be 22,500 lbs

- For a weatherized or 25-year-old home, that may drop to 5.2 to 8.7 tonnes or ~11,500 to ~19,200 lbs of CO2 per year
- Average will be 14,500 lbs

ASHP heated homes

- Studies have shown reductions in the range of 40-60% when switching to an appropriate ASHP.

- A dual fuel heat pump may see 30% reduction

- ASHP 50yr homes = ~9,900 lbs
- ASHP 25yr homes = ~7,000 lbs
- Dual fuel 50yr homes = ~15,750 lbs

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Embodied vs Operational Carbon – Existing Homes

Embodied carbon

- 16.03 tonnes CO2e
- 11.03 tonnes CO2e (HP upgrade only)

Over a 50-year life, the gas heated home would produce over 500 tonnes

Over a 50-year life, the gas heated home with Wxs and a new HP would produce over 150 tonnes

The dual fuel home would produce over 350 tonnes

An ASHP home would produce almost 250 tonnes

Operational carbon

- 10.2 tonnes per year for Gas homes to start
- 3.1 tonnes for Wx + ASHP
- 7.12 tonnes per year for dual fuel upgrade only
- 4.49 tonnes per year for ASHP house

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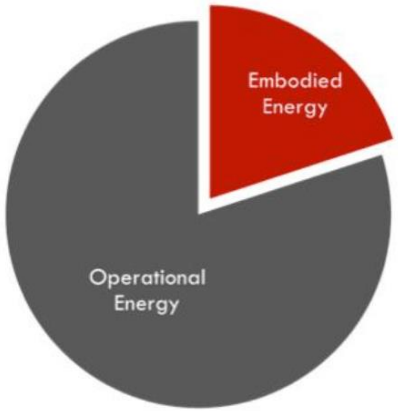
To wrap

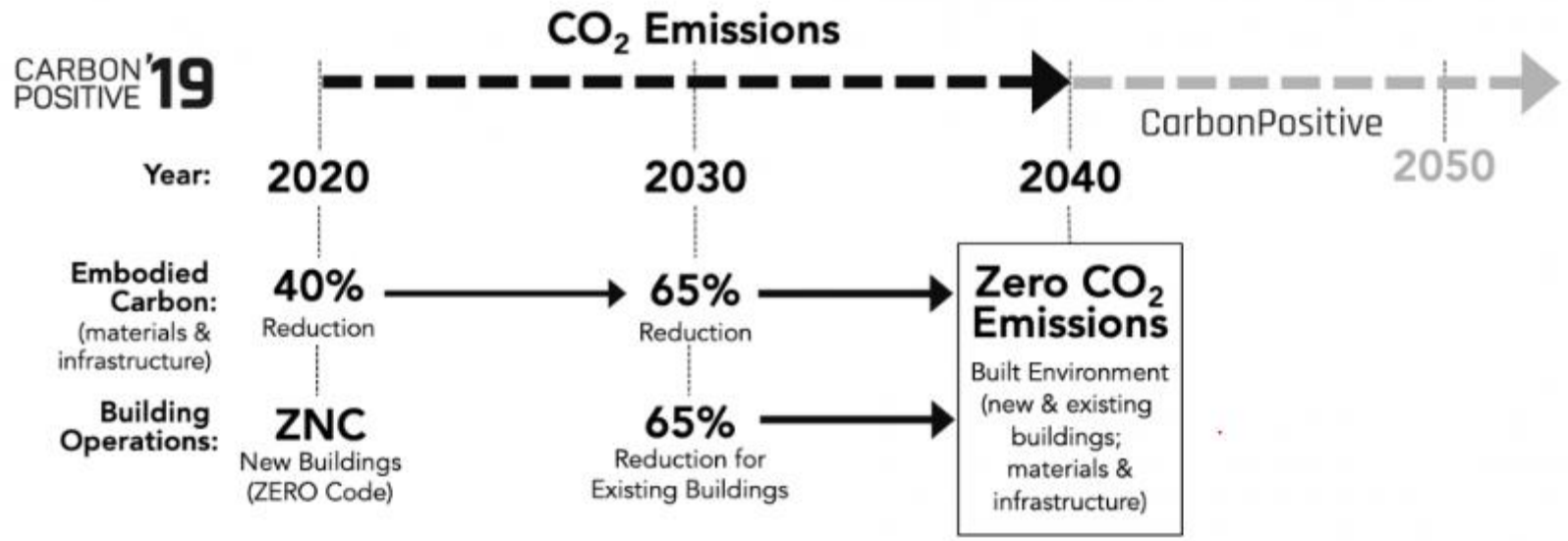
- Embodied carbon is still important in existing homes
- BUT, a gas heated home will outproduce the embodied carbon in about 1.2 years!
- So, choice 1 = Fuel Choice
- Choice 2 = Use better insulation, and better cladding, surfaces and windows during upgrades
- Note, electric heat pump homes with a cleaner grid, more efficient equipment, and lower GWP refrigerants will further make the carbon choice easier.



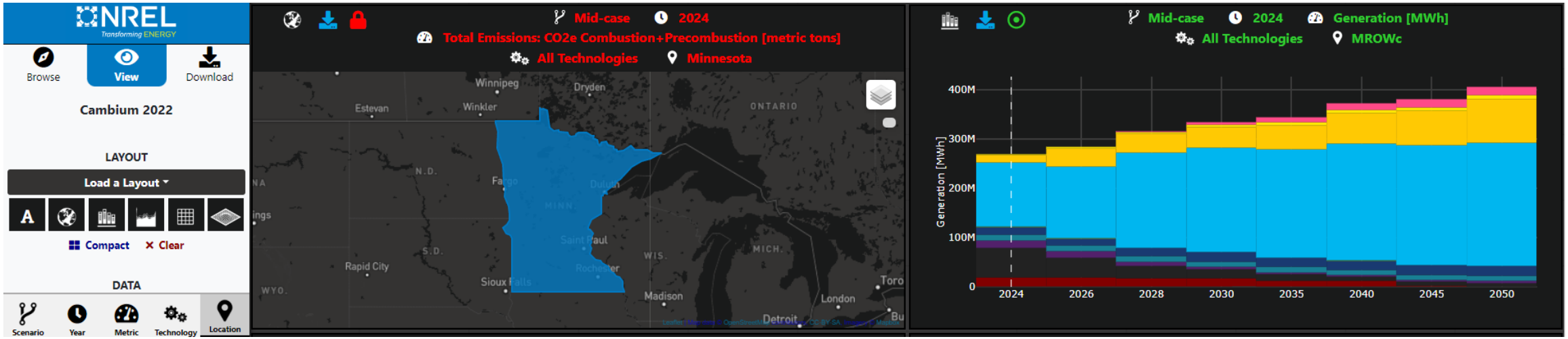
Typical Building

High Performance

Putting it all together



The Grid



Blue = wind
Yellow = solar

https://scenarioviewer.nrel.gov/?project=82460f06-548c-4954-b2d9-b84ba92d63e2&mode=view&layout=Default

Discussion

- Any Decarb experts in the room?
- Do you focus on operational or embodied or both?
- Anyone in the room drafting any carbon policy?

Discussion

- Any manufacturers in the room?
- Can you tell us about how your company is addressing carbon?

Thank You!!f

Dan Wildenhaus

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