TRI-COUNTY
REGIONAL ENERGY NETWORK

SAN LUIS OBISPO • SANTA BARBARA • VENTURA

Reducing Carbon Emissions from MEP systems

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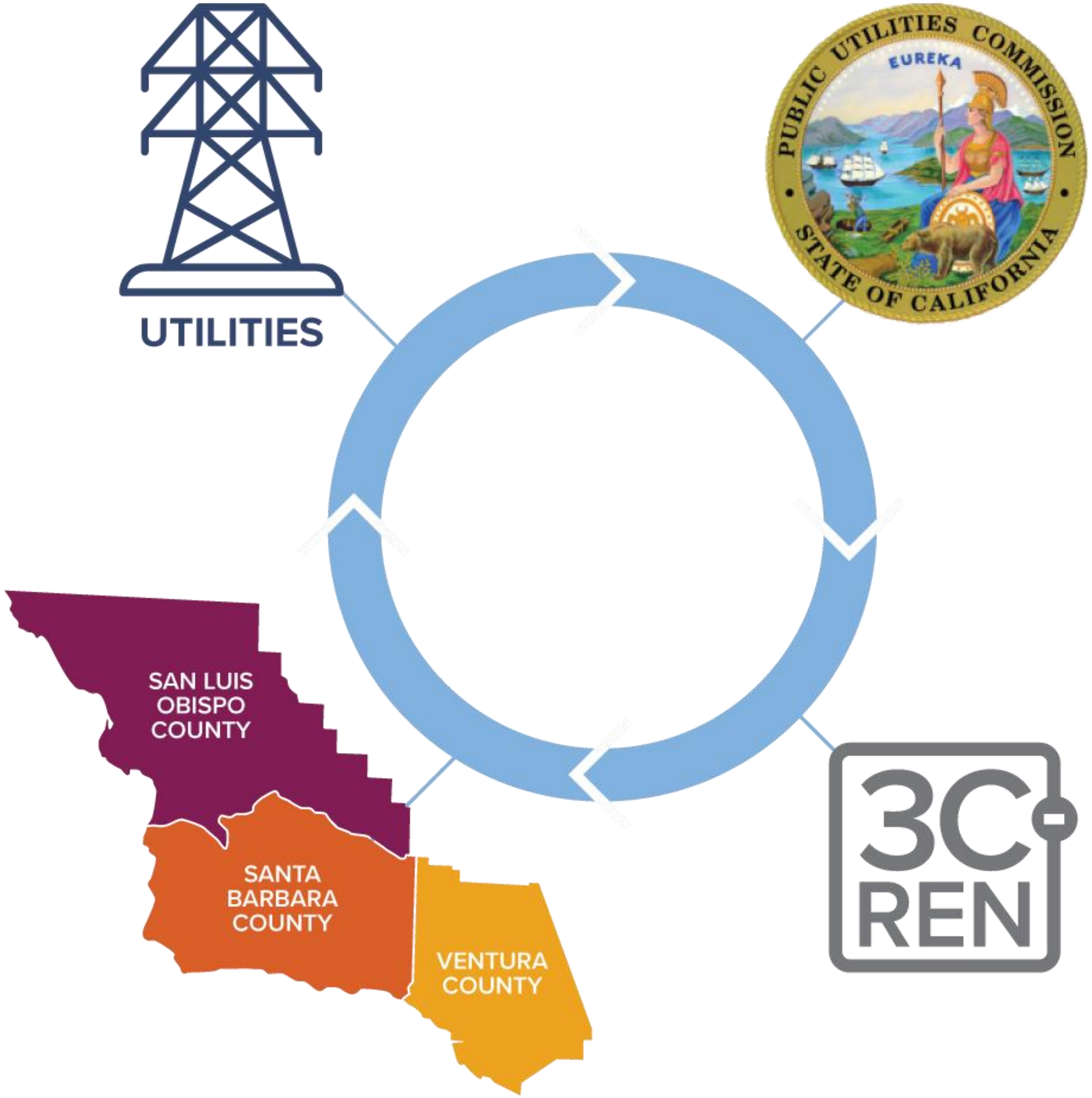
In Balance Green Consulting

Before We Begin

Here are some quick reminders:

- Call in? Please **share** full name to confirm attendance
- To receive AIA LUs, you **must attend** at least 80% of the training. Attendance will be verified
- Use the "**Chat**“ to share questions or comments
- Slides/recording are **shared** after most events and can be found on 3C-REN's on-demand page
- 3C-REN does **not** allow **AI notetakers**, unless used to accommodate a disability



Tri-County Regional Energy Network

3C-REN is a collaboration between the tri-counties

Our programs reduce energy use for a more sustainable, equitable and economically vibrant Central Coast

Our free services are funded via the CPUC, bringing ratepayer dollars back to the region

Our Services

Incentives

HOME ENERGY SAVINGS

3c-ren.org/for-residents
3c-ren.org/multifamily

COMMERCIAL ENERGY SAVINGS

3c-ren.org/commercial

Contractors can enroll at
3c-ren.org/contractors

Training

BUILDING PERFORMANCE TRAINING

3c-ren.org/events
3c-ren.org/building

ENERGY CODE CONNECT

3c-ren.org/code

View past trainings at
3c-ren.org/on-demand

Technical Assistance

AGRICULTURE ENERGY SOLUTIONS

3c-ren.org/agriculture

ENERGY ASSURANCE SERVICES

3c-ren.org/assurance

Learning Objectives

- Understand the Impact of **mechanical, electrical, and plumbing (MEP)** systems to whole-life carbon emissions for buildings.
- Learn about emerging tools and methodologies for measuring embodied carbon in MEP systems, including the challenges and opportunities in data availability and standardization
- Learn near-term strategies to reduce MEP carbon emissions within the context of a whole-life carbon approach to design and engineering
- Become familiar with the state of the industry for assessing and reporting emissions and the work currently in progress.

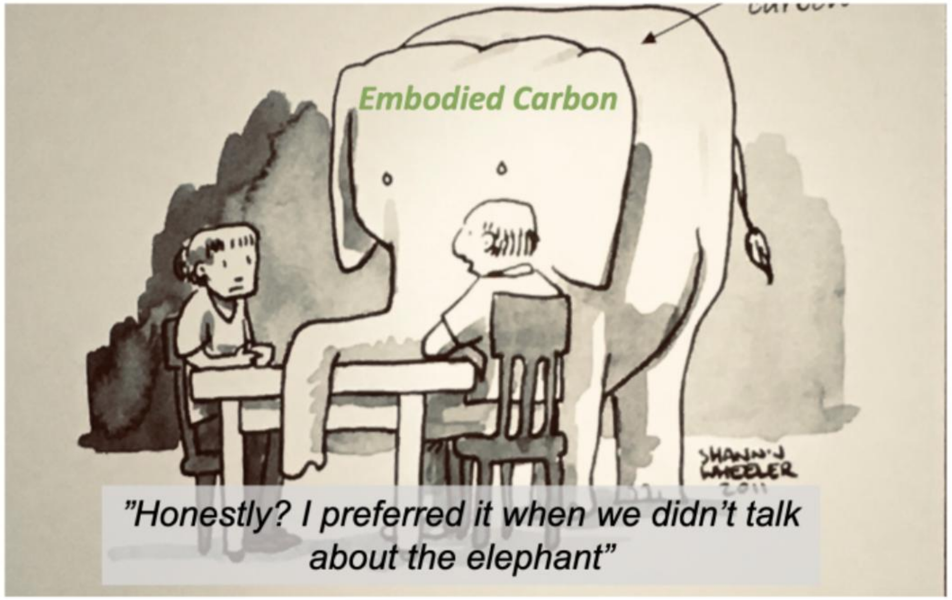
Learning Units

- 1.0 AIA HSW LUs approved for this course
- 1.0 ZNCD Continuing Education units for CAB

Agenda

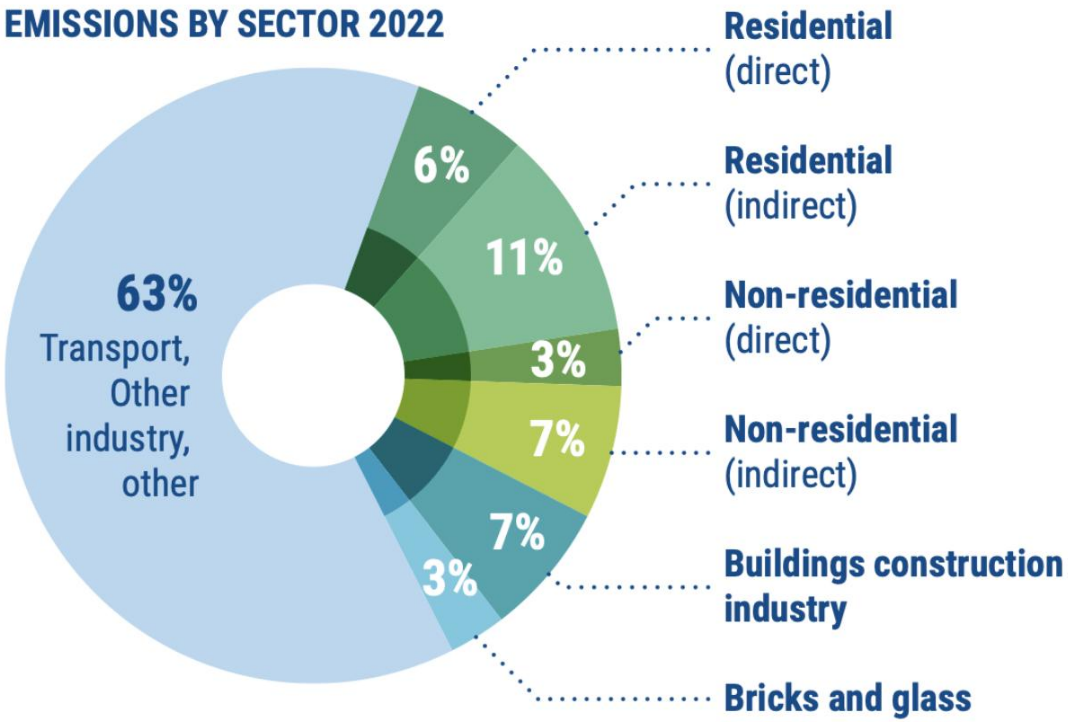
1. Carbon Emissions Overview
2. MEP Factors for Tracking Emissions
3. Refrigerants
4. Whole Life Carbon for MEP
5. Strategies for Reducing Emissions
6. Industry Efforts and Resources

Carbon Emissions Overview



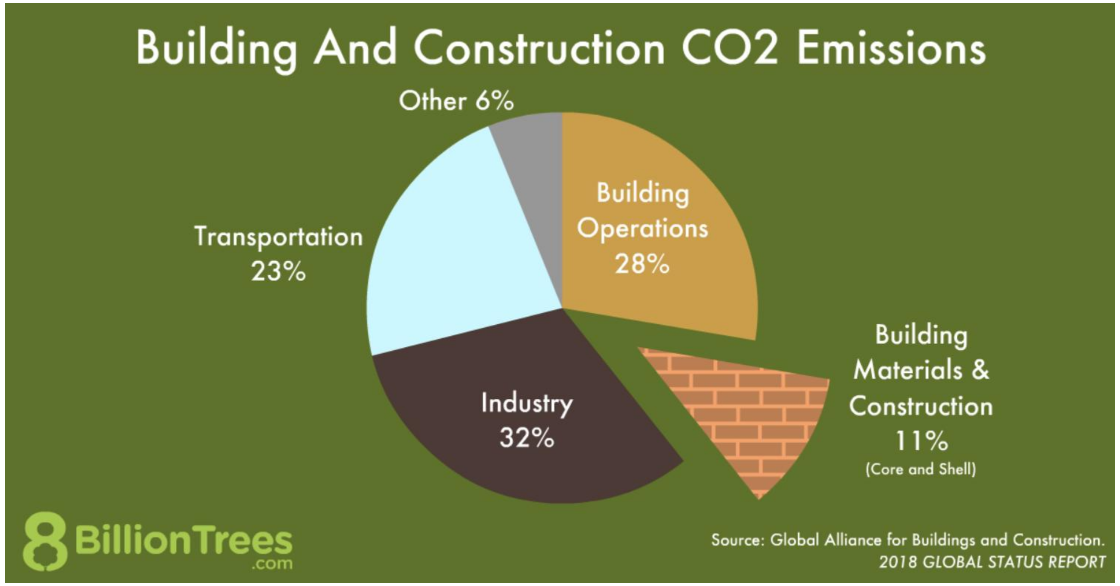
Ed Mazria @ CarbonPositive 2030

Carbon Emissions by Sector



(Source: IEA 2023a. Adapted from 'Tracking Clean Energy Progress')

Notes: Buildings construction industry refers to materials used in construction, including concrete, steel and aluminium. Other materials shown separately.



Understanding Carbon

Embodied Carbon

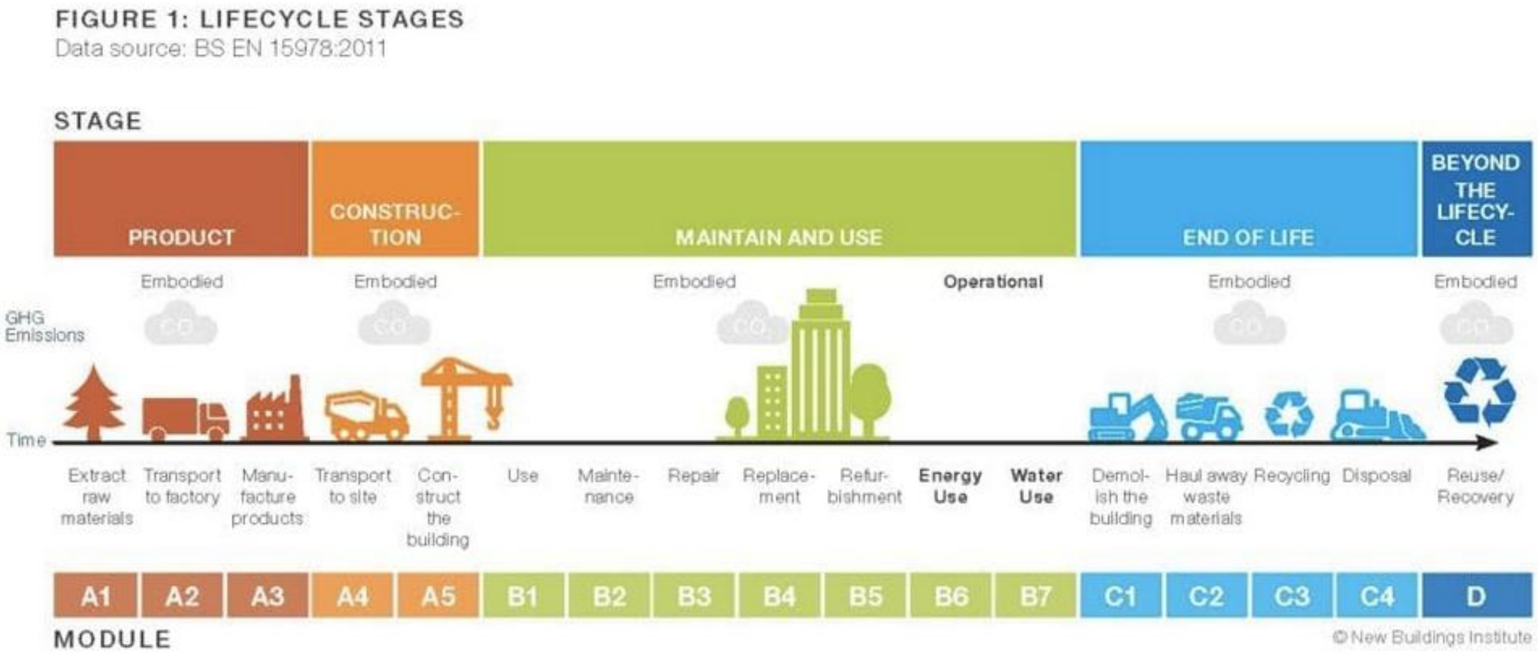
Manufacture, transport and installation of construction materials

Operational Carbon

Building energy consumption

SKANSKA

Tracking Emissions – Life Cycle Stages

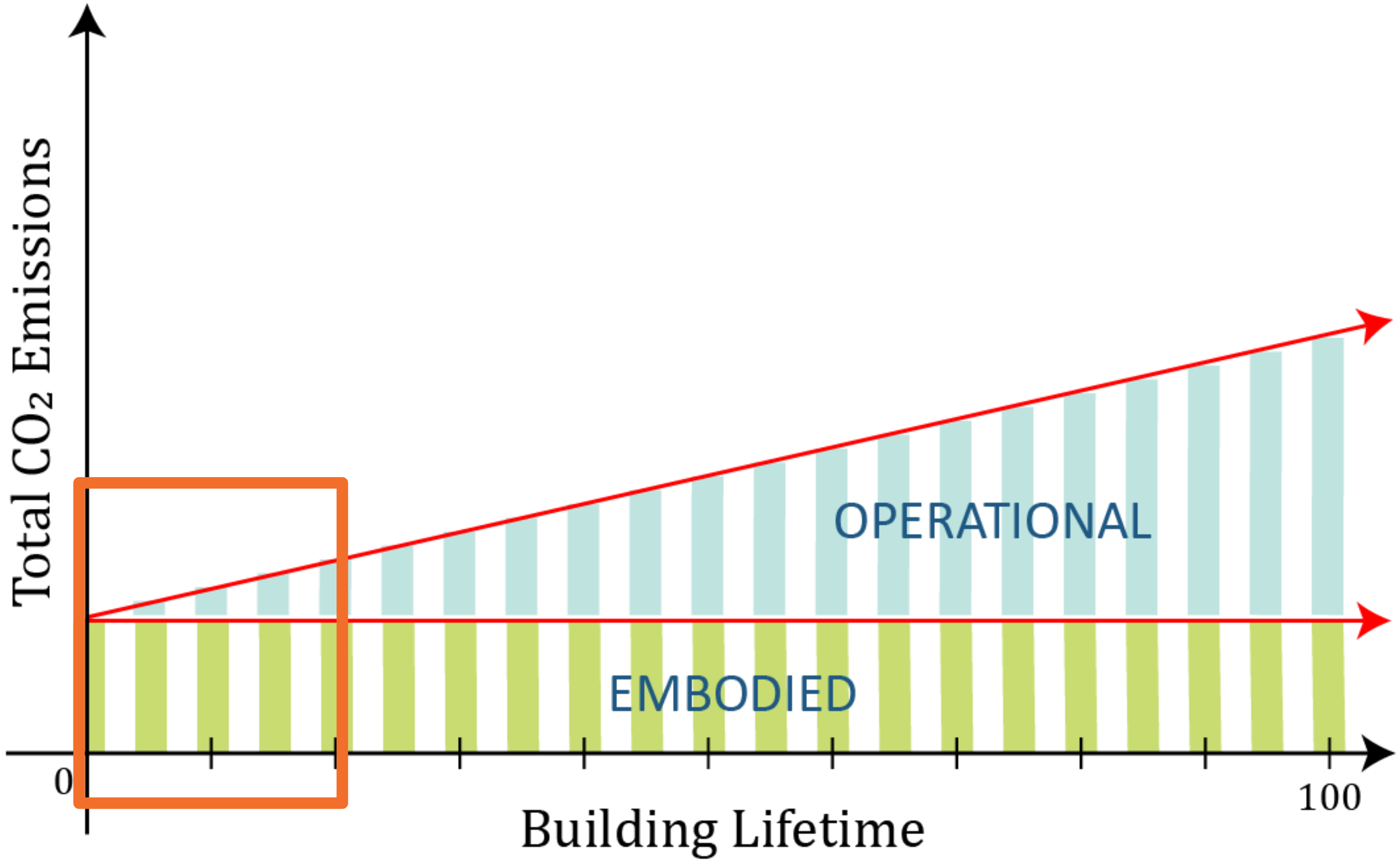


Cradle to gate

Cradle to grave

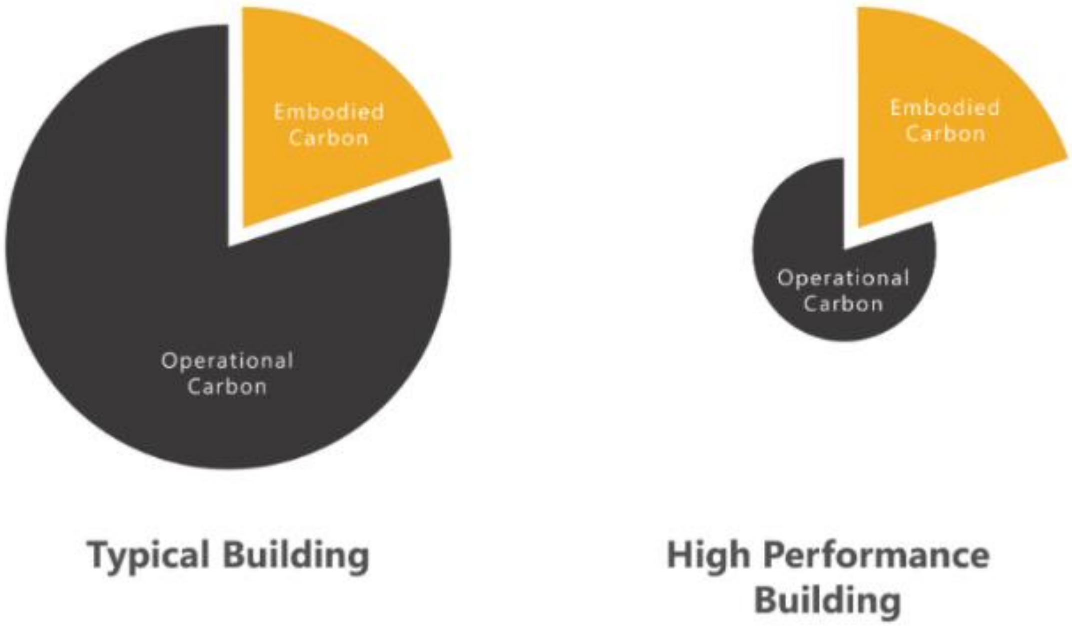
Cradle to cradle

Time Value of Carbon

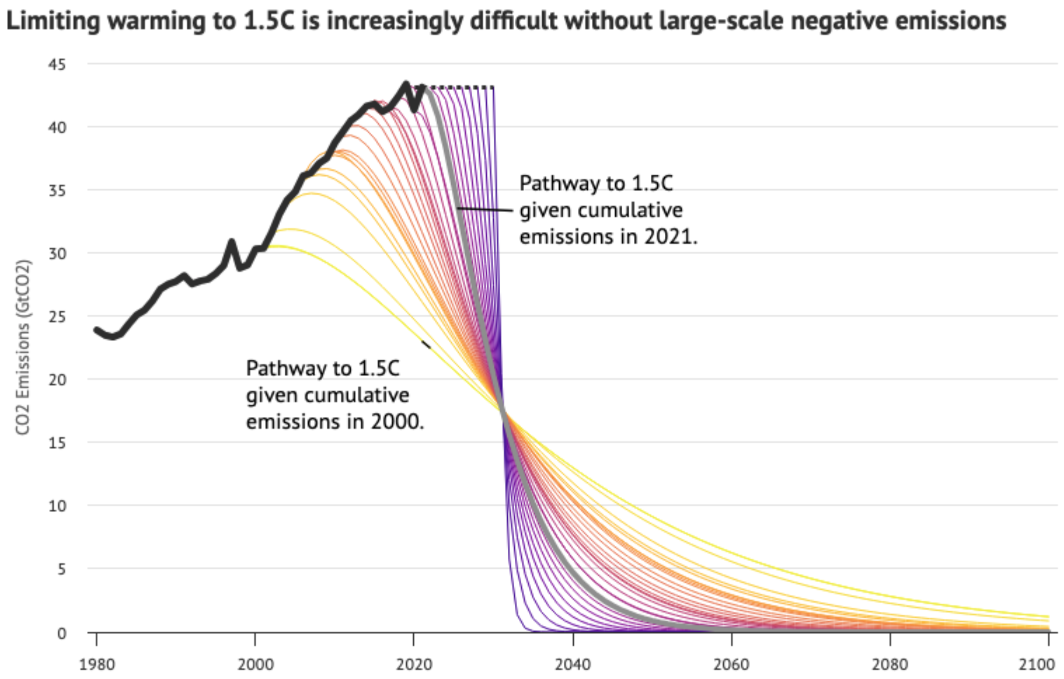


A Shifting Focus on Embodied Carbon…

- A bigger piece of the carbon pie

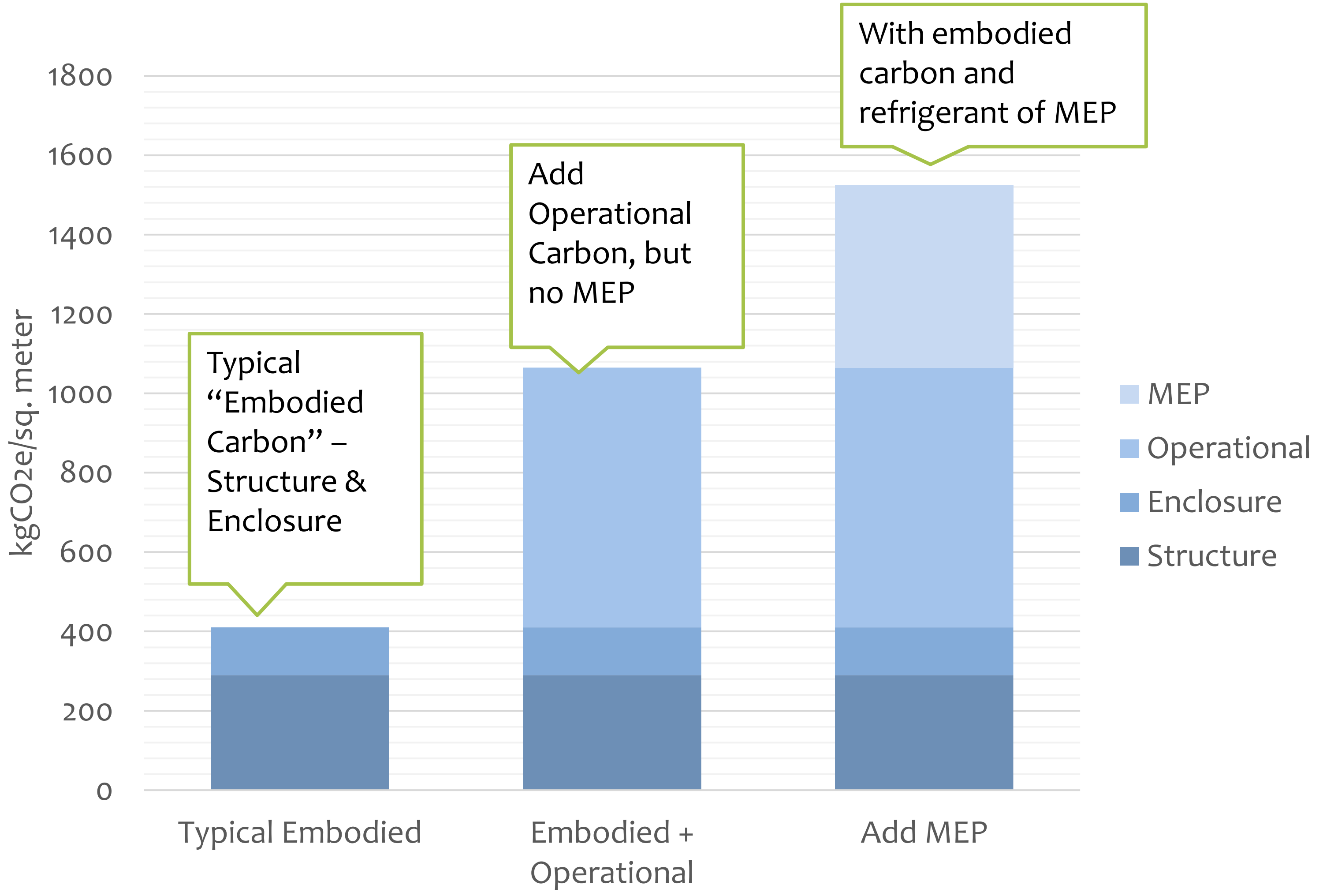


- And the time factor



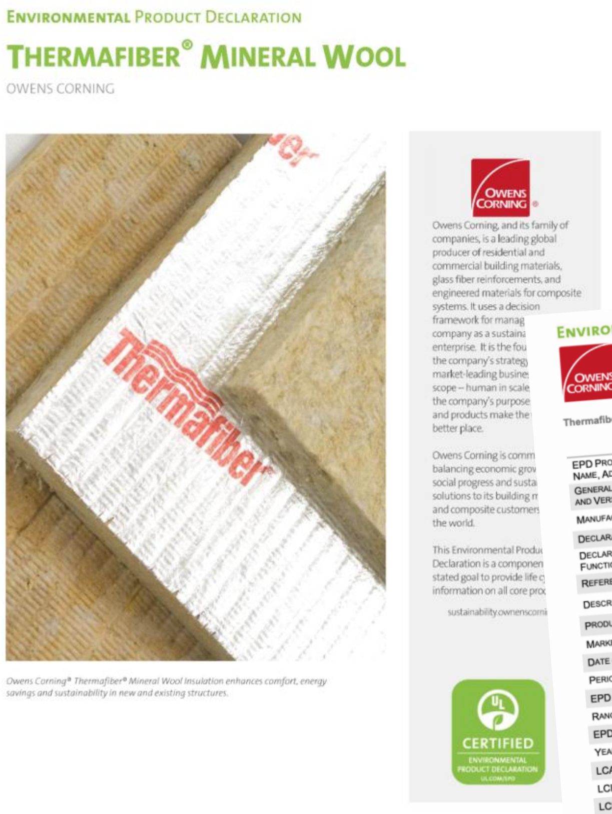
Courtesy Carbon Brief

… And a new look at MEP's Role



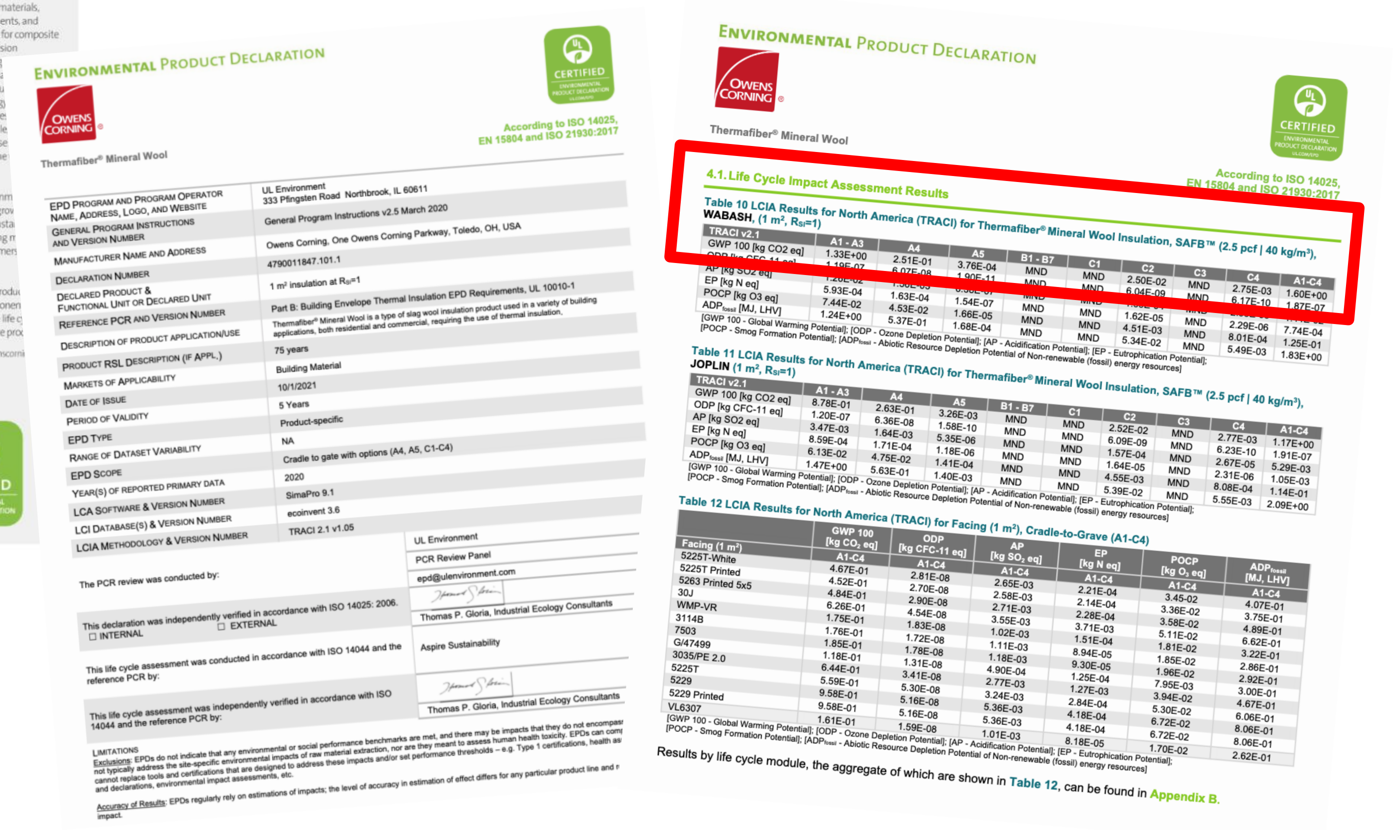
Case Study:
Wymer Hall, 100,000 SF Academic Building, Illinois
Credit: MEP 2040

Quantifying Carbon: Environmental Product Declarations (EPDs)



Product-specific EPD

- Standardized reporting on environmental impacts – including carbon
- Industry-level or product-specific analysis
- Can be in-house or third-party certified



GWP in kgCO2e is proxy for carbon emissions – here reported by life cycle stage

MEP Factors for Tracking Emissions

Material Scope of “MEP”

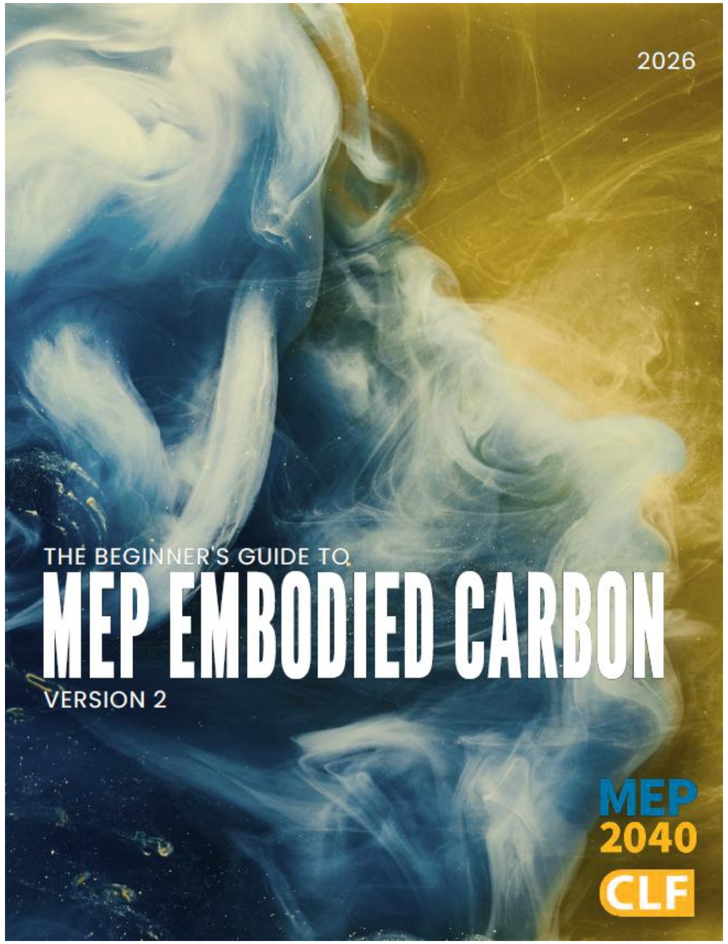
Included in Current Standards

- Mechanical (HVAC) Equipment
- Mechanical Piping and Ductwork
- Plumbing Pipe and Fixtures
- Electrical Equipment
- Lighting Fixtures
- Wiring and Conduit
- Photovoltaic Systems
- MEP Insulation

Other “MEP” Systems

- Vertical Transportation
- Fire Protection
- Low-voltage, data, communications
- Security, alarms
- A/V
- Misc. support – hangers, valves, fittings

MEP Whole Life Carbon Pilot



- 27 Participating Firms
- 20 pilot projects identified
- Results reported and tabulated
- Use of Revit and One Click LCA
- Required 60 – 80 EPDs per project, with many gaps in data

Carbon Leadership Forum - https://carbonleadershipforum.org/

Quantifying MEP

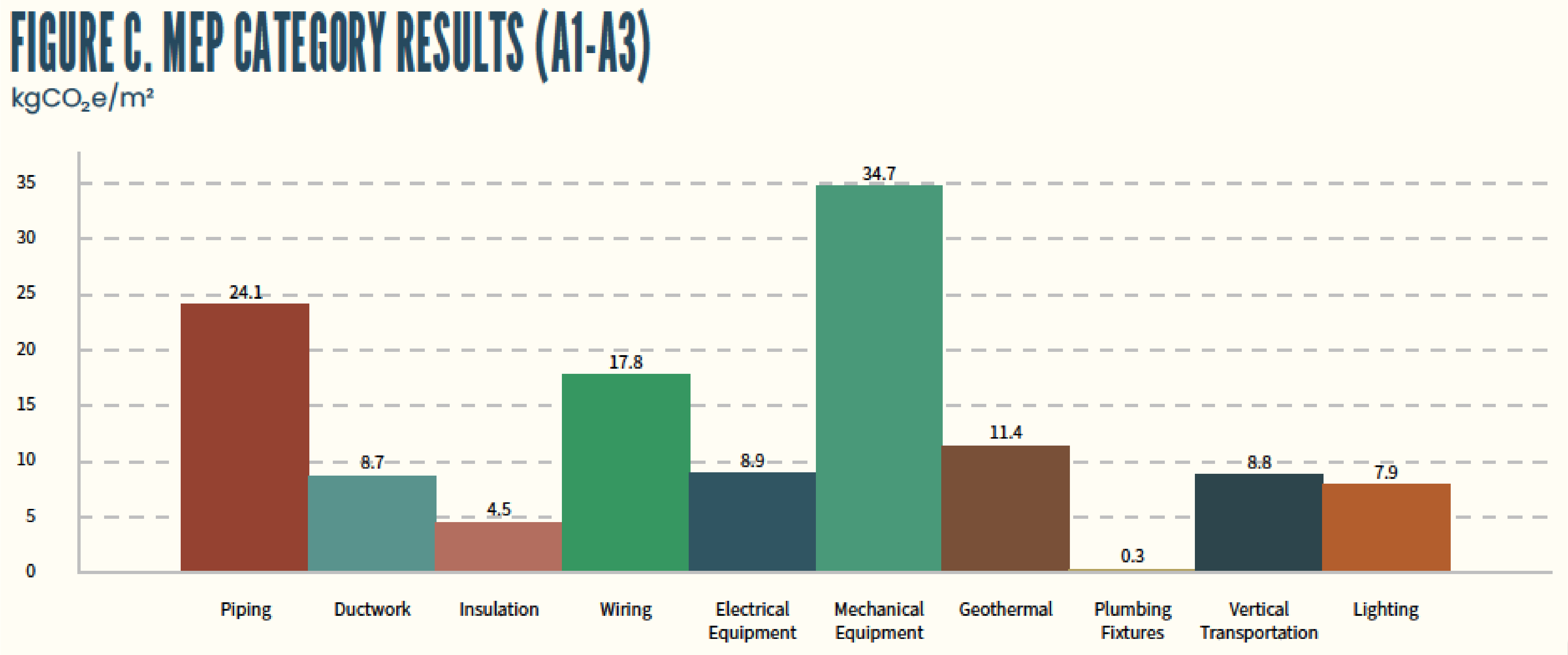
- Determine Units - Quantity, weight, length etc.
- Building Information Modeling (BIM) for take offs and tracking
- Define Exclusions

Case Study: Wymer Hall

Poll: Where is MEP Embodied Carbon impact highest?

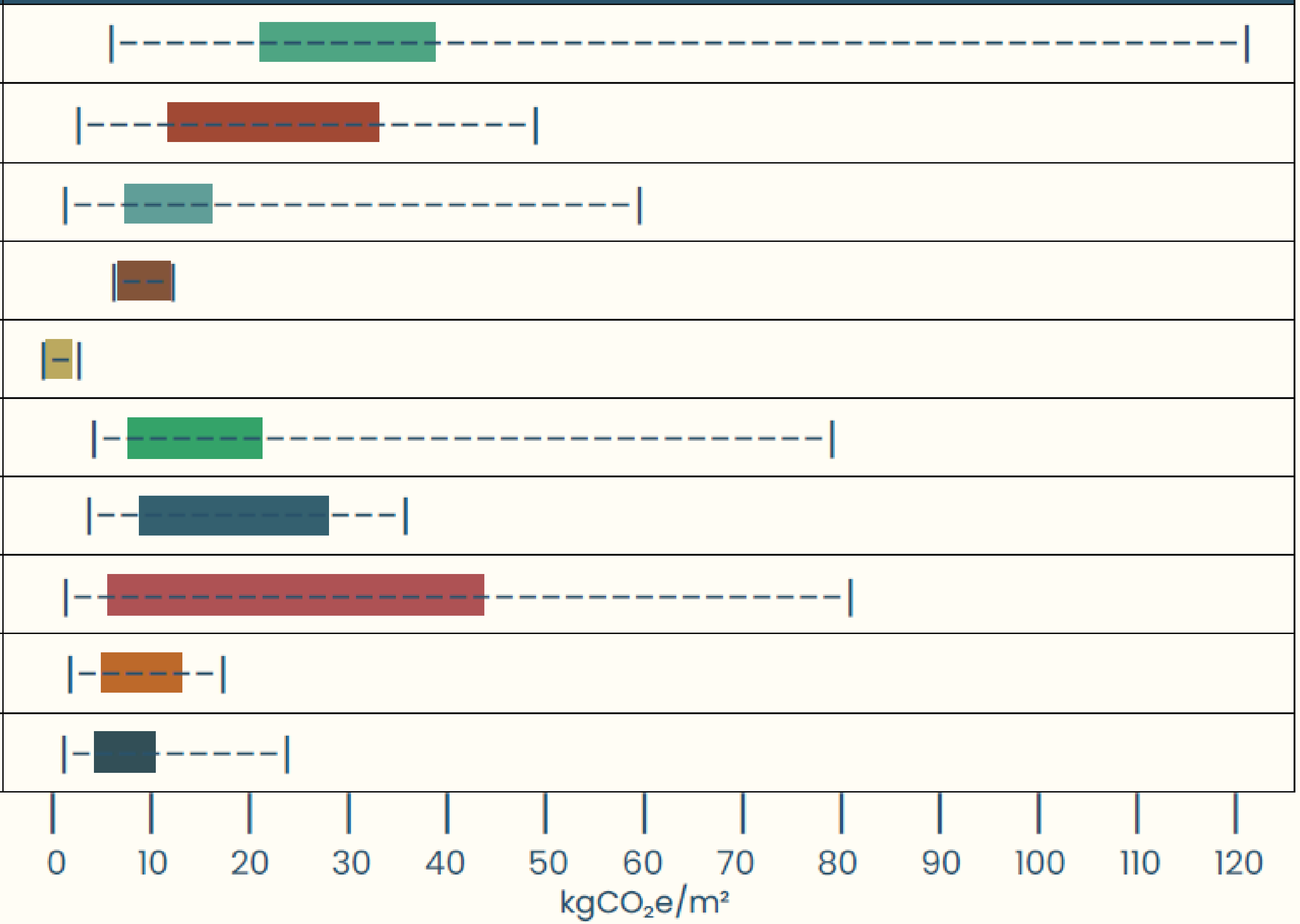
- Wiring
- Plumbing
- HVAC equipment
- Refrigerant
- Other?

Case Study, Cradle to Gate



MEP WHOLE LIFE CARBON PILOT - EMBODIED CARBON (A1-A3) BY CATEGORY

Category	Median $kgCO_2e/m^2$	Average $kgCO_2e/m^2$	n=
Mechanical Equipment	25	37	19
Piping	22	24	19
Ductwork	12	20	19
Geothermal	10	9	3
Plumbing Fixtures	1	1	19
Wiring	13	18	19
Electrical Equipment	14	17	19
Photovoltaic	27	31	9
Lighting	8	9	19
Vertical Transportation	6	8	16



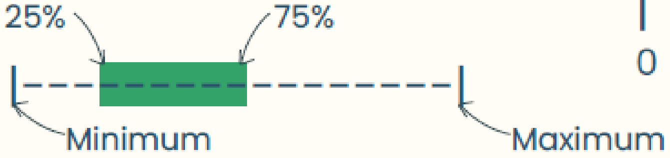
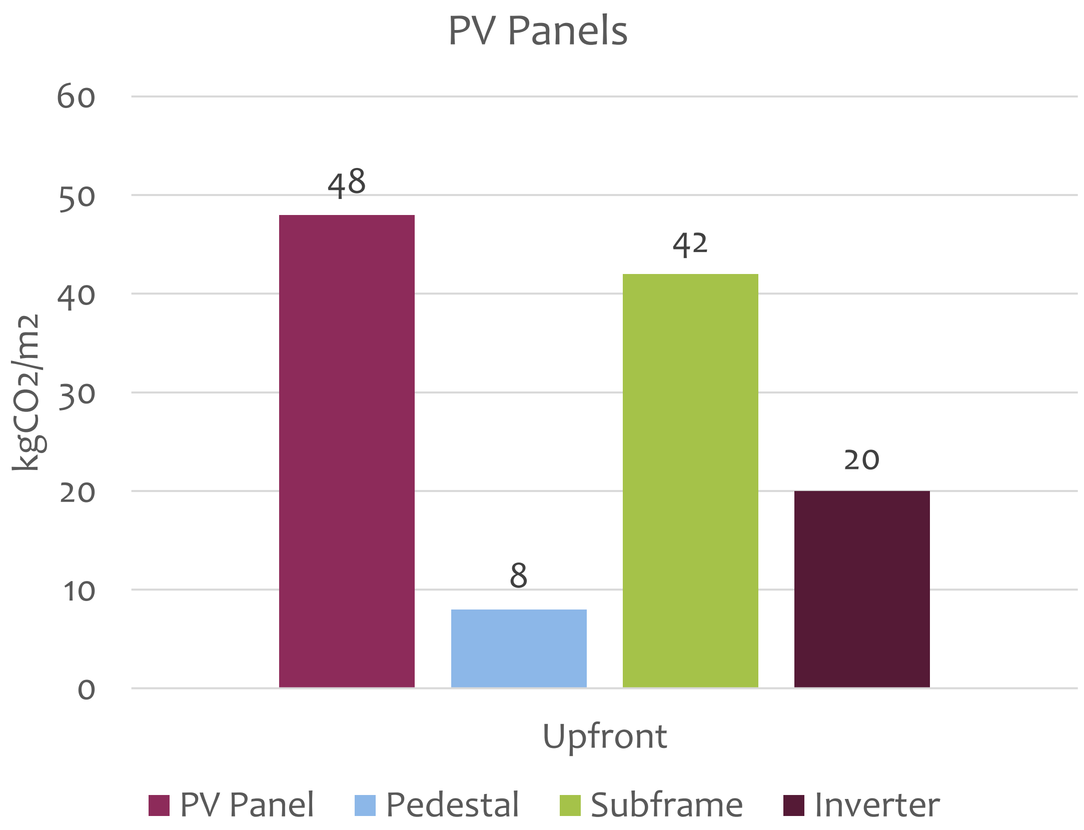


Figure 3. MEP 2040 Whole Life Carbon Pilot Embodied Carbon (A1-A3) by Category. Box and whisker plot showing cradle-to-gate LCA results for each category from the MEP Whole Life Carbon Pilot.

Sample Emissions – PVs



MEP Whole Life Carbon Pilot

Sample Emissions: Wiring and Piping

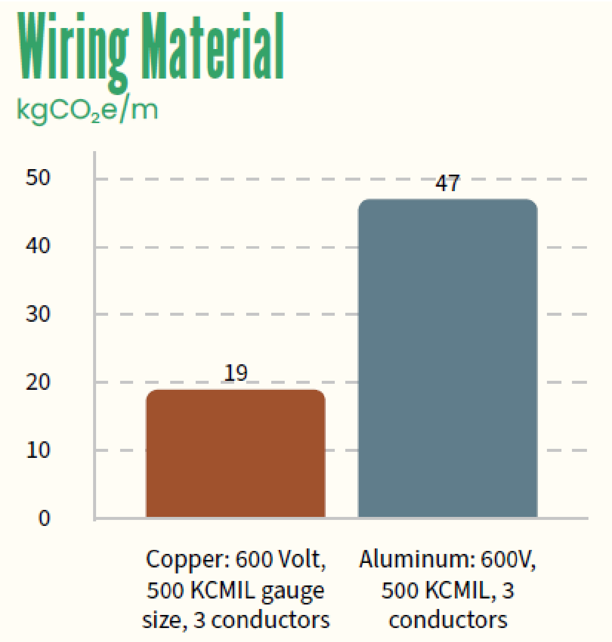


Figure 11. Wiring Material. For a functionally equivalent 600V, 500kcmil, 3 conductor wiring, aluminum appears the most carbon intensive, followed by copper.

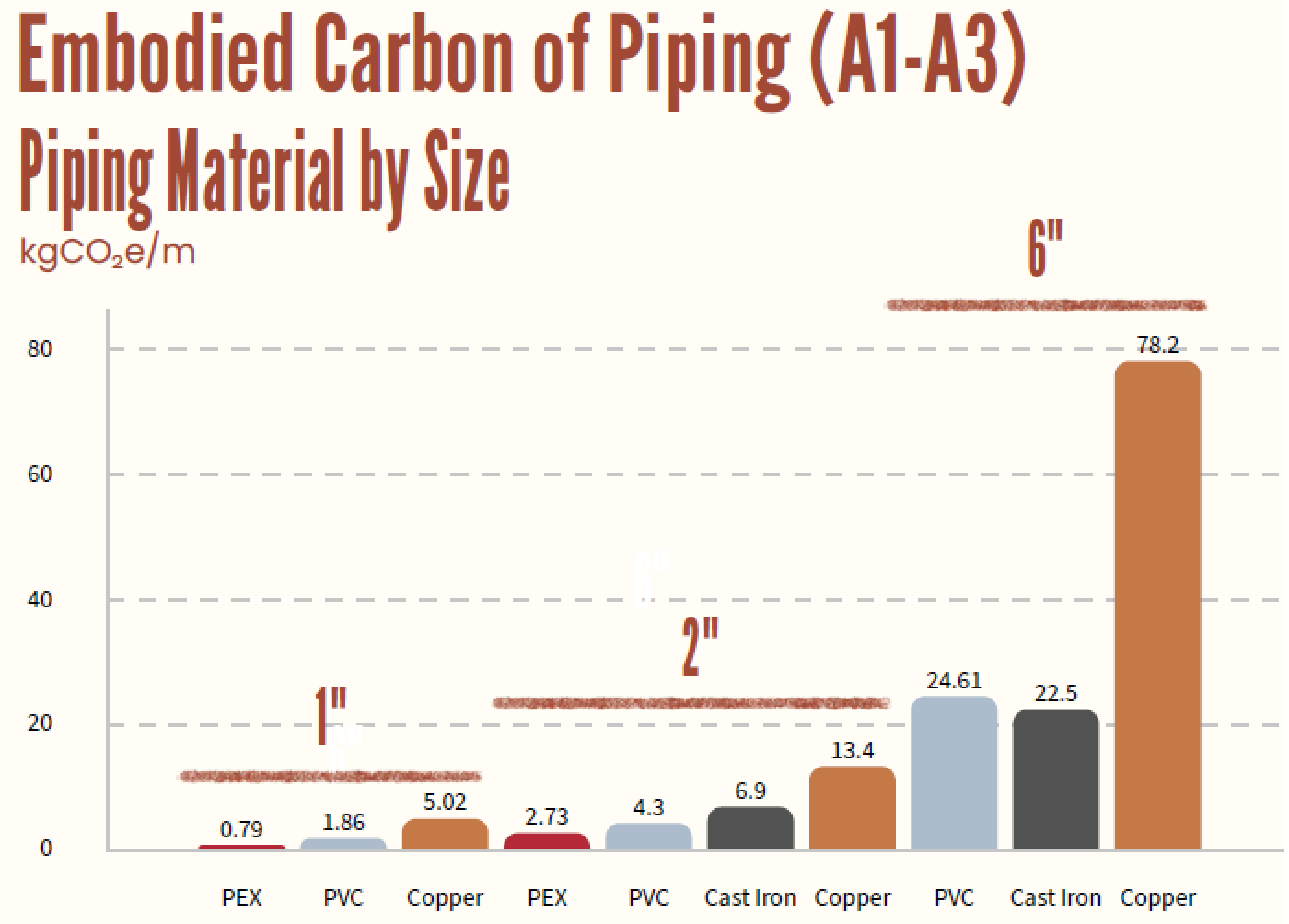
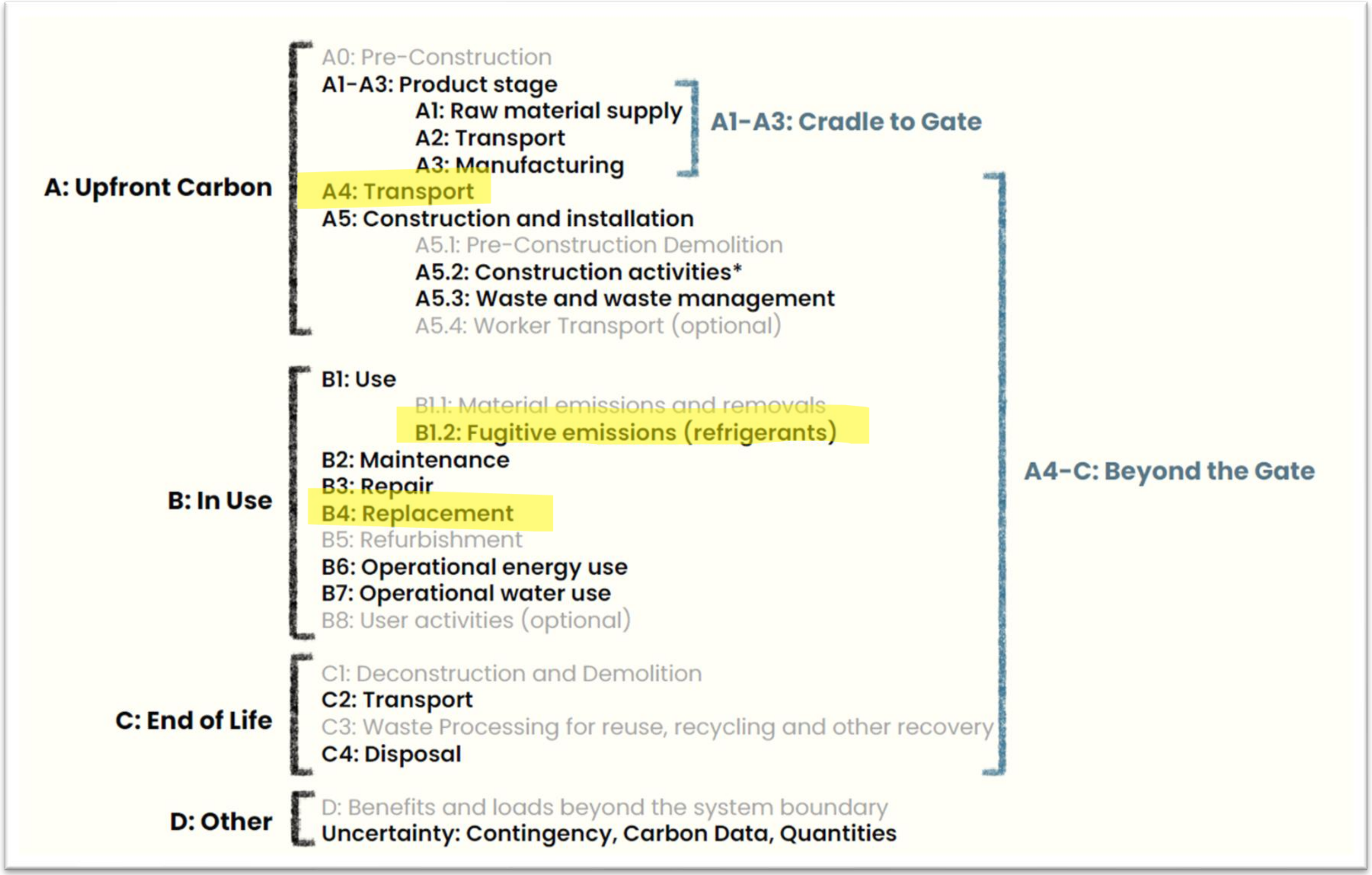


Figure 6. Piping Material by Size. For a functionally equivalent cross-sectional piping dimensions of 1", 2" and 6" sizes, copper appears the most carbon intensive. followed by PVC and then cast iron. Depending on the application size, PVC and cast iron trade places in their ranking.

Beyond the Gate (A4-C) + Contingency



Beyond the Gate (A4-D)

A4 - Transportation

- Transportation emissions are based on mass, distance and mode
- Compared to other building systems, MEP systems are high-mass and often travel significant distances

B4 Replacement

- Industry standards for Equipment Service Life
- Override with actual warrantied service life

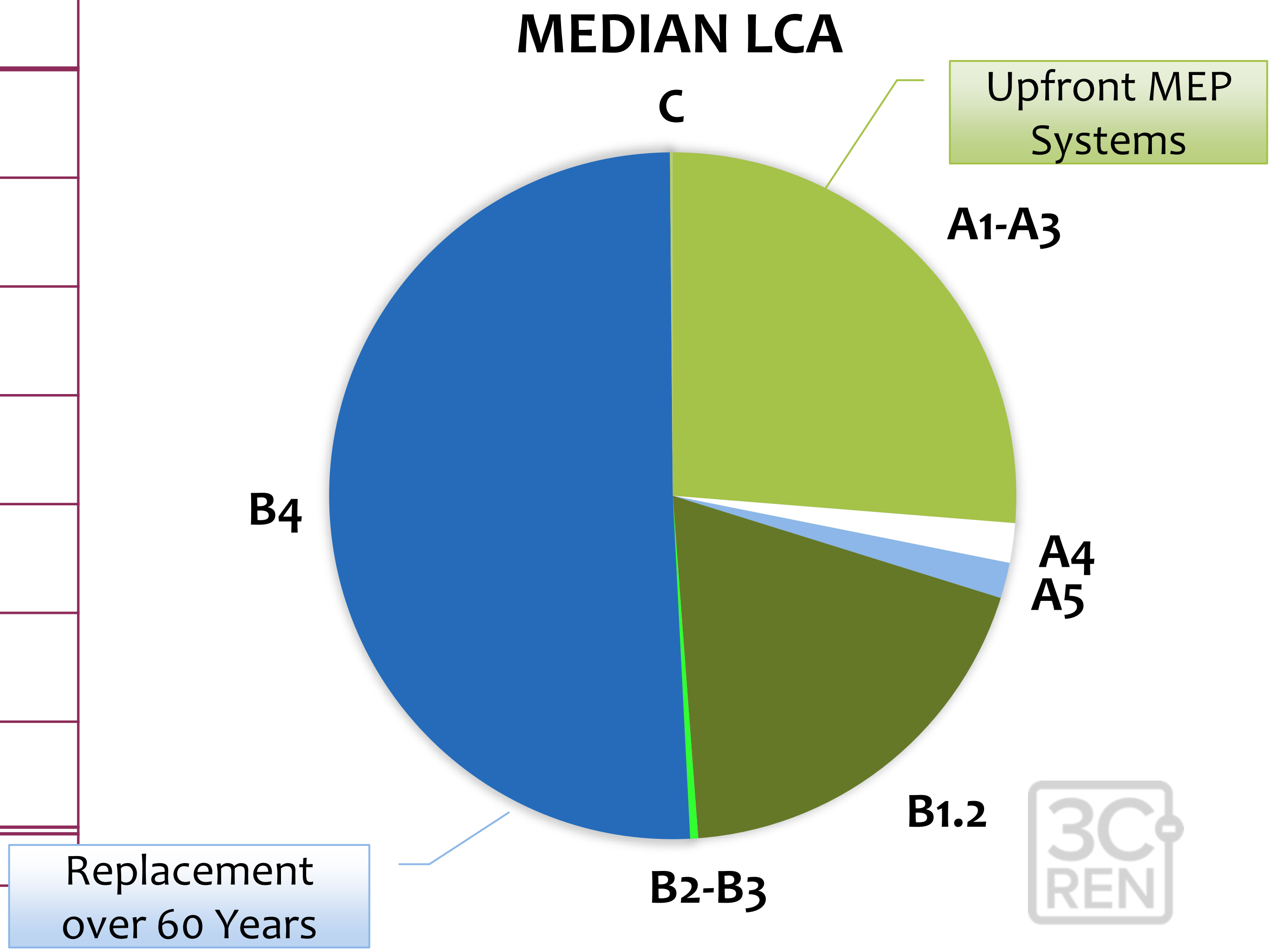
Poll: Where is MEP Carbon impact highest (by life cycle stage)?

- A1-A3 Product Manufacture
- A4 Transport
- B1.2 Refrigerants
- B4 Replacement
- B6 Operational

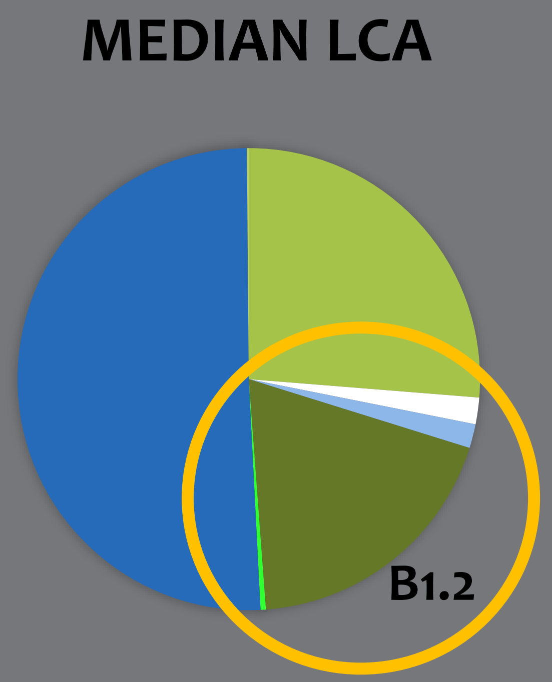
MEP Embodied Carbon - by Life Cycle Stage, $kgCO2e/m^2$

LCA Stage	Median	% of Total	Stage
A1-A3	141.0	26.3%	Product
A4	10.0	1.9%	Transport
A5	9.0	1.7%	Construction
B1.2	102.0	19.0%	Refrigerant
B2-B3	2.0	0.4%	Repair
B4	272.0	50.7%	Replacement
C	0.7	0.1%	End of Life
A-C Total	**1,087.1**		

MEP 2040 Pilot



Refrigerants (B1.2)



It's the Global Warming Potential (GWP)

Refrigerant	GWP	Common System Application	Notes
R410A	2088	Conventional VRF systems and Heat Pumps / Chillers	Commonly used refrigerant with high GWP, also regularly used in distributed refrigerant systems with high system volumes increasing risk of leakage and potential climate damage
R134a	1430	Heat Pumps/ Chillers	
R32	633	Hybrid VRF systems and Heat Pumps / Chillers	R32 is mildly flammable* and is a HFC with a reasonably high GWP, however this is <1/3 of the GWP of other common HFCs such as R410A
R290 (propane) & R600 (butane)	3 & 4 respectively	Heat Pumps/ Chillers	R290 and R600 are Hydrocarbons which are highly flammable and heavier than air*
R1234ze	<1	Heat Pumps/ Chillers	An HFO refrigerant, typically available for large plant, R1234ze is mildly flammable*
R744 (CO2)	1	Heat Pumps	CO2 can be used in high temperature heat pumps, such as those dedicated to the production of domestic hot water. Systems are high pressure and require a low water temperature onto the heat pump to maximise coefficients of performance (COP) in heating
R717 (NH4, ammonia)	0	Heat Pumps	Typically available for large plant. Ammonia is mildly flammable and has medium toxicity concerns*

Table 1 - Table of refrigerants, their GWP and their common applications

Recall GWP measured in kgCO2e

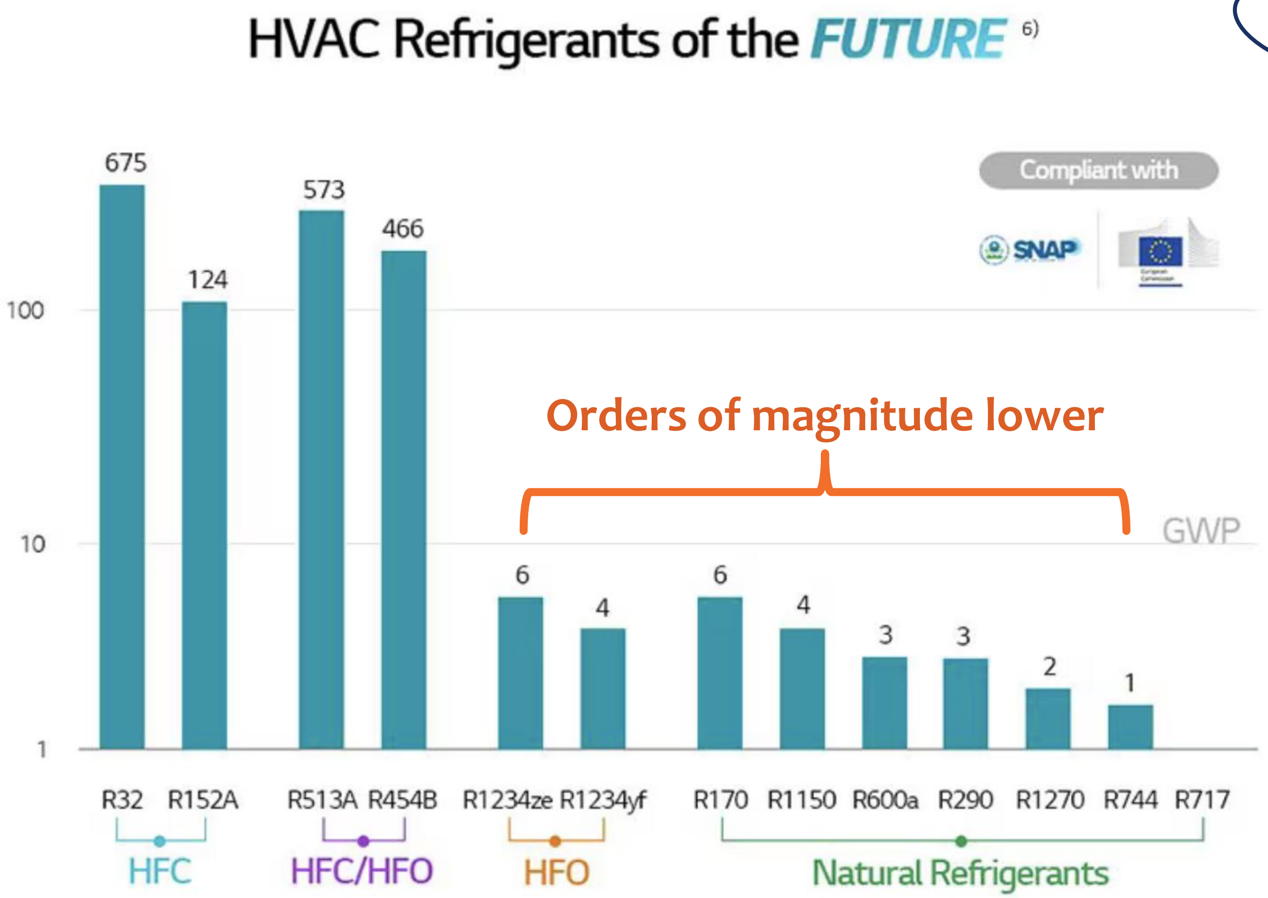
GWP of R410a = 2088, or the equivalent of 2088 times CO2

California building and mechanical codes limit (as of January 2025) the GWP of refrigerants to 750.

This has prompted a shift toward lower GWP refrigerants – including CO2 (1) and R717 (0).

Refrigerants of the Future

CFCs and HCFCs phased out globally with The Montreal Protocol (1987)



Calculating Fugitive Emissions and Leakage

“Different types of systems pose different leakage scenarios, given variation in the refrigerant charge, extent of piping, equipment type, installation, maintenance, refill and disposal practices.” – *MEP 2040*

B1.2 Fugitive Emissions Refrigerants Calculations[2]

$$[\text{B1.2 Installation}] = REF_{ch,site} \times x_i \times GEF_{ref} \times \#Inst$$

$$[\text{B1.2 Annual}] = REF_{ch,tot} \times x_o \times GEF_{ref} \times RSP$$

$$[\text{B1.2 EOL}] = REF_{ch,tot}\ (1-Z_d) \times GEF_{ref} \times \#Disp$$

- REF_{ch} = Refrigerant charge weight
- X_i and X_o are leakage rates
- GEF_{ref} = 100-yr emissions factor of refrigerant used

Example: Wymer Hall

- REF_{ch} = 240lb or 108.8kg
- X_i and X_o = 0.01 and 0.03
- GEF_{ref} = 2285 (R410a)

B1.2 Fugitive Emissions Refrigerants Calculations[2]

[B1.2 Installation] = $REF_{ch,site} \times x_i \times GEF_{ref} \times \#Inst$

[B1.2 Annual] = $REF_{ch,tot} \times x_o \times GEF_{ref} \times RSP$

[B1.2 EOL] = $REF_{ch,tot}\ (1-Z_d) \times GEF_{ref} \times \#Disp$

[B1.2 Installation] = 108.8kg x 0.01 x 2255kgCO$_2$e/kg x 4 installations = 9813 kgCO$_2$e

[B1.2 Annual] = 108.8kg x 0.03 x 2255kgCO$_2$e/kg x 60 years= 441,619kgCO$_2$e

[B1.2 EOL] = 108.8kg x (1-0.8) x 2255kgCO$_2$e/kg x 4 disposals= 196,275kgCO$_2$e

Total 647,707 kgCO$_2$e

Table 16. Default Leakage Rates for Refrigeration/Air Conditioning Equipment[1]

Equipment Type as Listed in ASHRAE 240P Draft	Equipment Type Listed in MEP 2040 Reporting Template	Installation Leakage Rate[a]	Annual Operating Leakage Rate	Recovery Efficiency
Residential AC/HP (ducted)	Split Systems - Ducted	1%	5%	80%
Small self contained AC/HP (PTAC/HP)	Heat Pumps - self-contained (PTAC, PTHP, WSHP)	NA	1%	80%
Residential mini-split and multi-split ductless AC/HP	Split Systems - Ductless	1%	2.5%	80%
Commercial ductless VRF Systems	VRF Systems	1%	3%	80%
Light Commercial Rooftop AC/HP units (5-25 tons)	Air Handling Units < 25 tons	1%	8%	80%
Large Commercial Rooftop AC/HP units (>25 tons)	Air Handling Units > 25 tons	1%	6%	80%
Water-cooled Centrifugal & Screw Chillers (all sizes)	Chillers/heat pumps - water cooled	1%	3%	80%
Air-cooled Chillers (all sizes)	Chillers/heat pumps - air cooled	1%	6%	80%

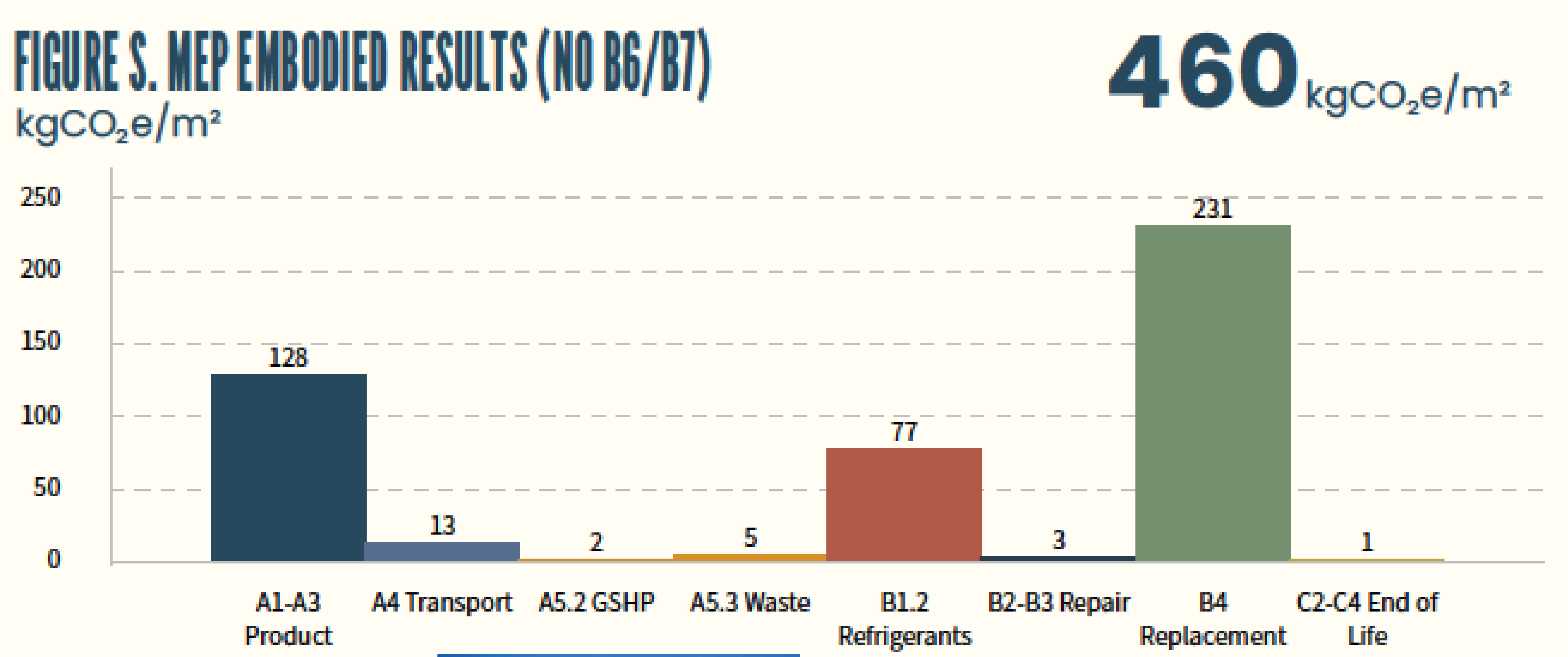
a. For equipment charged at a factory and not connected to field refrigerant piping, use an installation rate of 0.0%.

Strategies for Possible Reductions

Strategy	Reduction
Equipment switch could double annual leakage, but not a lot of commercial options for savings.	Limited
Less Refrigerant (e.g. reduce line length by half)	325,000 kgCO$_2$
Lower GWP refrigerant (e.g. R32)	430,000 kgCO$_2$

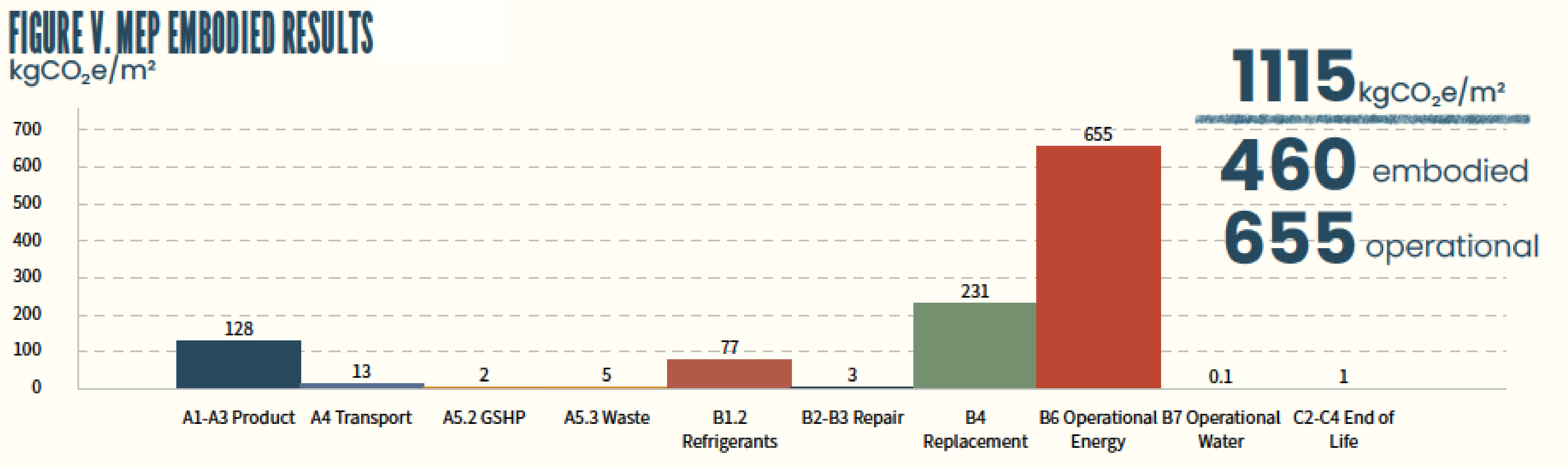
Whole Life Carbon for MEP

Embodied Carbon for MEP – Whole Life (60 years)



Case Study: Wymer Hall

With operational energy

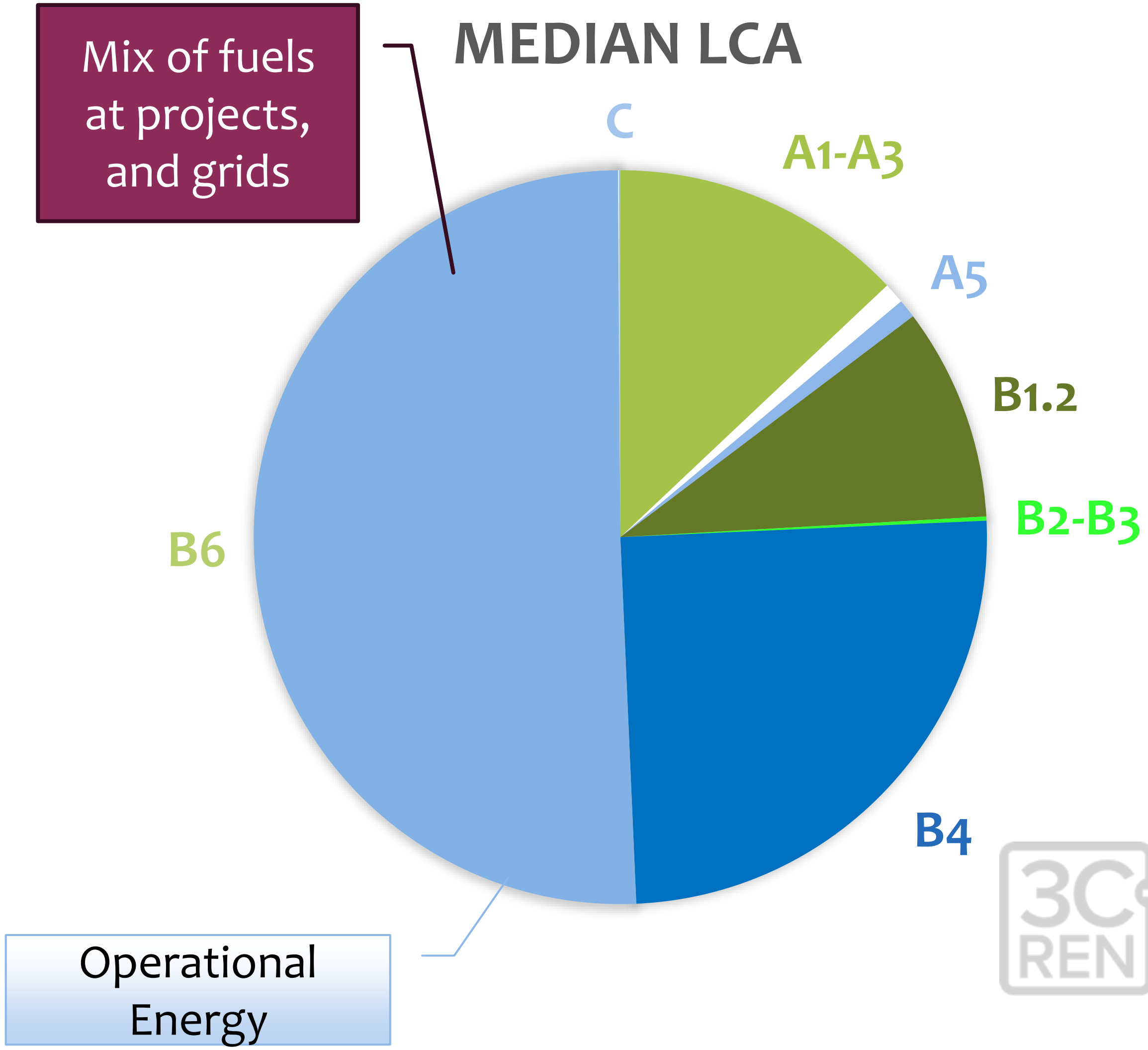


Case Study: Wymer Hall

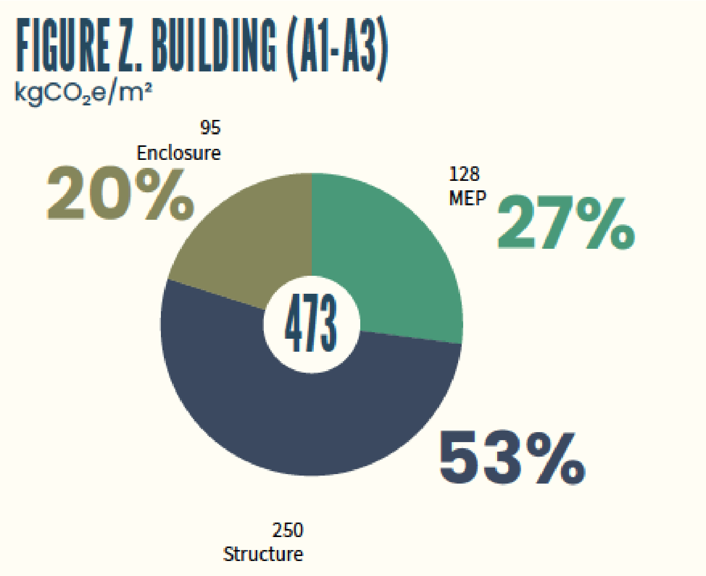
LCA with Operational Carbon, $kgCO2e/m^2$

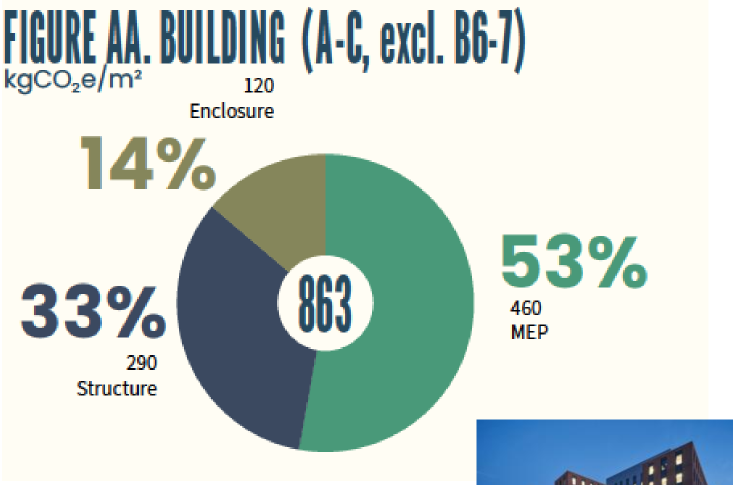
LCA Stage	Median	% of Total	Stage
A1-A3	141.0	13.0%	Product
A4	10.0	0.9%	Transport
A5	9.0	0.8%	Construction
B1.2	102.0	9.4%	Refrigerant
B2-B3	2.0	0.2%	Repair
B4	272.0	25.0%	Replacement
B6	**550.0**	**50.6%**	**Operational Energy**
B7	**0.4**	**0.0%**	**Operation Water**
C	0.7	0.1%	End of Life
A-C Total	**1,087.1**		

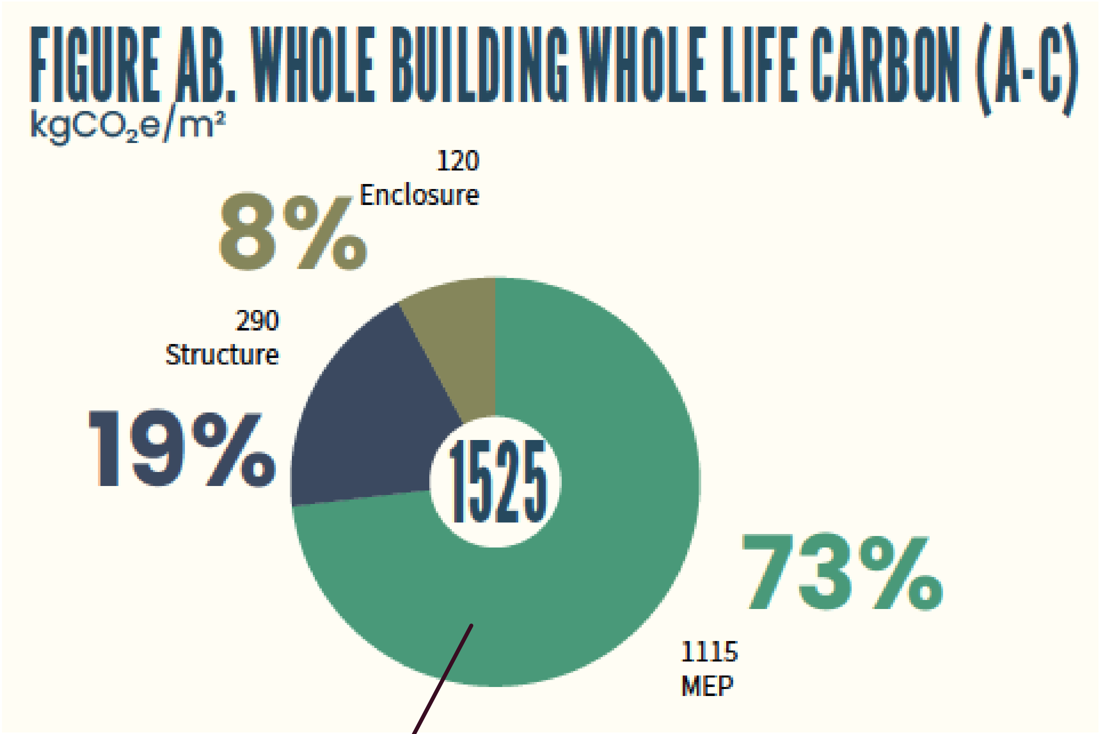
MEP 2040 Pilot



Full Circle: All together now







Lumps Operational Energy into MEP. Reasonable?

Case Study: Wymer Hall

Strategies for Reducing Emissions

Design for Energy Efficiency, of course

- e.g., Better Windows
  - *May* have higher embodied carbon
- Reduced HVAC
  - Smaller mechanical equipment and ducting
- Reduced Electrical
  - Smaller Electrical gear and wiring
- Lower-impact replacements
  - May have longer lifespans

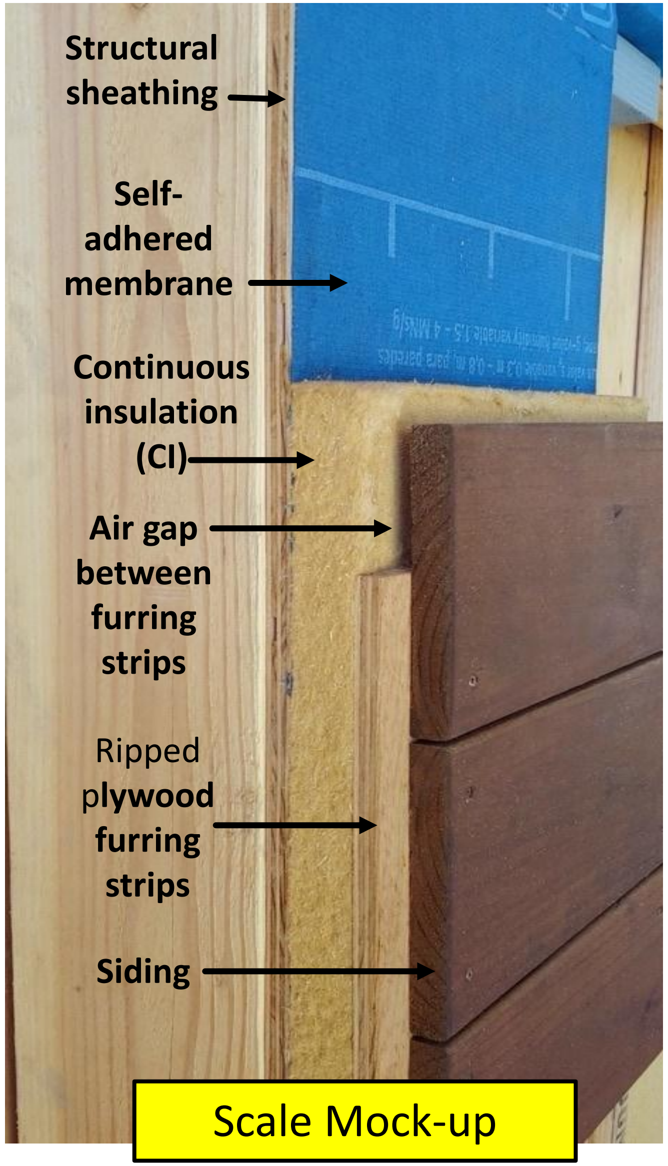
AND Reduced Operational Carbon

Think about the "Domino Effect" of LCA Choices:

- Passive Design Strategies
- Quality insulation and windows
- Great air sealing
- Balanced daylighting
- Design for 'off'

Energy Efficiency and ZNE

Passive House, San Luis Obispo. *Design-Build: Mike Horgan, Cairn Collaborative*



- Passive House level of insulation and air sealing
- Quality windows, strategic sizing and placement
- One ductless mini-split with Ducted HRV
- No natural gas
- 12 solar panels – fully ZNE
- Very small MEP Carbon footprint…

Consider LCA at Conceptual MEP Design

- Consider fewer heating and cooling systems and more balanced air distribution for thermal comfort
- Consider thermal energy storage (TES) to reduce peak cooling loads and the subsequent peak equipment and refrigerant charge
- Use targeted metrics when appropriate, e.g., emissions per "cooling ton" vs. per floor area
- Select products for a long lifespan

3C REN

Additional MEP Strategies

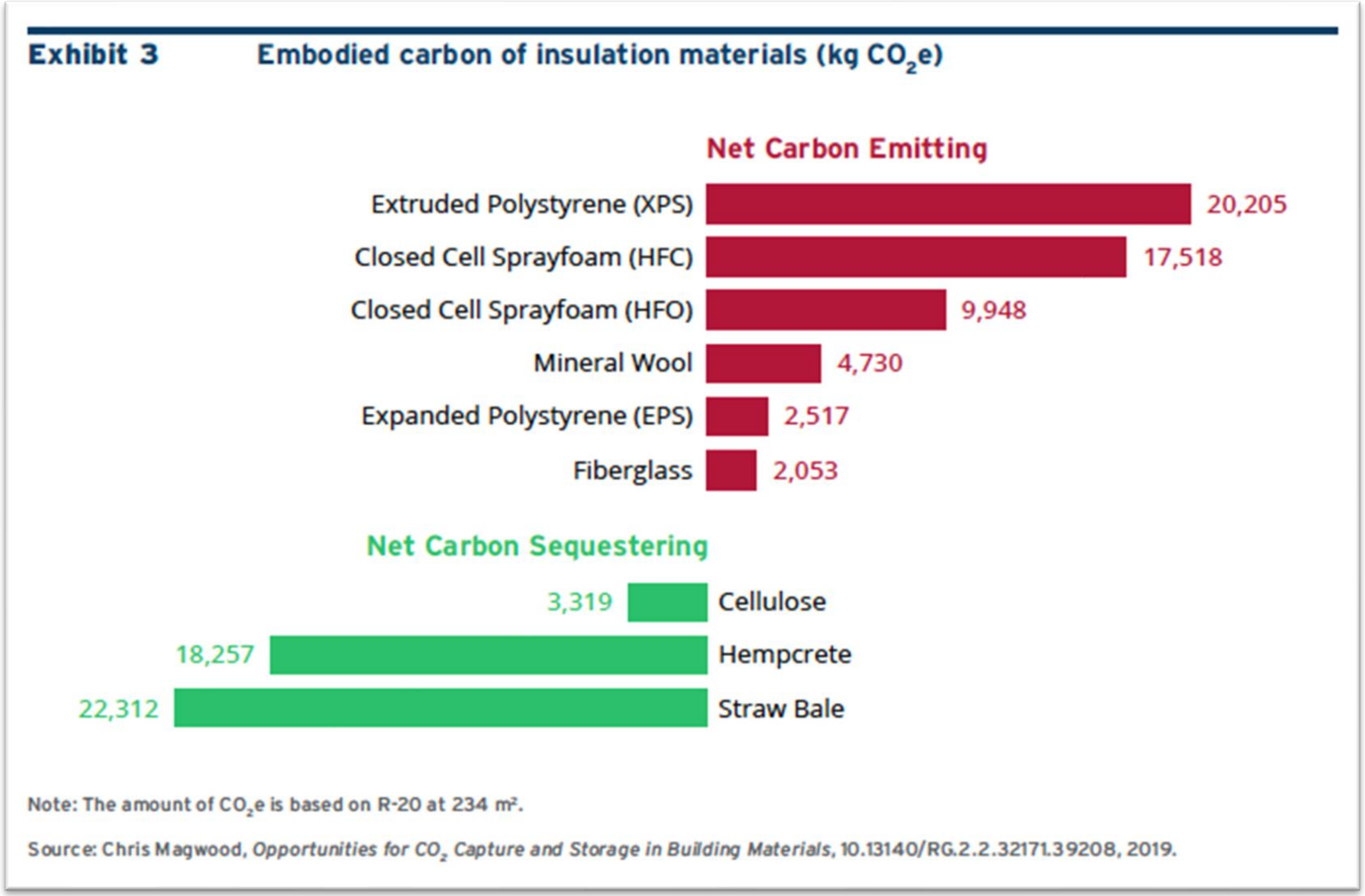
- Review EPDs and compare data for equivalent products
- Select metals with higher recycled content
- Design distribution systems for efficiency, *and coordinate in the field*
- Understand 'hidden' embodied carbon, e.g., PV subframe.

Single family home bath fan ducts
Photo: Energy Vanguard

Specify low-emitting insulation

- Look for low-GWP insulation for ducts and pipe
- Run ducts in conditioned space

Rockwool Pipe Insulation



Reduce Refrigerants

- Select low-GWP refrigerants
- Consider distribution options, e.g., hydronic vs. refrigerant, to reduce leakage potential
- Right-size equipment; tight factors of safety
- Consider shifting peak demand

Looking Ahead

- ASK suppliers and manufacturers for EPDs and explain why they're helpful
  - Even when you're not doing a full LCA
  - Become familiar with what's available and where the variables are
- Advocate for policies and programs that recognize MEP embodied carbon and refrigeration impacts

GENERAL INFORMATION

MANUFACTURER INFORMATION

Manufacturer	Daikin Applied Europe SpA
Address	Via Piani di Santa Maria, 72 00072 Ariccia (Rome) Italy
Contact details	epddae@daikinapplied.eu
Website	https://www.daikinapplied.eu/ EWYT-CZ (daikinapplied.eu)

PRODUCT IDENTIFICATION

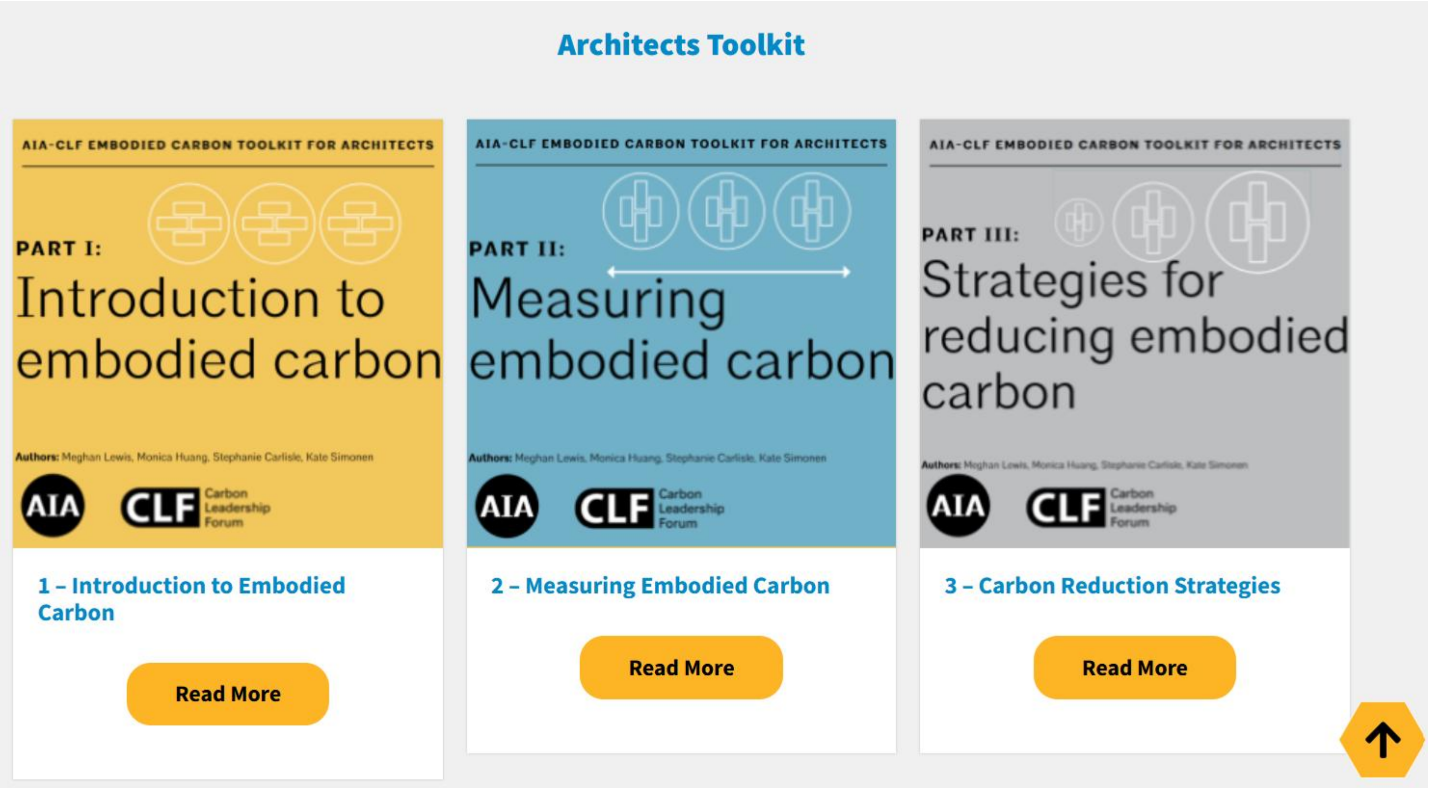
Product family	EWYT-CZ

PRODUCT INFORMATION

Product	EWYT-CZ		
Function	Reversible heat pump for comfort heating and cooling for residential or light commercial applications.		
Model	EWYT64CZP-A2		
$P_{heating}$ (P_h)	43,42 kW	$P_{cooling}$ (P_c)	64,28 kW
$t_{heating}$	2066	$t_{cooling}$	600
SCOP	2,87	SEER	5,34
Capacity, P rev	$P_{rev}(kW) = \frac{(t_{heating} * P_h + t_{cooling} * P_c)}{(t_{heating} + t_{cooling})}$		48,11 kW

Industry Efforts and Resources

Carbon Leadership Forum



- Research
- Resources
- Benchmarking
- Case studies
- Toolkits
- Etc.

https://carbonleadershipforum.org/

The MEP 2040 Challenge

MEP 2040
Committing to Zero

"All systems engineers shall advocate for and achieve net zero carbon in their projects: operational carbon by 2030 and embodied carbon by 2040."

architecture 2030

SEI ASCE STRUCTURAL ENGINEERING INSTITUTE

SE2050 COMMITTING TO NET ZERO

The MEP 2040 Commitment

1. Establish a company plan
2. Request low-GWP refrigerants
3. Request EPDs
4. Participate in Forums

Sign the Commitment – MEP Firms

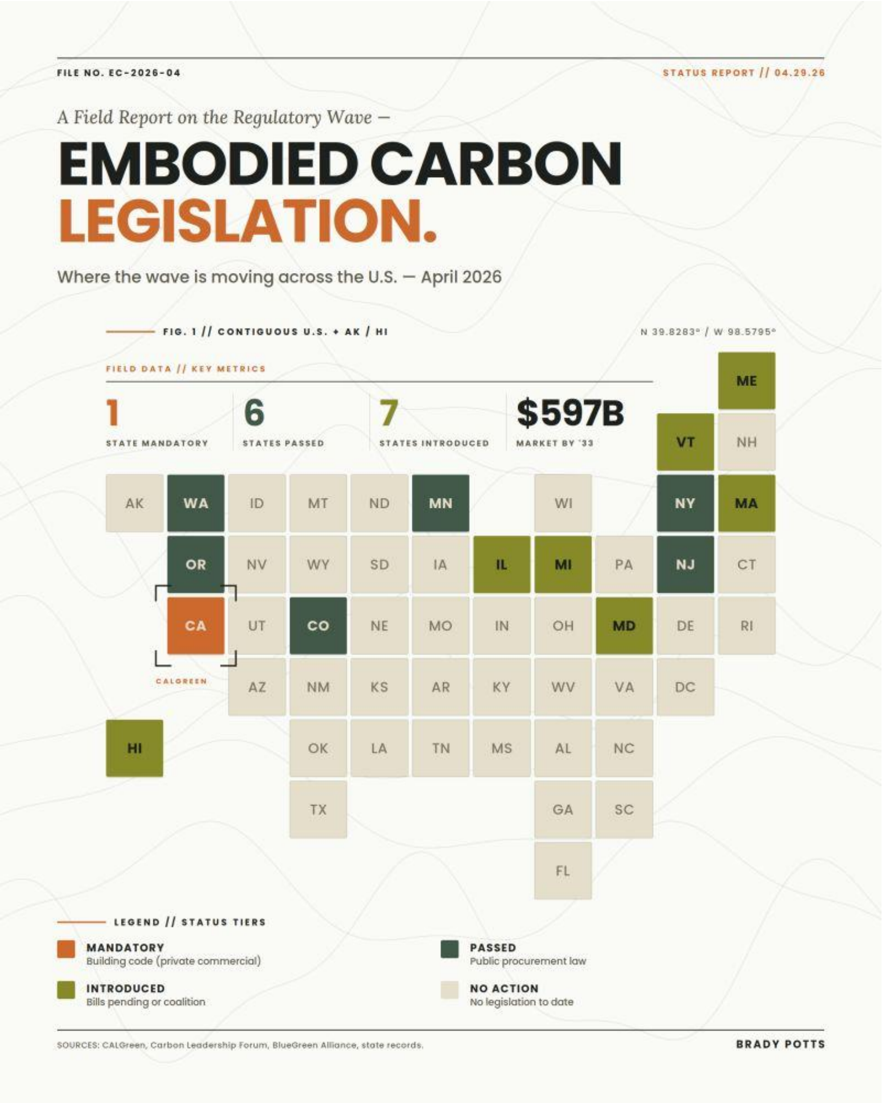
Sign the Commitment – Non-MEP Organizations

MEP Signatories – a snapshot

LONE STAR MEPI	LORING CONSULTING ENGINEERS	LPA	MacDonald-Miller FACILITY SOLUTIONS®	MaGrann ASSOCIATES	MAZZETTI
MCE	McKinstry For The Life Of Your Building	me engineers	MEPCE	MERITS	MEYERS+ ENGINEERS
MODUS	Mueller	NEWCOMB & BOYD NB	NEXT 2nd CO., LTD	NORR	NV5
ONNA ENGINEERING CONTRACTING	P2S INC	PAE	PALADÍN	PLEX BUILDING SYSTEMS INC.	POINTENERGY INNOVATIONS
positive energy	PROGRESSIVE COMPANIES	RANDALL LAMB	REG RESOURCE ENGINEERING GROUP	rda Robert Director Associates Consulting Engineers	RWS R.W. Sullivan Engineering
ryan soames engineering	SÄZÄN	SDC SURVEY.DESIGN.CONSULT	Smith + Andersen	SMITHGROUP	SSR
SOM	SYSKA HENNESSY GROUP	STAENGL ENGINEERING	Stantec	taylor engineers	TLC ENGINEERING SOLUTIONS

Closing Thoughts

- Evolving Knowledge
- Evolving Policy and Legislation
- CALGreen journey on Embodied Carbon
  - Current: 50,000 SF Non-Res
  - 3 pathways, all with limited scope, no MEP
- Addressing challenges along the way
  - Quantities, complexity, EPD availability
- Increasing industry interest and/or acceptance



Questions about Title 24?

3C-REN offers a *free* Code Coach Service

Online:
3c-ren.org/code

Call:
805.781.1201

Energy Code Coaches are local experts who can help answer your Title 24 Part 6 or Part 11 questions.

They can provide code citations and offer advice for your res or non-res projects.

Thanks for coming!

Continuing Education Units Available

- Contact chloe.swick@venturacounty.gov with any questions

Today's Slides and Recording are Coming to Your Inbox Soon!

Upcoming Courses:

- **Green Building Construction Tour– Morro Bay (6/16)**
- What a Load Calculation Is and Why One Is So Important (7/7)
- Next Generation Passive Solar and Passive House (7/22)
- Ask the Experts: Energy Compliance and Modeling (8/19)
- Introduction to Residential HVAC Design (8/20)