Embodied Carbon in Energy Codes? Yes, No, Maybe, I Don't Know

Michael Waite

National Energy Codes Conference | Chicago, IL

May 4, 2023

American Council for an Energy-Efficient Economy

Overview

- What is the Potential for Embodied Carbon and Codes?
- Material-Focus | Prescriptive and/or Mandatory
- Whole Building Lifecycle | Performance
- What About Energy Codes?
- What Next?

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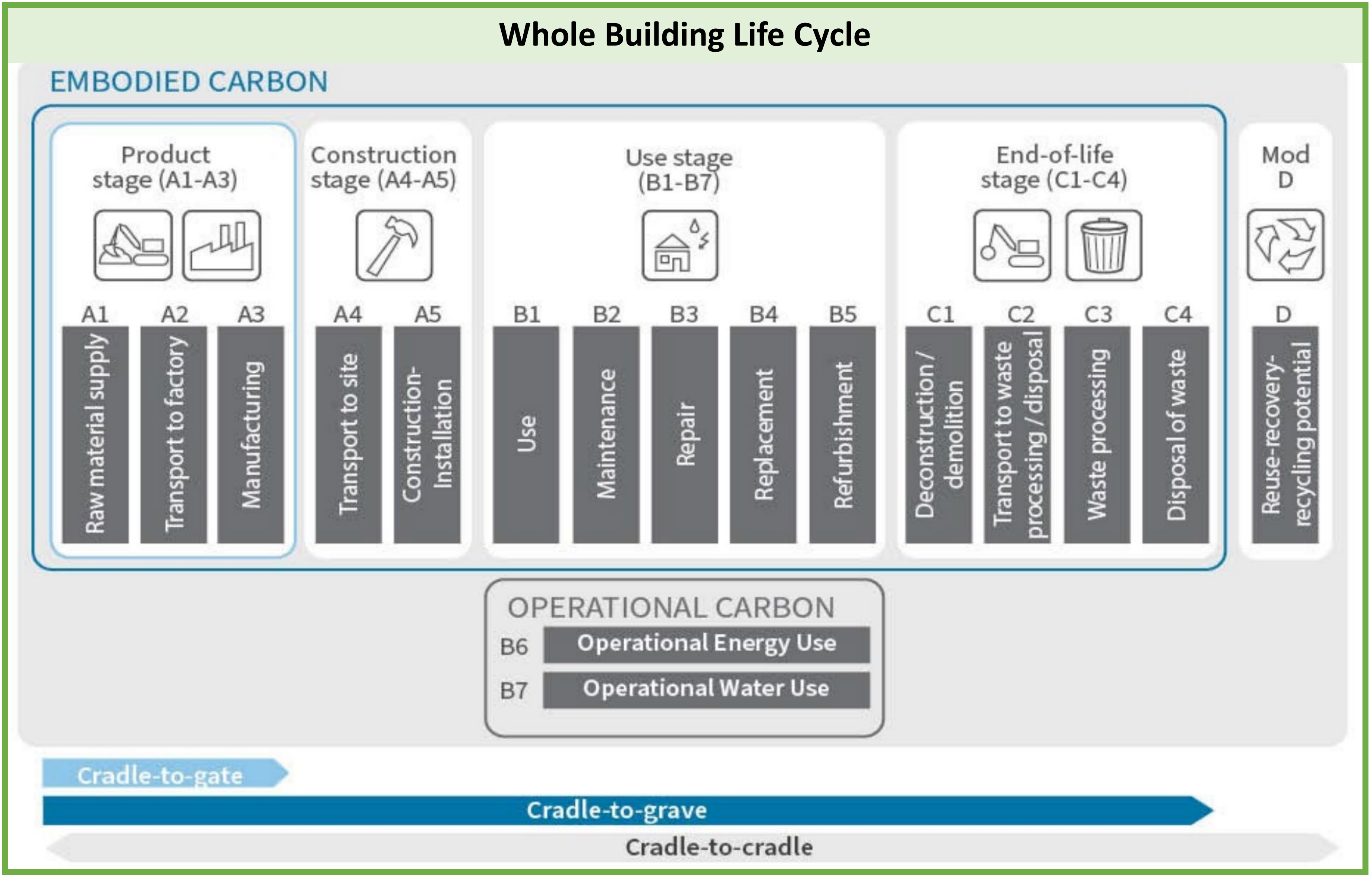
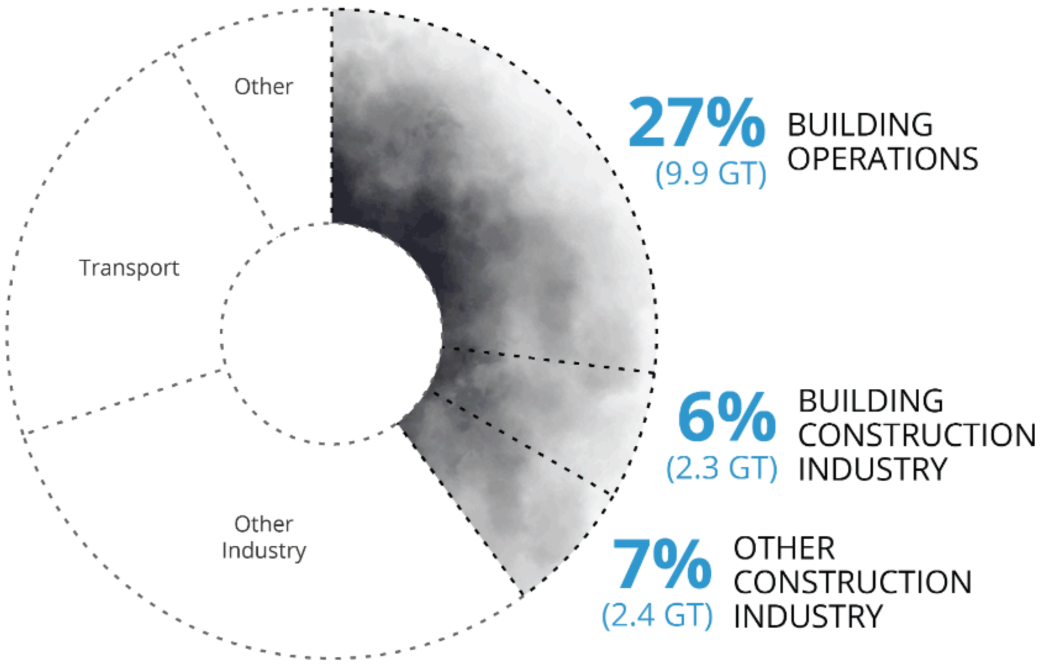
What is Embodied Carbon?



- Material extraction
- Manufacturing
- Transportation
- Construction
- Usage (not "operation")
- Maintenance and repair
- Deconstruction
- Waste processing

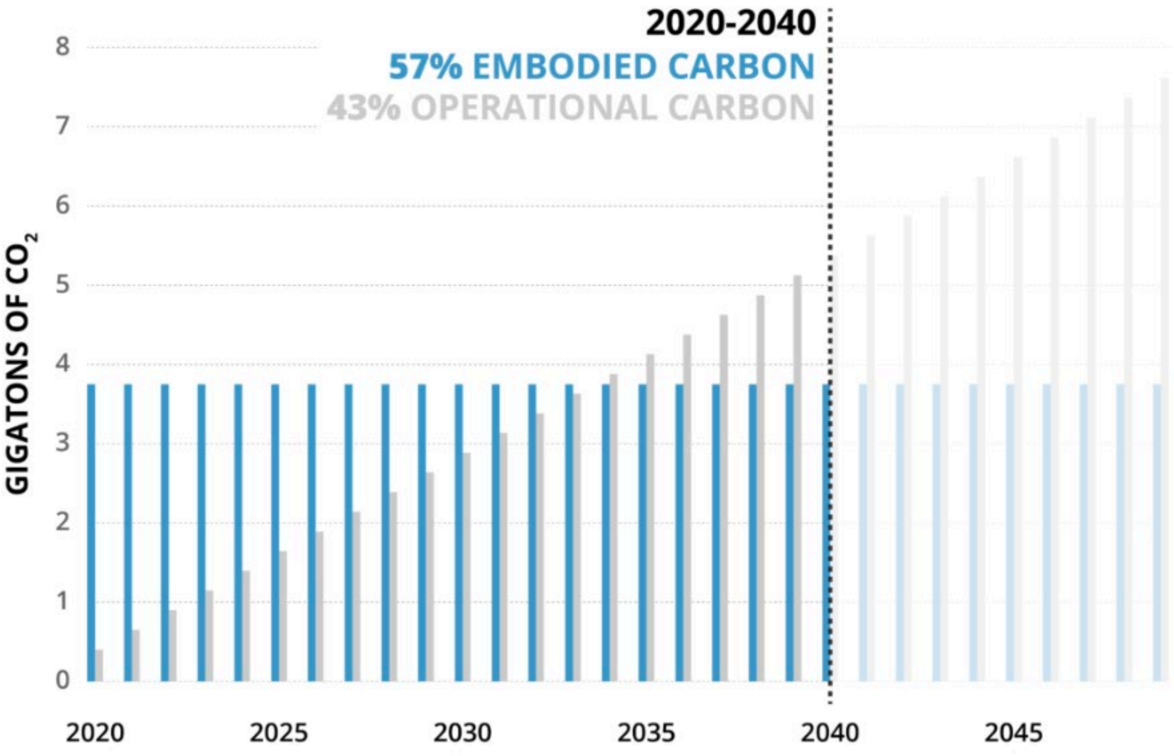
Advisory Public Review draft of BSR/ASHRAE/ICC Standard 240P-202X, available at https://osr.ashrae.org/

Why Embodied Carbon?



 Data Source: IEA (2022), Buildings, IEA, Paris

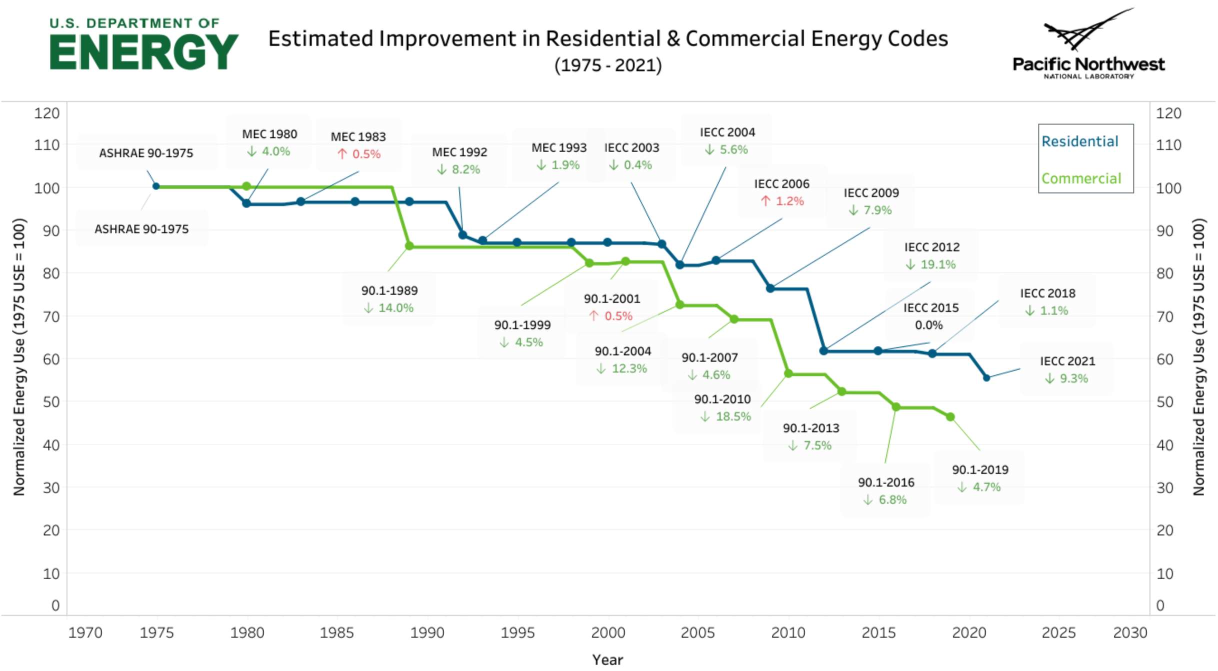
Building Construction Industry and Other Construction Industry represent emissions from concrete, steel, and aluminum for buildings and infrastructure respectively.



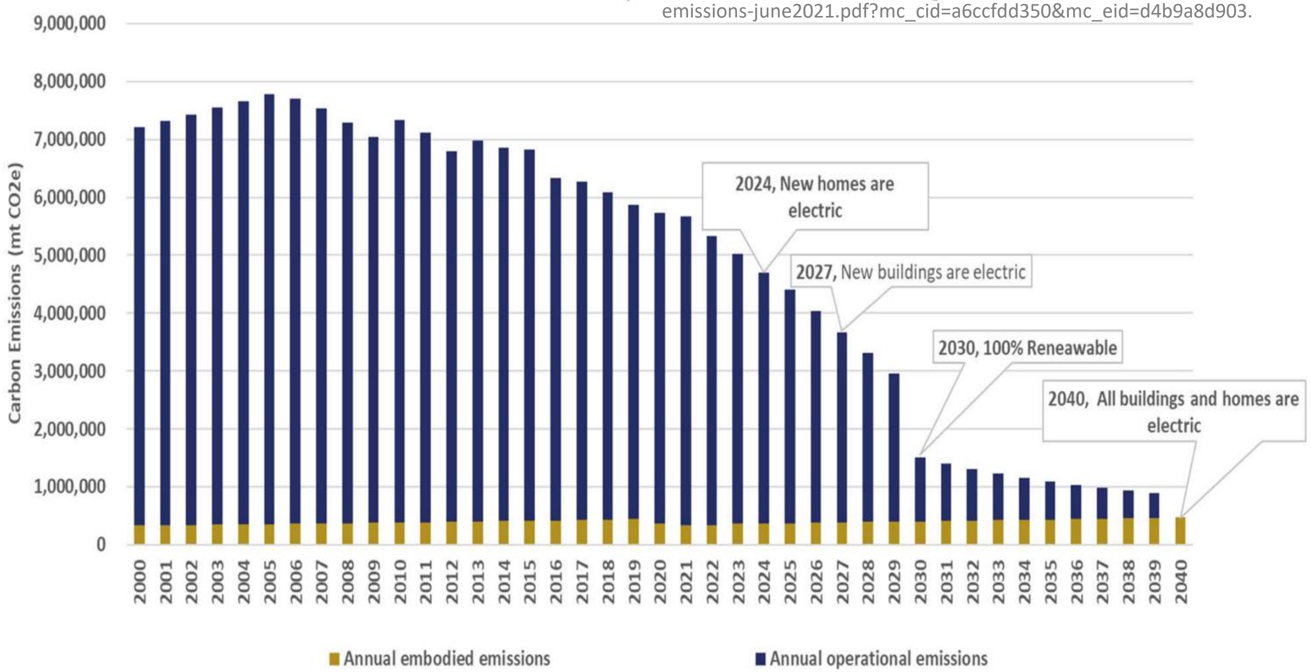
Data Sources: UN Environment Global Status Report 2017; EIA International Energy Outlook 2017

Concrete (11%) + Steel (10%) + Aluminum (2%) = 23% of Total Global CO2!

Why Embodied Carbon and Codes?



City and County of Denver. 2021. Denver's Building Sector Embodied Carbon Emissions. www.denvergov.org/files/assets/public/climate-action/documents/hpbh/nze/denversbuilding-sector-embodied-carbon-emissions-june2021.pdf?mc_cid=a6ccfdd350&mc_eid=d4b9a8d903.



- ICC has an Energy and Carbon Advisory Council guiding the I-codes
- ASHRAE has committed to a net zero carbon 90.1 by 2031 version

+Demand-side push to reduce industrial emissions

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What's stopping us?

ACEEE's 2022 Summer Study Informal Session asked:

- "Are we ready for embodied carbon in building codes?"
- "Are we ready to compare operational and embodied carbon in buildings?"

40+ participants: designers, researchers, policymakers and manufacturers

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1. The goal is a whole building life cycle assessment (WBLCA) that can be used to set standards and code provisions for embodied carbon. It is important to chart a pathway to that end.

LCA Tools Applicable to U.S.

Tool	Provider	Cost of use	Stand-alone versus embedded	Database used	Focus level	Life-cycle stage	Methodology
Athena	Athena Sustainable Material Institute	Free	Standalone	GaBi database	*Whole building*	A1-A3, A1-C4	Process LCA
GaBi	Thinkstep; Building Transparency (as of 2021)	No price information provided	Standalone	GaBi database	*Material*	A1-A3, A1-C4	Process LCA
Tally	Building Transparency, KT Innovations, thinkstep, and Autodesk	USD 695/year; free for non-commercial educational and research use	Plug-in	GaBi database	*Whole building*	A1–C4	Process LCA
Simapro	Pre Sustainability consultants	No price information provided	Standalone	ecoinvent, Japan database, NREL LCI	*Material*	A1–A3	Process LCA
BEES	NIST	Free	Standalone	NREL LCI	*Material, Product*	A1–A3	Economic I-O
EC3	Building Transparency	Free	Standalone	EPD data	*Material*	A1–A3	Process LCA
One Click LCA	One Click LCA	No price information provided	Plug-in; Standalone	Varies	*Whole building*	A1–C4	Process LCA

Esram and Hu. 2021. Knowledge Infrastructure: The Critical Path to Advance Embodied Carbon Building Codes
aceee.org/white-paper/2021/12/knowledge-infrastructure-critical-path-advanceembodied-carbon-building-codes.

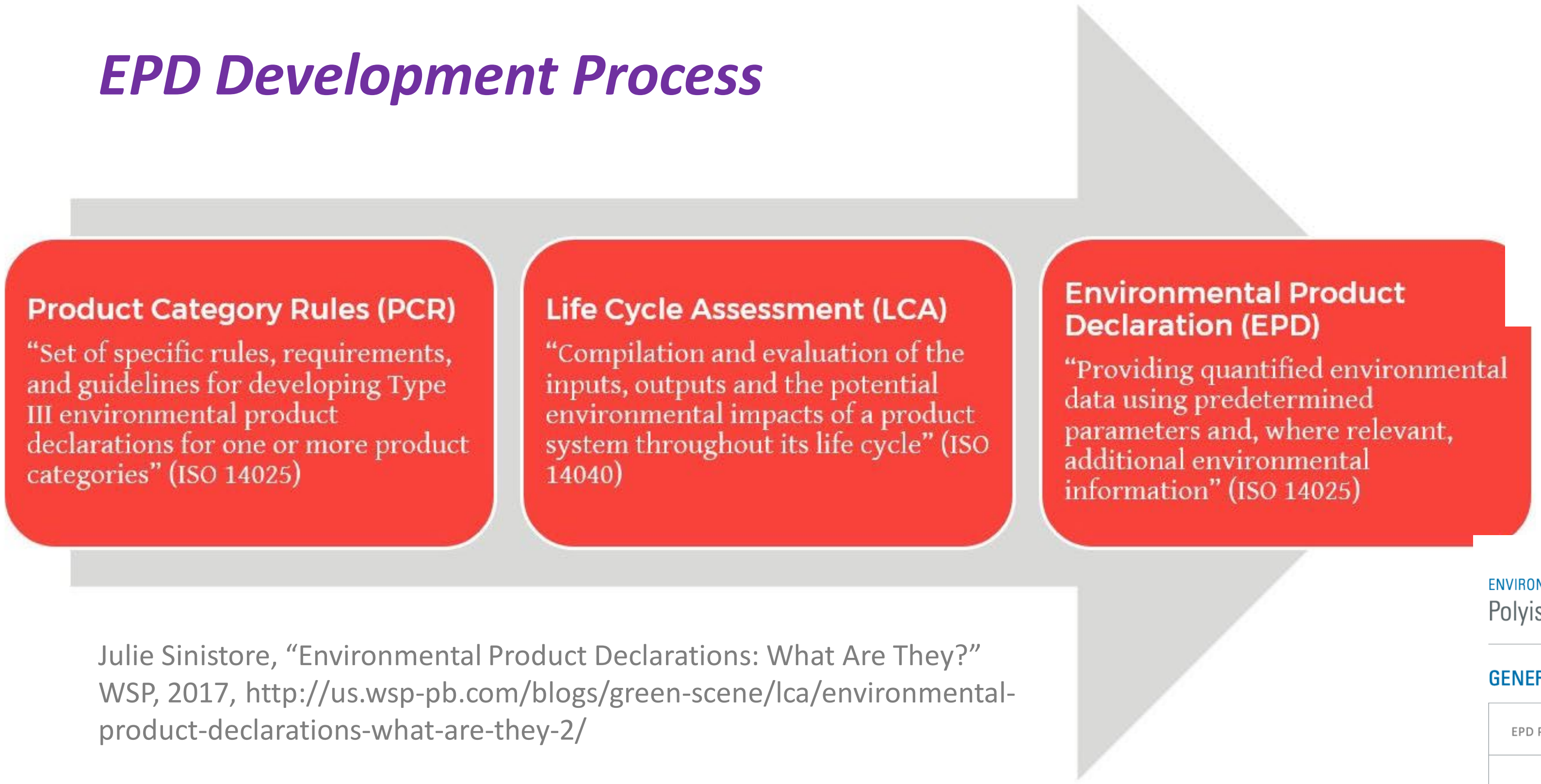
Common Environmental Product Databases

Database	Cost of use	Stand-alone versus embedded	No. of datasets	Region	Data source	Life-cycle stage
ecoinvent [a]	EUR 3,800 (USD 4,482)	Standalone, Embedded	18,000+	Global, Europe focus	Secondary [b]	A1–A3, A1–A5, A1–C4
U.S. National Renewable Energy Laboratory (NREL) LCI Database [c]	Free (companies or agencies pay to publish data)	Standalone	600+	U.S. focus	Primary	A1–A3, A1–A5, A1–C4
USDA LCA Digital Commons	Free (manufactures and agencies pay to publish data)	Standalone	300+	U.S. focus	Primary	A1–A3, A1–A5, A1–C4
NIST BEES database [d]	Free	Standalone, Embedded	Unknown	U.S. focus	Secondary	A1–A3, A1–C4
Quartz [e]	Free	Standalone	102 products	U.S. focus	Secondary (no lingered maintained)	
GaBi database	USD 3,000	Standalone, Embedded	15,000+	Global, Europe focus	Primary and Secondary	A1–A3, A1–A5, A1–C4
Athena database	Free	Standalone	200,000+ (building and construction materials specific)	U.S. and Canada focus	Secondary	A1–A5, A1–C4
Carnegie Mellon database [f]	Free	Standalone	3,500+	U.S., Canada, Germany, Spain, China	Secondary	A1–A3, A1–A5
Environmental Product Declaration (EPD) library	Free	Standalone	149 products [g]	Global	Primary	Vary
Embodied Carbon in Construction Calculator (EC3)	Free	Standalone	47,000+	Global, with a U.S. focus	Primary	A1–A3 (as of 2021)

Sources: [a] Wernet et al. 2016. [b] ecoinvent 2021. [c] NREL 2021. [d] Curran et al. 2002. [e] Quartz 2015. [f] Greenhouse Gas Protocol 2021b. [g] Greenhouse Gas Protocol 2021c.

Sidebar: Environmental Product Declarations (EPDs)

EPD Development Process



Julie Sinistore, "Environmental Product Declarations: What Are They?" WSP, 2017, http://us.wsp-pb.com/blogs/green-scene/lca/environmental-product-declarations-what-are-they-2/

Product-Specific EPDs

Program Operator	NSF International 789 N. Dixboro Ann Arbor, MI 48105 www.nsf.org
General Program Instructions and Version Number	Part A: Life Cycle Assessment Calculation Rules and Report Requirements, Version 2.0
Manufacturer Name and Address	GAF 1 Campus Drive Parsippany, NJ 07054
Declaration Number	EPD10151
Declared Product and Functional Unit	EnergyGuard™ NH Polyiso Roof Insulation 1 m2 of installed insulation material with a thickness that gives an average thermal resistance RSI = 1m²KW and with a building service life of 75 years
Reference PCR and Version Number	Part A: Life Cycle Assessment Calculation Rules and Report Requirements, Version 3.1 Part B: Building Envelope Thermal Insulation EPD Requirements UL 10010-1
Product's Intended Application and Use	Thermal Insulation for Roofing Applications
Product RSL	75 years as per PCR guidelines
Markets of Applicability	North America, Europe
Date of Issue	06/21/2018
Period of Validity	5 years from date of issue

Industry-Wide EPDs

ENVIRONMENTAL PRODUCT DECLARATION
Polyiso Roof Insulation Boards

PIMA
POLYISOCYANURATE INSULATION MANUFACTURERS ASSOCIATION

GENERAL INFORMATION

EPD Program Operator (NSF Certified Environmental Product Declaration www.nsf.org)	NSF Certification, LLC 789 N. Dixboro Road Ann Arbor, Michigan, 48105, USA www.nsf.org
Refererence PCRs	Product Category Rules for Building-Related Products and Services Part A: Life Cycle Assessment Calculation Rules and Report Requirements (UL 10010, Version 3.2), and Product Category Rule (PCR) Guidance for Building-Related Products and Services Part B: Building Thermal Insulation EPD Requirements (UL10010-1, Version 2.0), and ISO 21930: 2017
Declaration Holder	Polyisocyanurate Insulation Manufacturers Association 3330 Washington Boulevard, Suite 200 Arlington, Virginia, 22201, USA www.polyiso.org
LCA & Declaration Preparer	Shelly Severinghaus, LCACP Long Trail Sustainability 830 Taft Road

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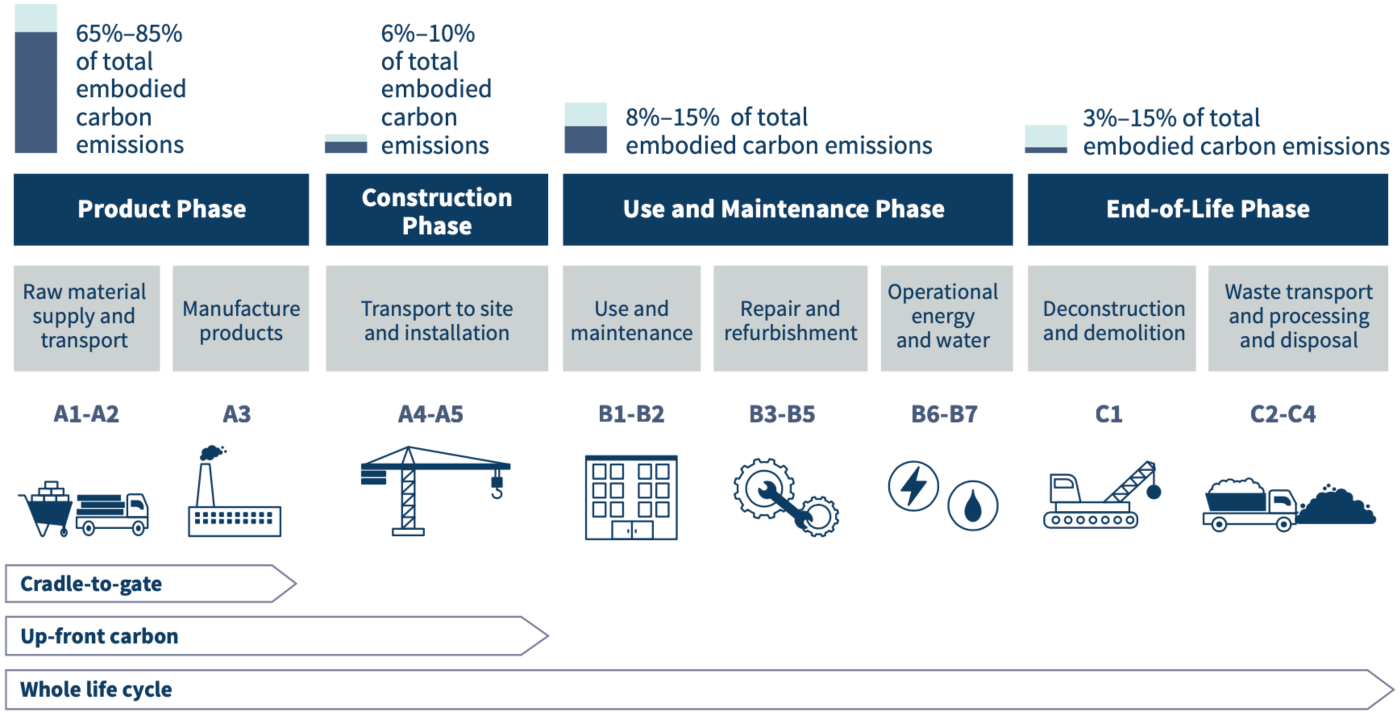
2. There is an immediate need to fill gaps and reduce uncertainty in data reported at the material level, but initial standards can likely be set for the Product Stage (Modules A1-A3) for a handful of materials.

Exhibit 6 **Life-Cycle Assessment Phases**



Source: RMI

Embodied Carbon by Material/Product

Figure 47: Total tCO_2e per material across the first five case studies

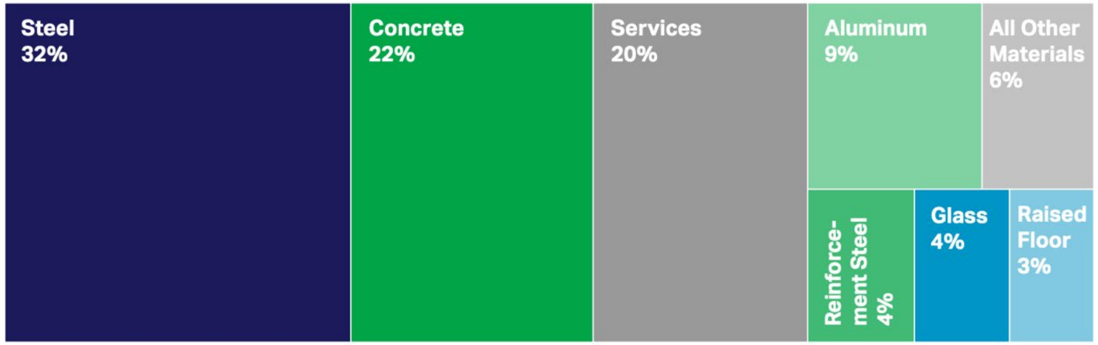
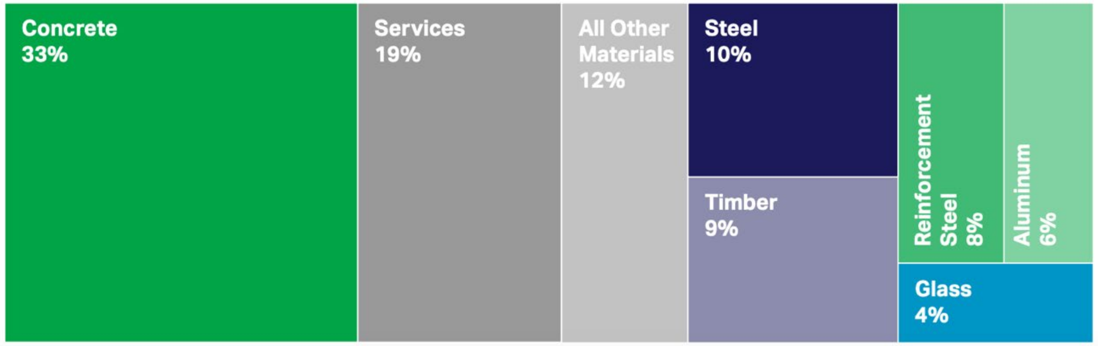


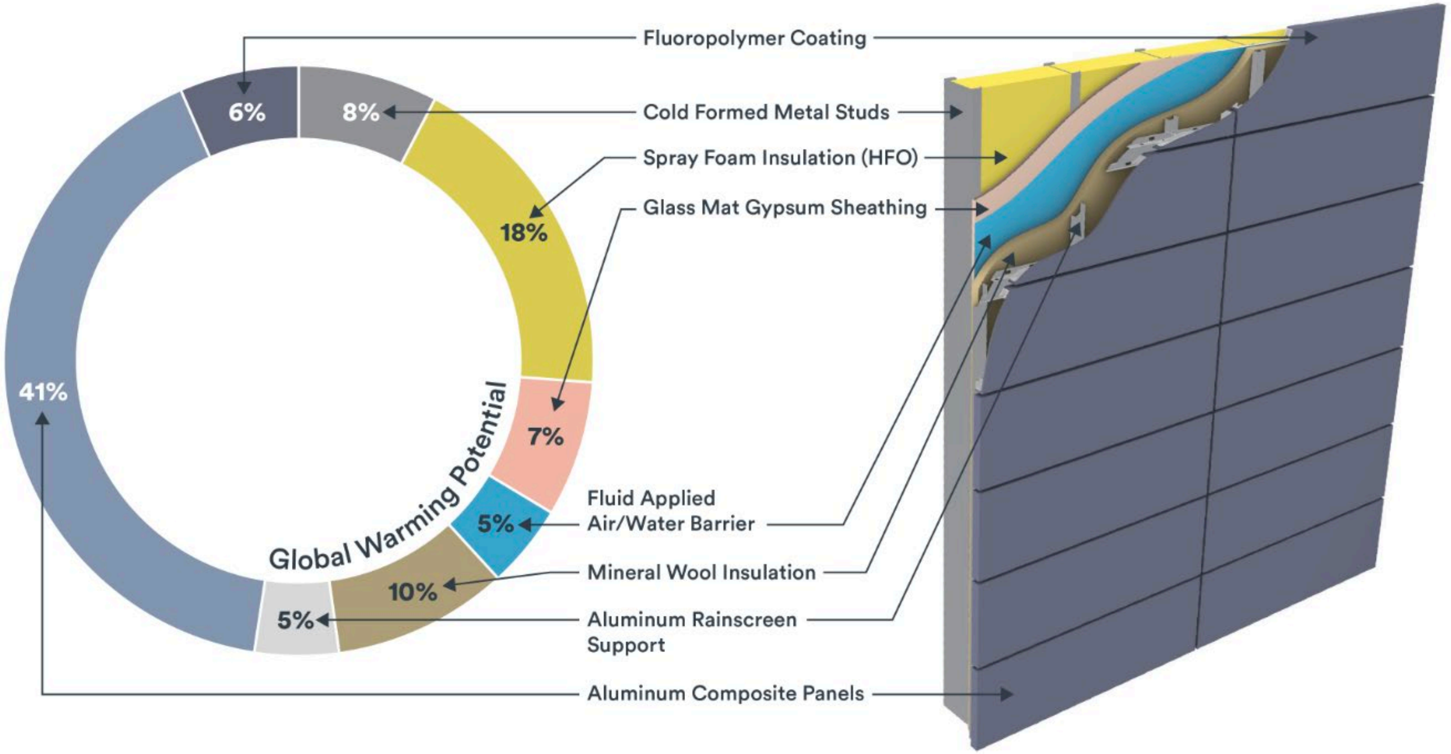
Figure 48: Total tCO_2e per material for case study 06 – Residential timber building



Chris Magwood and Tracy Huynh, *The Hidden Climate Impact of Residential Construction*, RMI, 2023, https://rmi.org/insight/hidden-climate-impact-of-residential-construction/

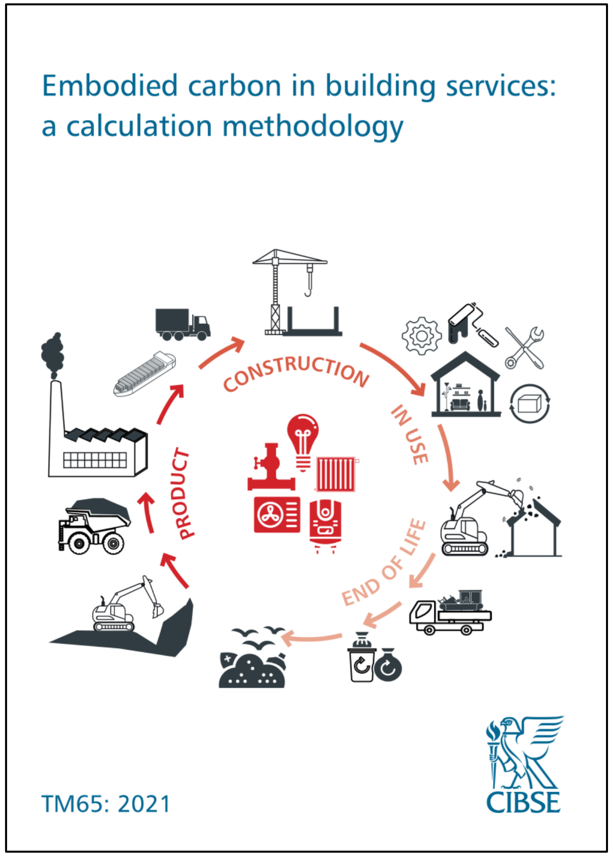
WBCSD and Arup, "Net-zero buildings: Where do we stand?" https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/Net-zero-buildings-Where-do-we-stand

3. *Stepping up from the material level to building envelope assemblies, fenestration products, HVAC equipment and other building components is likely a beneficial intermediate phase.*



Embodied Carbon in Building Enclosures: Why It Matters. Laura Karnath (Walter P. Moore) https://www.walterpmoore.com/embodied-carbon-building-enclosures-why-it-matters

MEP 2040
Committing to Zero



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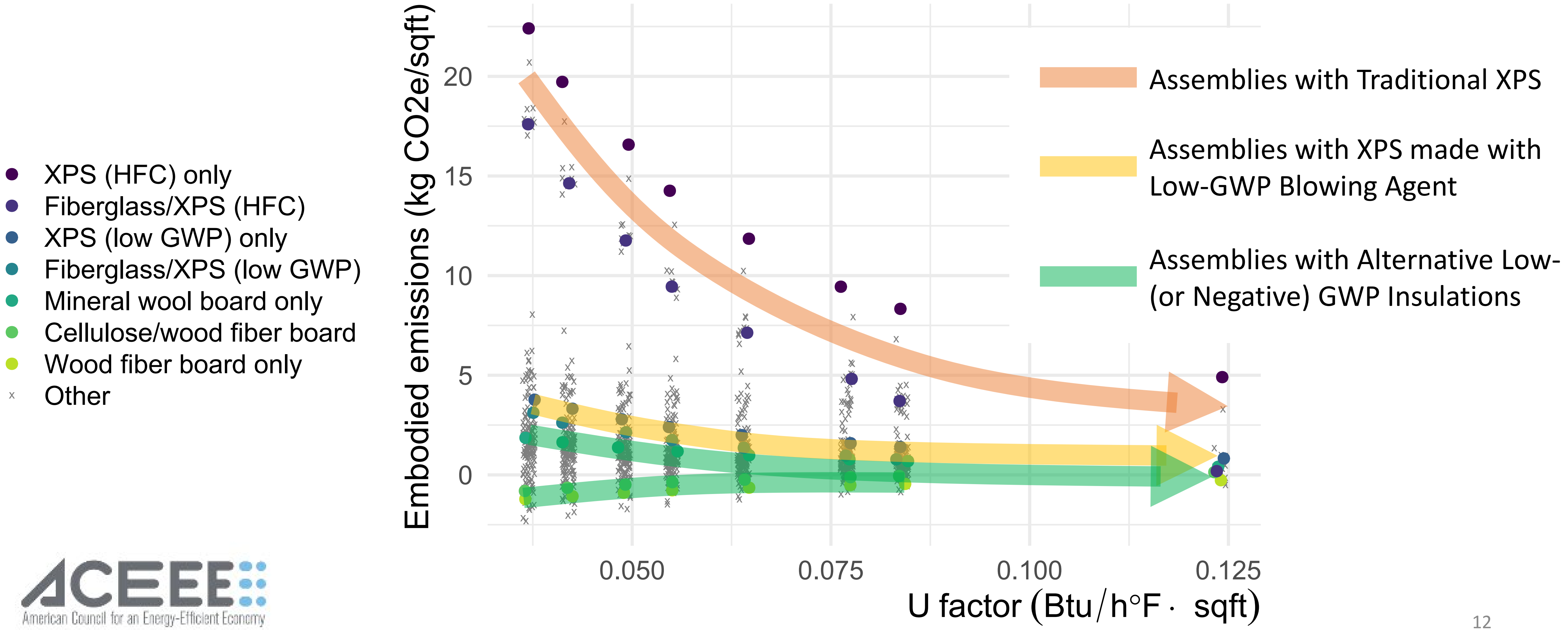
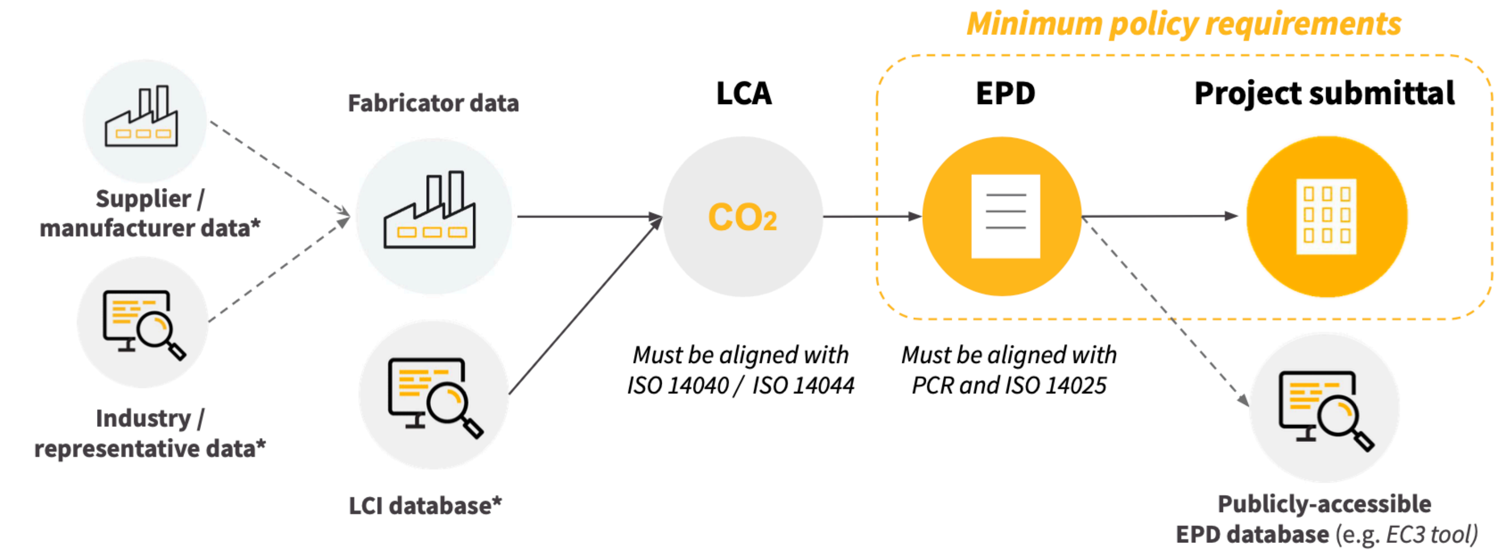
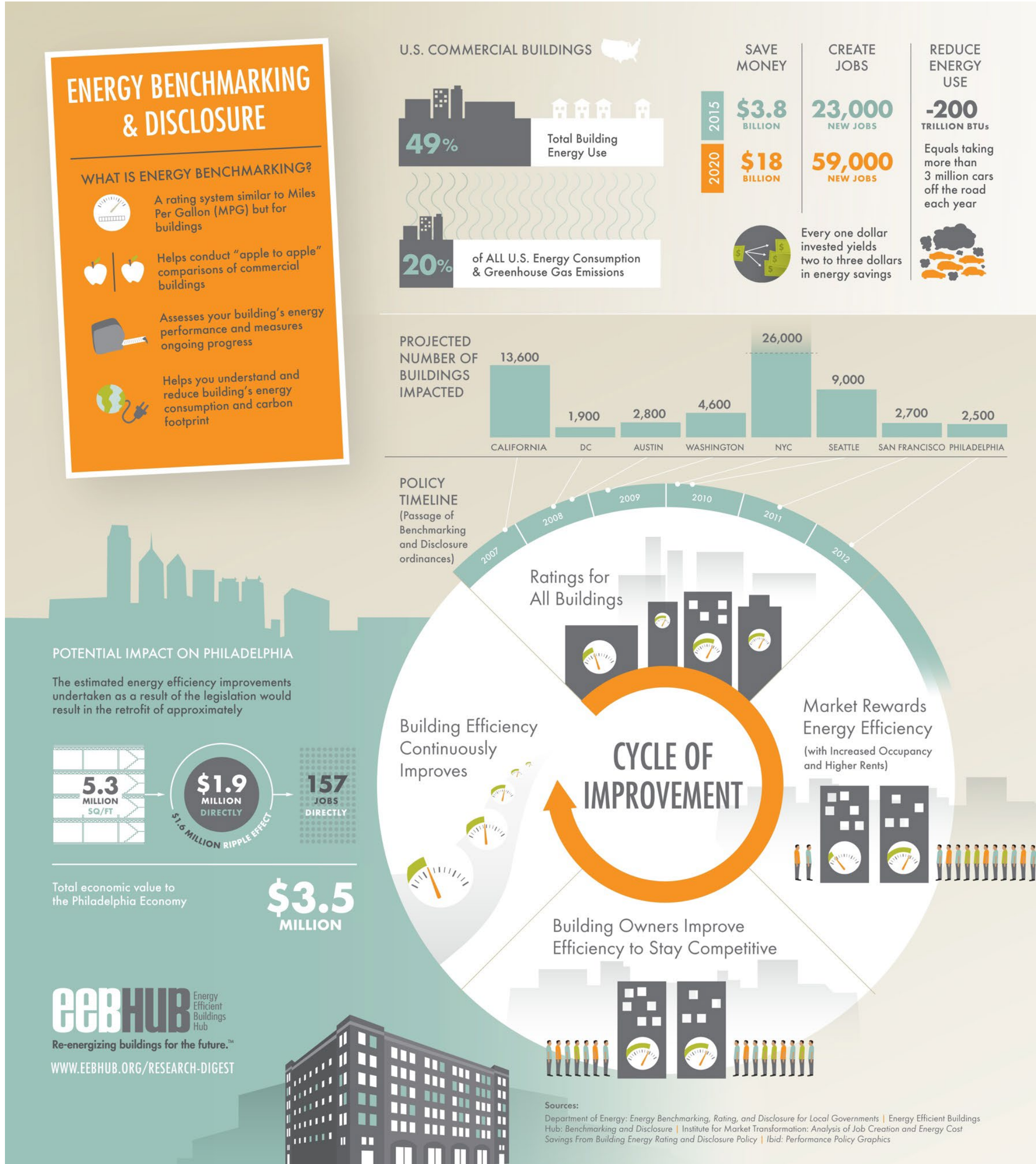
4. Code provisions aimed at reducing embodied carbon – and potentially prioritizing existing buildings – should not allow energy efficiency to be traded off.



5. Embodied carbon benchmarking and disclosure could be a useful step towards whole building standards by building capacity and improving data.



Above: “Guidance on Disclosure,” Carbon Leadership Forum, https://carbonleadershipforum.org/guidance-on-embodied-carbon-disclosure/
Right: http://www.cbei.psu.edu/benchmarking-and-disclosure/index.html



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6. To support whole building life cycle code provisions, we need:

- *Improved and expanded material-level data,*
- *widely accessible and applicable modeling tools,*
- *a trusted central data and information repository, and*
- *more better-trained LCA modelers*

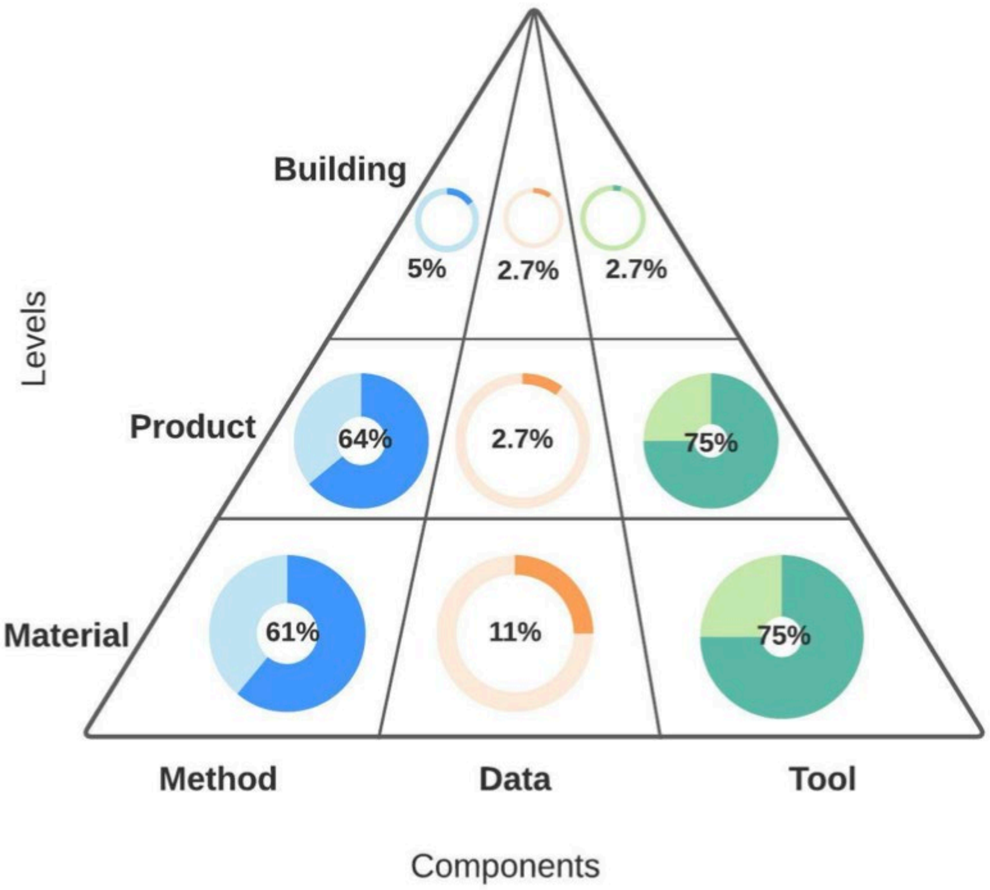

Figure 1. Embodied carbon assessment knowledge matrix

Esram and Hu. 2021. Knowledge Infrastructure: The Critical Path to Advance Embodied Carbon Building Codes aceee.org/white-paper/2021/12/knowledge-infrastructure-critical-path-advanceembodied-carbon-building-codes.

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Emerging Embodied Carbon Policies in the U.S.

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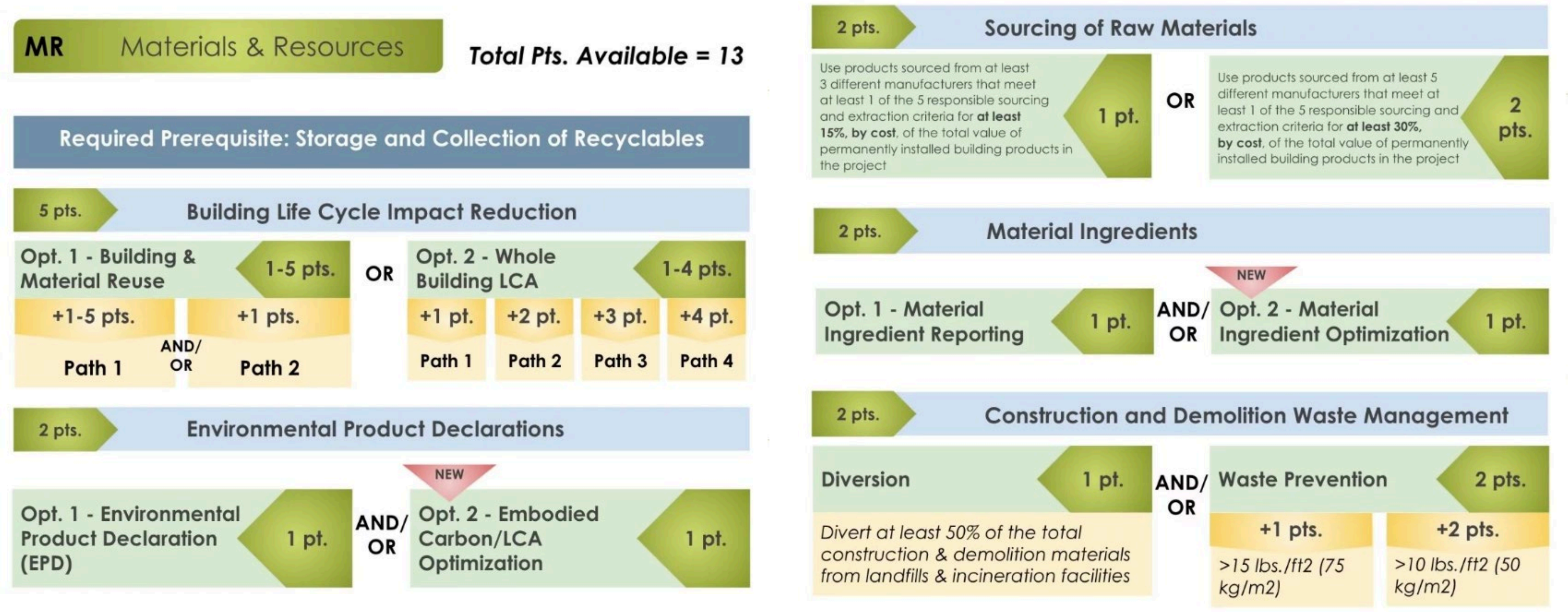
LEED v4.1 and Green Globes Rating Systems



"What You Need to know about Building Materials Under LEED v4.1," CaraGreen, https://www.caragreen.com/what-you-need-to-know-about-building-materials-under-leed-v4-1/

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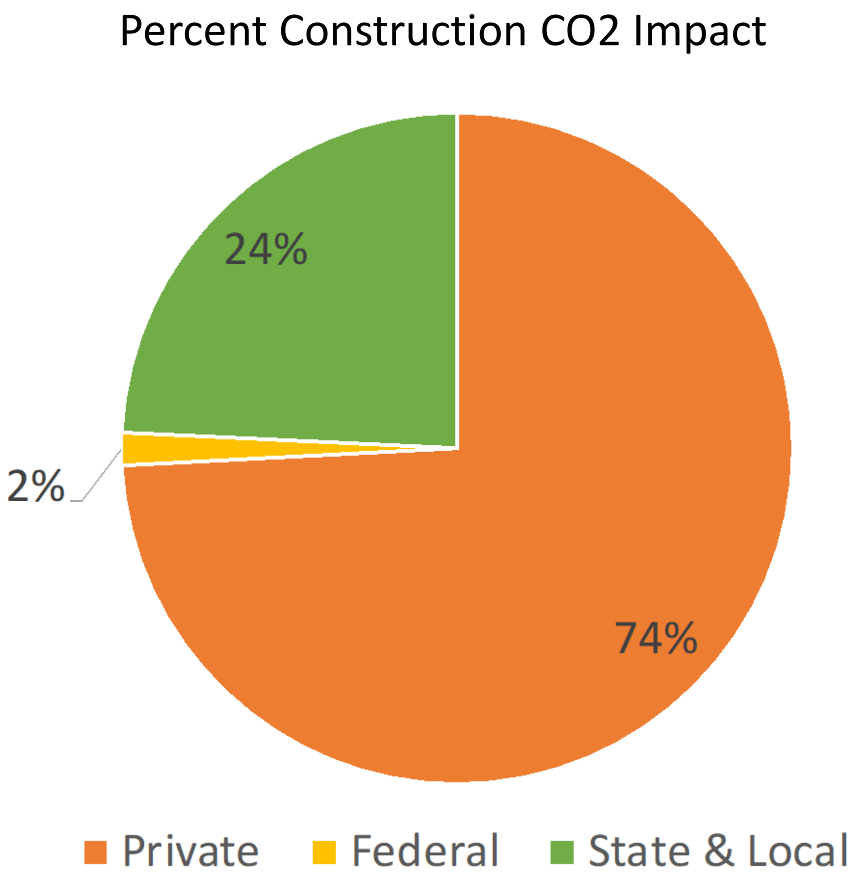
Public Project Procurement Policies – “Buy Clean”

- Generally aimed at big ticket items
  - **Concrete, steel, glass, some insulation**
- “Like to like” – not comparing materials
- 5 states with active policies
  - **California, Oregon, Washington, Minnesota, Colorado**
- Some localities
- Federal government in guidance and scoping process (incl. IRA funding)



Computed from: US Census Bureau (“Annual Value of Construction Spending Put in Place” for 2012 – 2022); CO_2 impact per dollar added US EPA (USEEIO v1.1 data).

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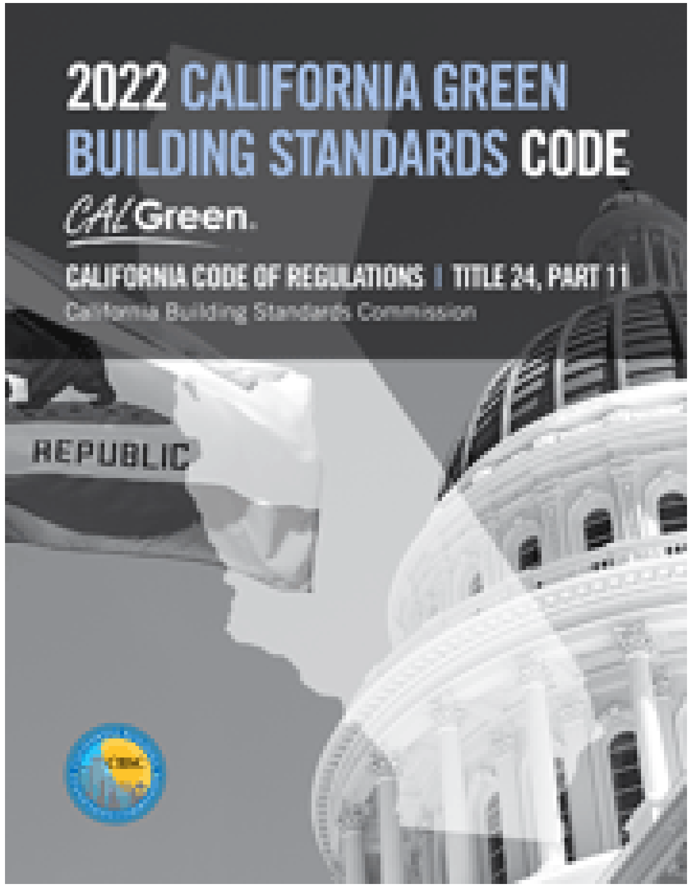
Green Codes – CalGreen



- Mandatory refrigerant GWP limits
- Voluntary provisions aimed at reduced embodied carbon in materials
- Proposed <u>whole building LCA</u> provisions aimed at reducing embodied carbon ~10% in commercial buildings >50,000 sf
  - **In line with AB 2446 (2022)**

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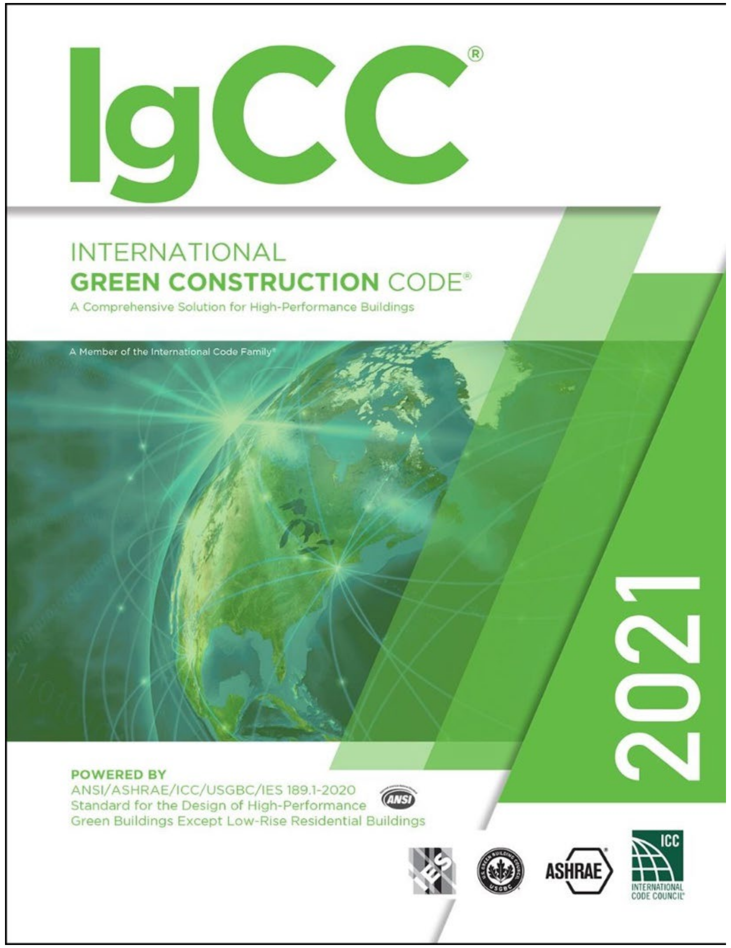
Green Codes – IgCC / ASHRAE 189.1



- International Green Construction Code ”powered by” ASHRAE Standard 189.1

- Proposed material-focused provisions:
  - Mandatory disclosure of Cradle-to-Grate (A1-A3) for subset of installed materials *[Add z]*
  - Jurisdiction option: Material procurement Cradle-to-Gate emissions limits *[Add ak]*

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Building codes

- Just one! Only concrete! Marin County, CA

	Cement limits for use with any compliance method 19.07.050.2 through 19.07.050.5	**Embodied Carbon limits** for use with any compliance method 19.07.050.2 through 19.07.050.5
Minimum specified compressive strength f'_c, psi (1)	Maximum ordinary Portland cement content, lbs/yd^3 (2)	Maximum embodied carbon kg CO_2e/m^3, per EPD
up to 2500	362	260
3000	410	289
4000	456	313
5000	503	338
6000	531	356
7000	594	394
7001 and higher	657	433
up to 3000 light weight	512	578
4000 light weight	571	626
5000 light weight	629	675

Notes

(1) For concrete strengths between the stated values, use linear interpolation to determine cement and/or embodied carbon limits.

(2) Portland cement of any type per ASTM C150.

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Marin County Low Carbon Concrete Requirements: https://www.marincounty.org/-/media/files/departments/cd/planning/sustainability/low-carbon-concrete/12172019-update/low-carbon-concrete-code.pdf

So, what about Energy Codes?

- Historically we have not supported embodied carbon in energy codes
  - Energy codes set minimum energy efficiency requirements
  - Non-energy usage data reliability/comparability

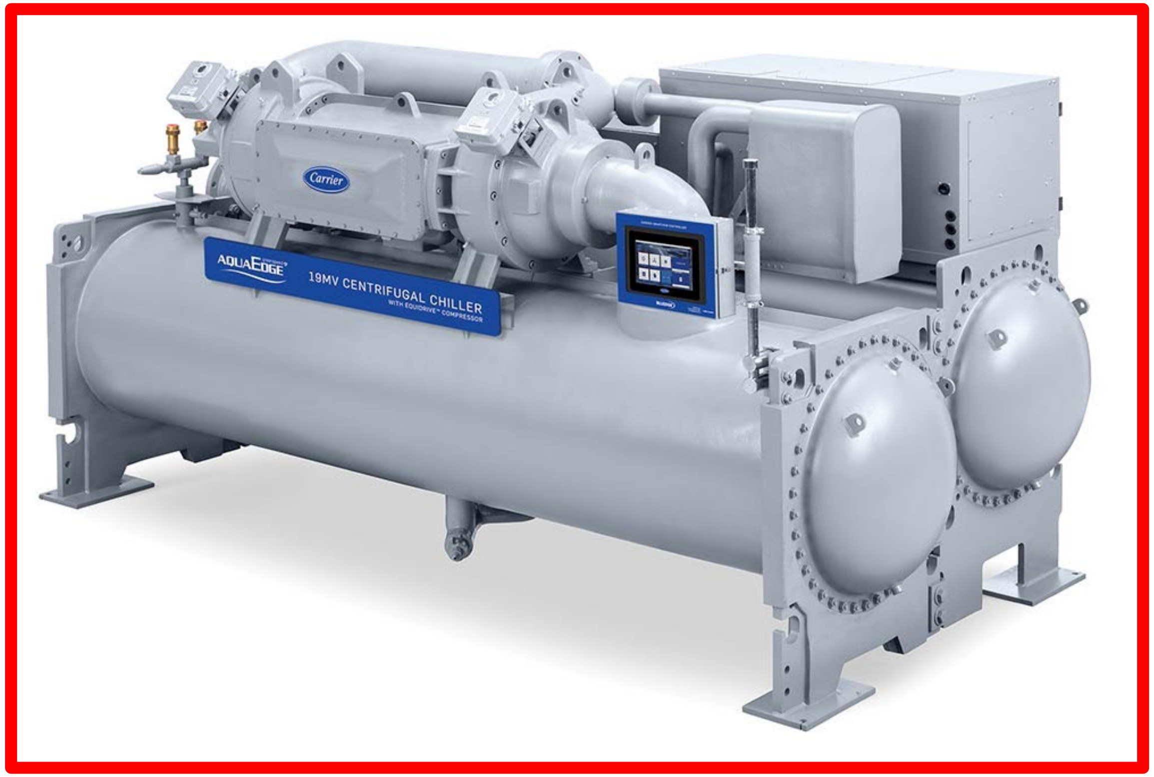
- Reconsidering with…
  1. Energy codes shifting to an emissions basis and decarbonization focus
  2. Efforts to improve data reliability/comparability
  3. Growth of buy clean policies and guidelines

One example of attempt in energy code...

2023

- Optional credits for reporting and/or reducing insulation embodied carbon

90.1 Work Plan Includes *Only* Refrigerants



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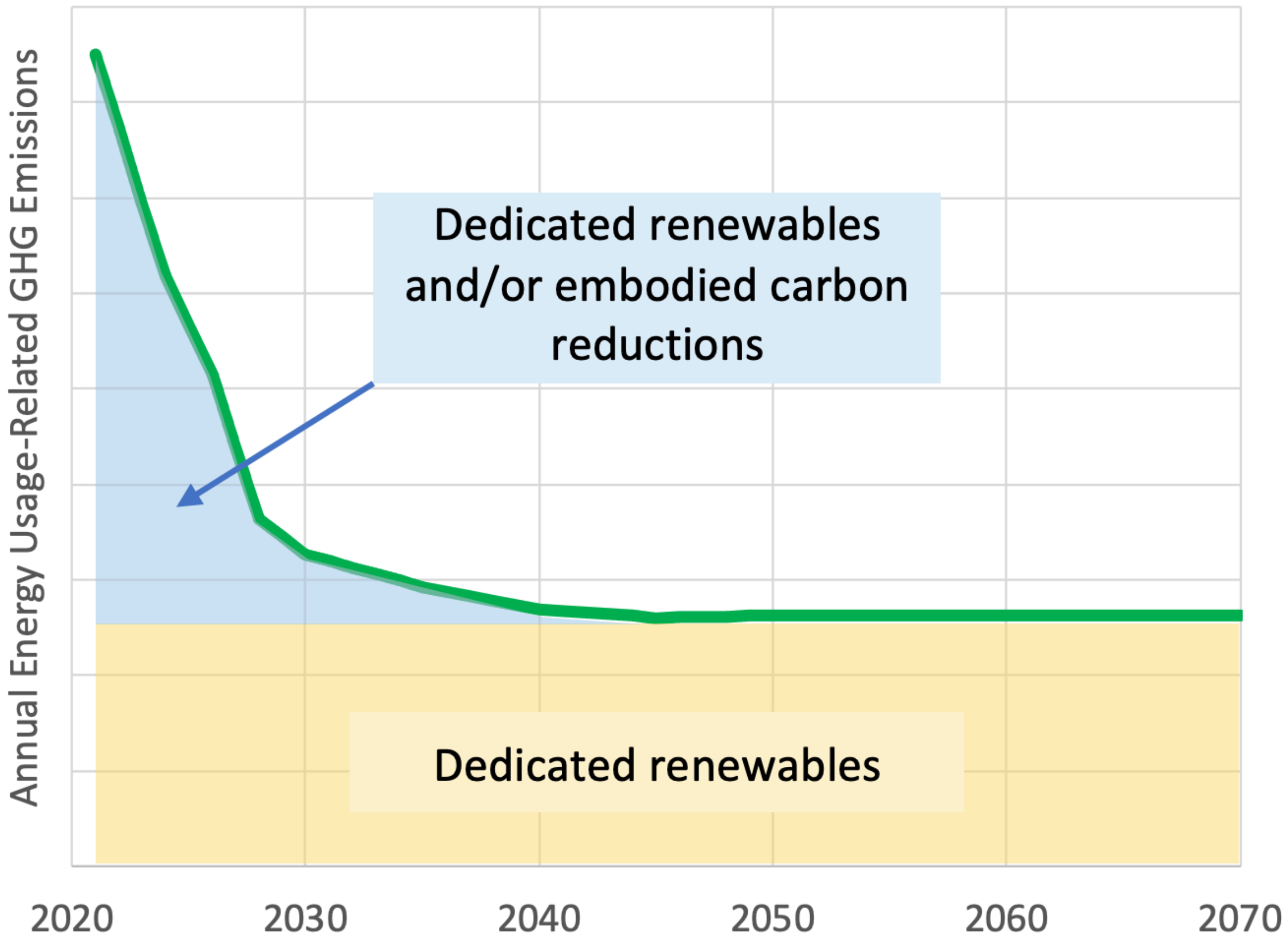
A proposed possible starting point



Michael Waite, "Rethinking Model Energy Codes for Net Zero Carbon Buildings," ACEEE, 2023, https://www.aceee.org/blog-post/2023/04/rethinking-model-energy-codes-net-zero-carbon-buildings

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Need: Standardization with comparable data

- Harmonization and standardization of PCRs
- Comparability of EPDs across products
- Comparability of embodied and operational emissions
  - **International standards and guidelines contribute to knowledgebase**
  - **ASHRAE/ICC Standard 240P in development – need this to work for codes!**

Drafts are posted and comments can be made until May 21st at: osr.ashrae.org.

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Need: Energy Code "Energy Credits"

>>> Carbon Reduction Credits

ID	Energy Credit Measure	Section	0A	0B	1A
E01	Envelope Performance	C406.2.1.1			
E02	UA reduction (15%)	C406.2.1.2	8	13	7
E03	Envelope leak reduction	C406.2.1.3	15	10	12
E04	Add Roof Insulation	C406.2.1.4	1	1	1
E05	Add Wall Insulation	C406.2.1.5	10	10	6
E06	Improve Fenestration	C406.2.1.6	7	7	4
H01	HVAC Performance	C406.2.2.1	20	19	16
H02	Heating efficiency	C406.2.2.2	x	x	x
H03	Cooling efficiency	C406.2.2.3	7	6	4
H04	Residential HVAC control	C406.2.2.4	9	10	8
H05	DOAS/fan control	C406.2.2.5	32	31	27
W01	SHW preheat recovery	C406.2.3.1 a	61	63	74
W02	Heat pump water heater	C406.2.3.1 b	50	52	62
W03	Efficient gas water heater	C406.2.3.1 c	38	39	46

ID	Energy Credit Abbreviated Title	Section	0A	0B	1A
R01	Renewable Energy	C406.3.1	9	15	11
G01	Lighting load management	C406.3.2	16	7	9
G02	HVAC load management	C406.3.3	42	41	21
G03	Automated shading	C406.3.4	11	x	7
G04	Electric energy storage	C406.3.5	10	10	10
G05	Cooling energy storage	C406.3.6	28	6	31
G06	SHW energy storage	C406.3.7	17	17	19
G07	Building thermal mass	C406.3.8	7	2	11

Snapshots from 2024 IECC Public Comment Draft #1: https://www.iccsafe.org/wp-content/uploads/IECC2024P1CE-UPDATE-110122.pdf

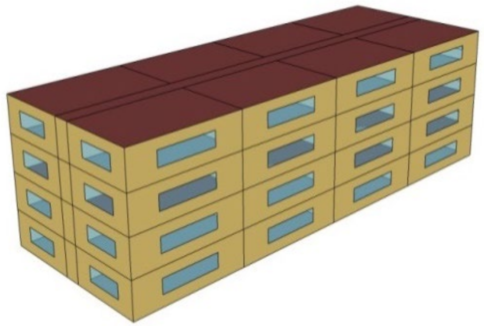
- Menu of options beyond minimum requirements
- Must attain a total amount by building type and climate zone

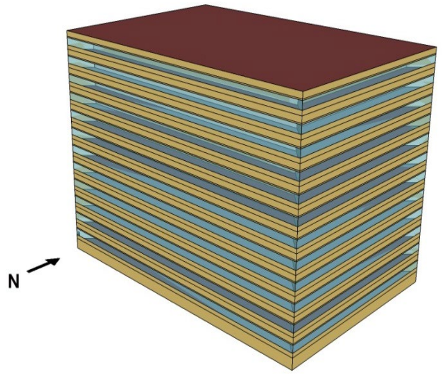
➢ Translate to emissions reduction basis

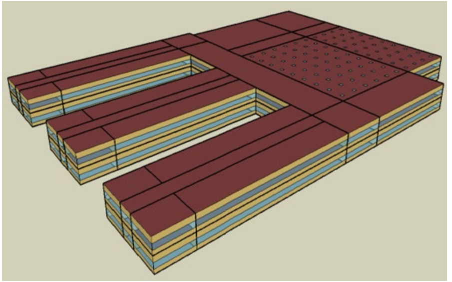
➢ Life cycle emissions

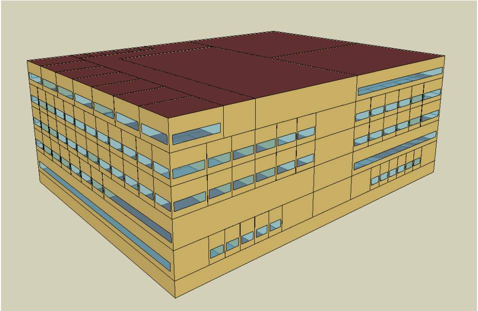
➢ What's the baseline?

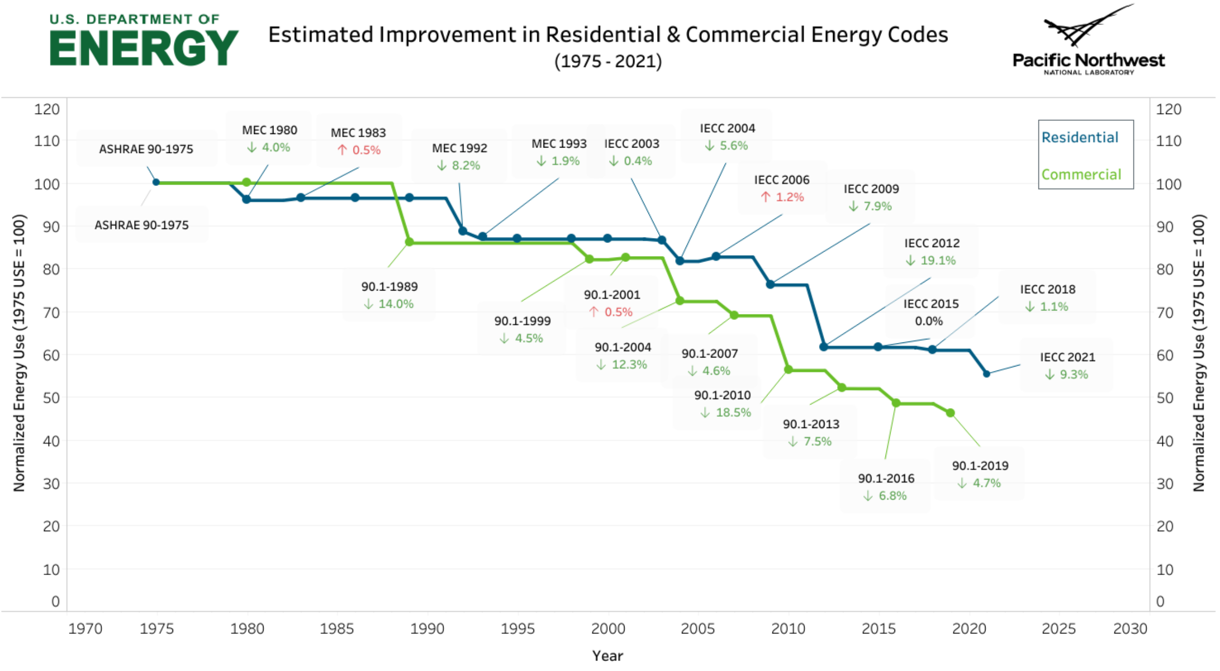
Need: Benchmarks, Prototypes, Baselines











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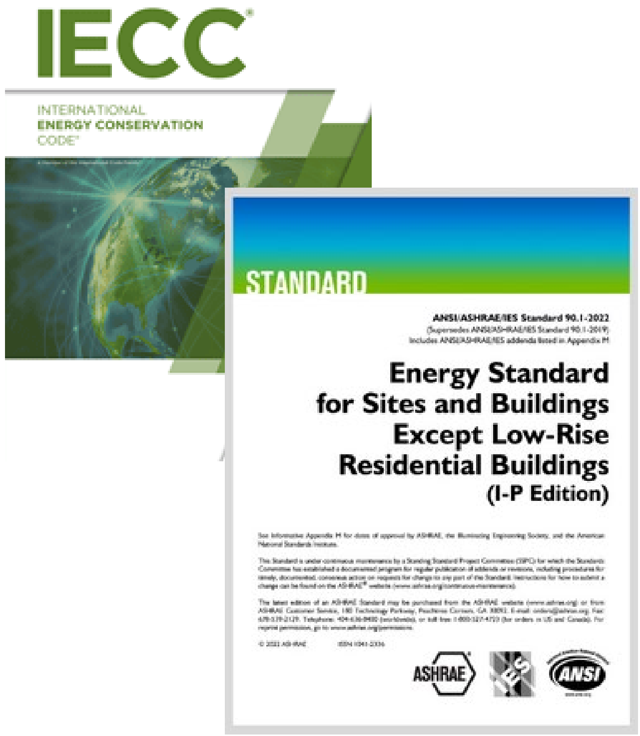
ENERGY STAR® Portfolio Manager®

CLF Carbon Leadership Forum

CLF WBLCA Benchmark Study v2

Need: Coordination across energy and building codes



One possibility:

- ➢Set limits in IBC/IRC
- ➢Flexibility to reduce whole building emissions in energy codes

- Analogue of reduced flow water fixtures

➢Current stage is likely testing through "green" codes

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Summary

- Embodied carbon increasing share of building lifecycle emissions
- Whole building, whole life emissions standards are the goal
- Need data improved and gaps filled, but there are steps we can take now
- Some material-focused policies are emerging in the U.S.
- There could be a role for embodied carbon in energy codes
    - Need: Carbon metrics, standardization, benchmarks, flexibility
    - Energy codes and building codes likely need to work in concert

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Thank you!

Michael Waite, PhD, PE

Senior Manager, Buildings Program, ACEEE

mwaite@aceee.org

Natural Resources Canada
Ressources naturelles Canada

Embodied Carbon in Canadian Model Codes

May 4, 2023

Canada

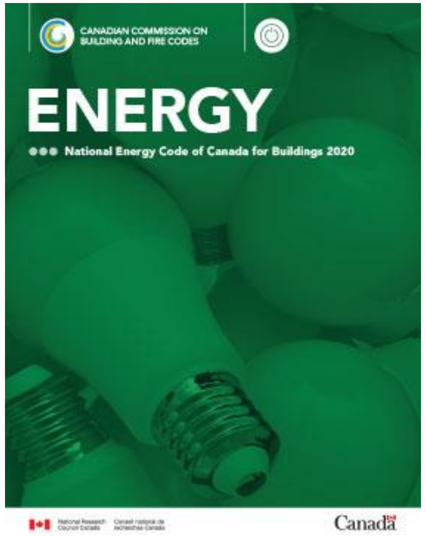
Agenda

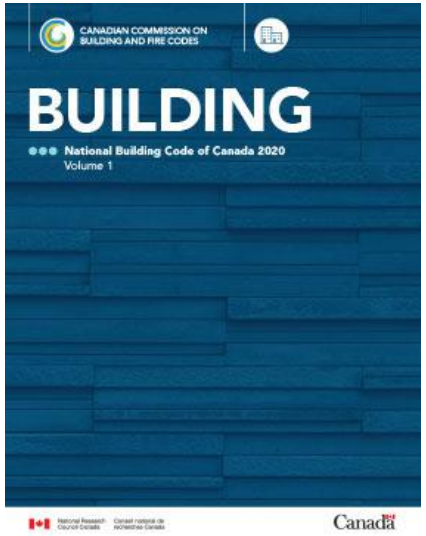
- Background
  - Canadian Model Codes
  - Model Code Development
  - Evolution of Model Codes
- Embodied Carbon in Canada
  - Preliminary Research
  - NRCan’s Material Carbon Estimator Tool
- Findings & Conclusions

Canadian Model Codes

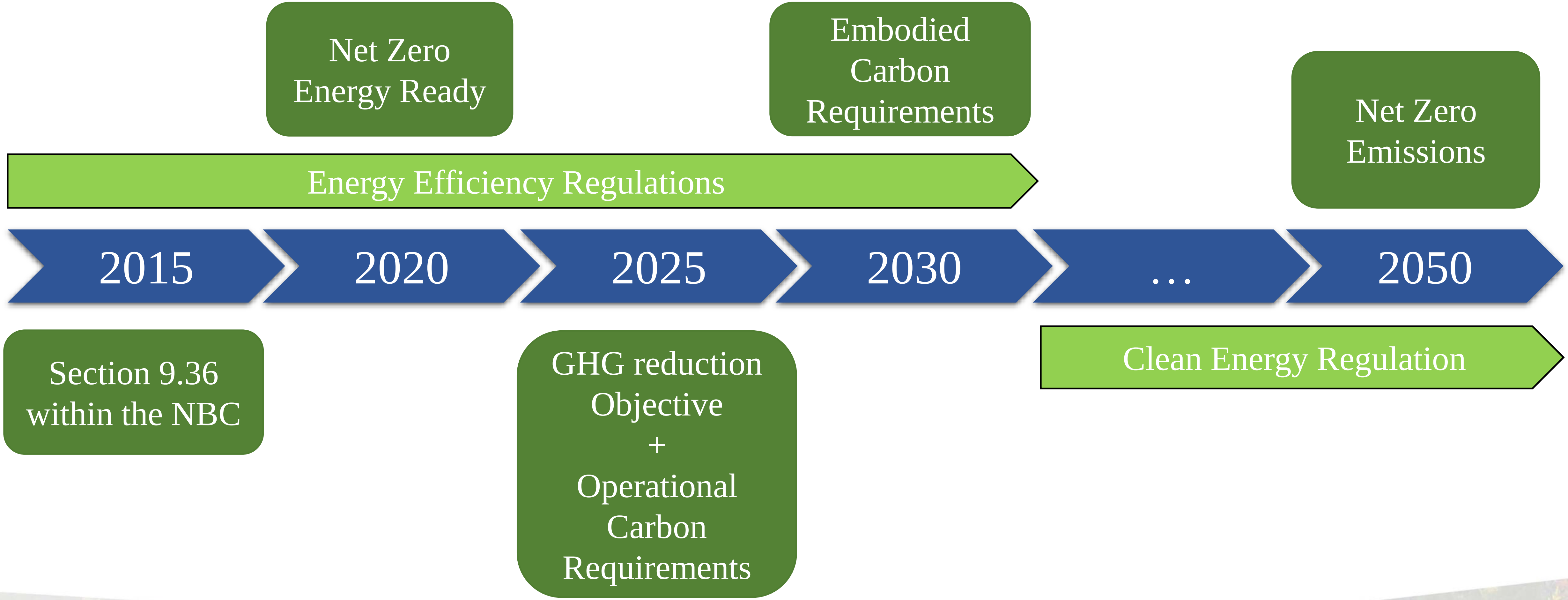
- National Building Code & National Energy Code for Buildings
  - AHJs responsible for the adoption of building codes
  - Reconciliation Agreement on Construction Codes

- Model Code Development Process
  - Provinces and Territories provide policy direction
  - Technical Committees, Task Groups and Working Groups
  - Consensus-based, accessible and transparent



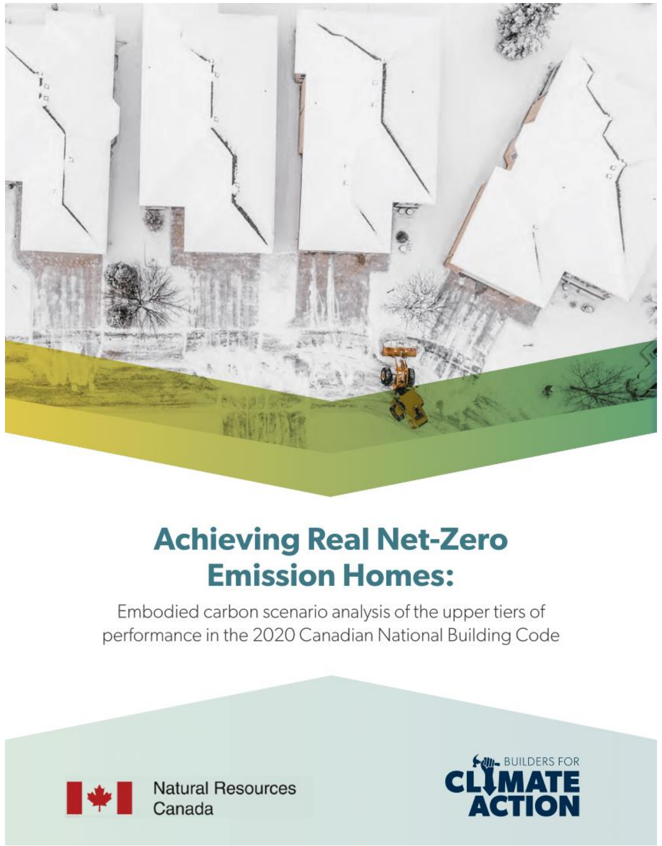


Evolution of Model Energy Codes in Canada



Preliminary Research on Embodied Carbon

- "Achieving Real Net-Zero Emission Homes"
  - Operational + Embodied carbon emissions
  - Three archetypes in five climate zones
    - Bungalow, 2-Storey and Row House End Unit
  - Three different Energy Code Tiers
    - Tier 3, Tier 4 and Tier 5
  - Four material palettes
    - High Carbon, Mid-Range, Best Available and Best Possible



NRCan's Material Carbon Emissions Estimator (MCE2)

- Estimation of Overall Carbon Emissions
  - Pulls data from HOT2000 energy simulation tool
  - User inputs material choice(s) for each component
  - GWP of each material is calculated from database of publicly available EPDs
    - Limited to "Product Stage" (A1-A3)
    - Subset of building materials
    - No waste factors included
- Intended to support design decision-making and capacity building

Project Carbon Content

Energy Consumption		Energy Generation
Elec. kWh/yr	N. Gas m^3/yr	Elec. kWh/yr
8195	1781	0
Propane L/yr	Oil L/yr	Wood kg/yr
0	0	0

To override energy GHG intensities, use the Energy GHG tab.

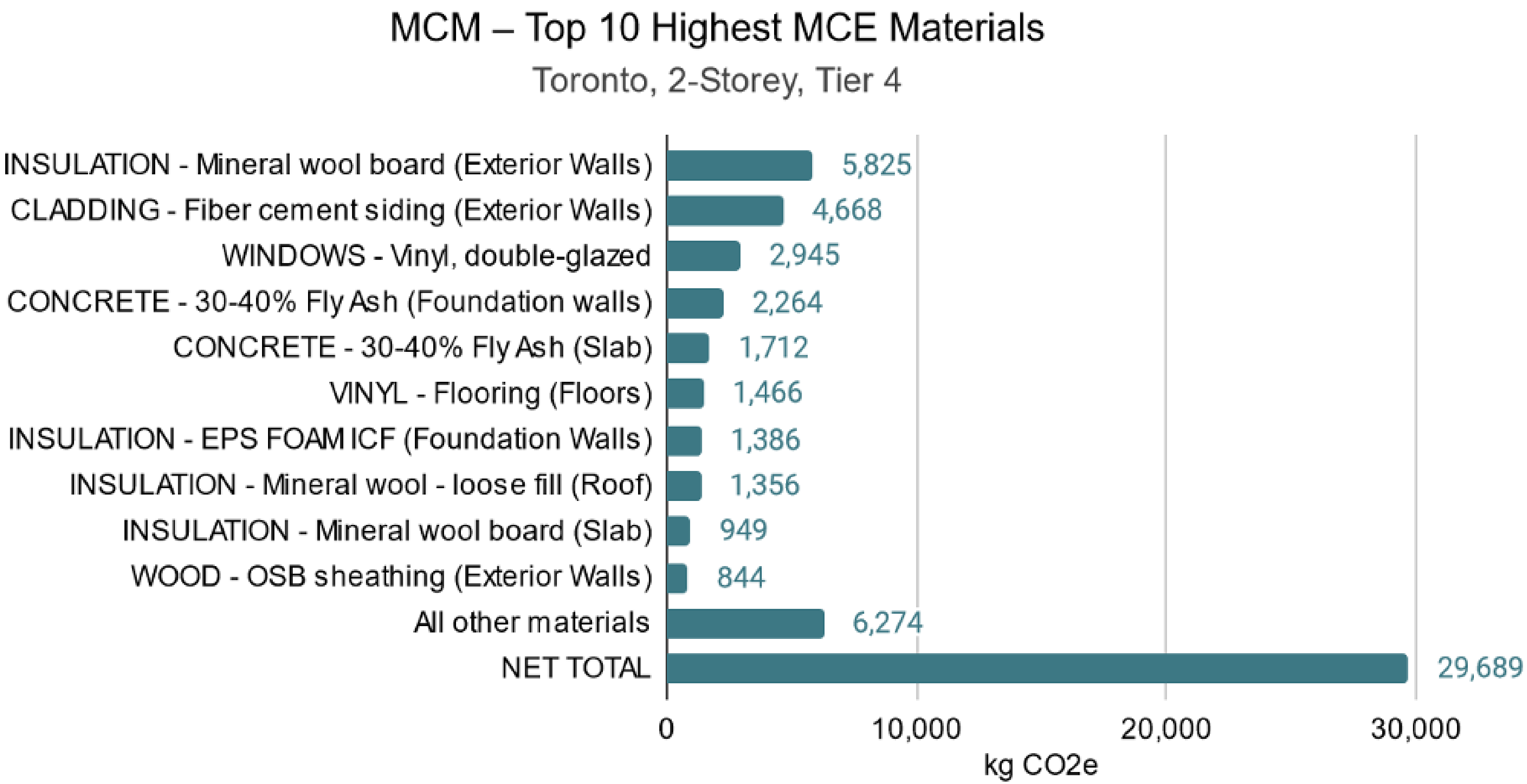
Operational Emissions

tonnes CO_2e / yr	t CO_2e / 30 yrs
3.7	110

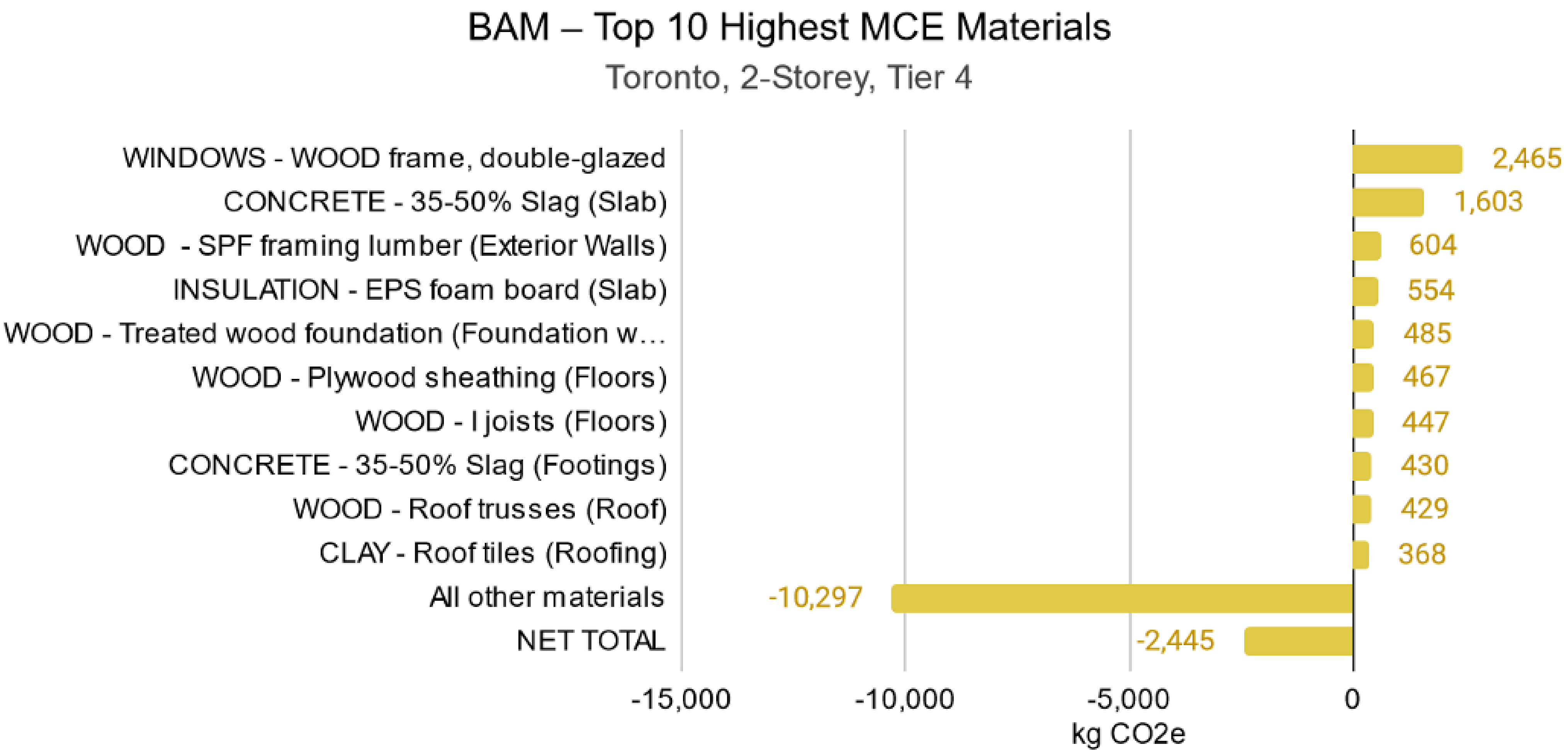
Material Emissions

tonnes CO_2e	kg CO_2e / m^2
46.5	221

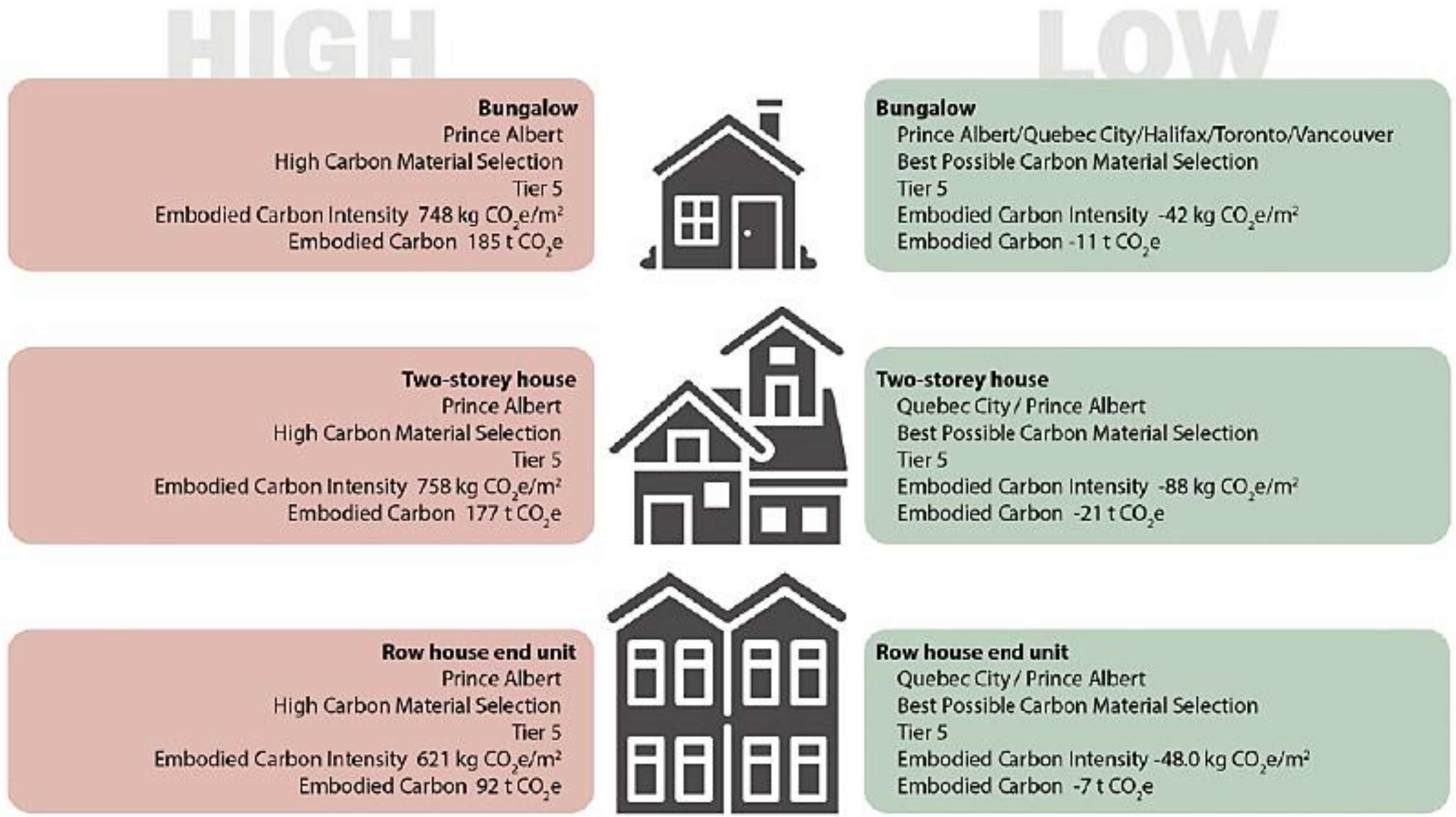
Preliminary Research on Embodied Carbon



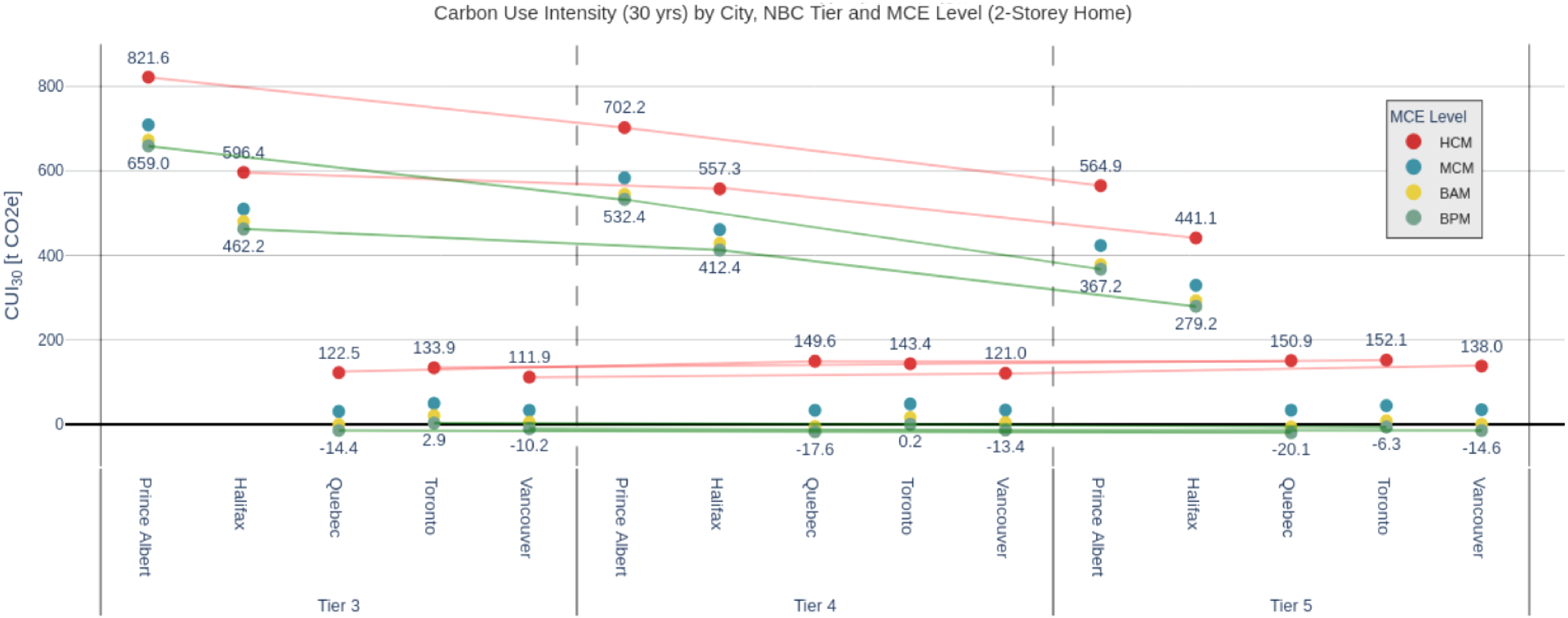
Preliminary Research on Embodied Carbon



Preliminary Research on Embodied Carbon



Preliminary Research on Embodied Carbon



Subsequent Research on Embodied Carbon

- Municipal studies of as-built homes
  - Mapped closely with preliminary findings
  - Demonstrated regional differences linked to architectural tendencies

Dataset	Material Carbon Emissions Intensity (kg CO2e/m2)		
	Highest	Average	Lowest
NRCan Archetypes	513	150	2*
Nelson & Castlegar, BC	309	150	72
Toronto, ON	561	189	116

Findings & Conclusions

- Material Carbon Emissions represents a significant, mostly overlooked and unregulated pool of GHGs
- Scope of Application and Methodology are important
- Consider availability of Data
- Mind the Regulatory Overlap
- Metrics matter!
- Net-Zero solutions vary by jurisdiction

Canada