Reframed Tech Series

Embodied carbon & deep retrofits

#Reframed

July 22, 2020

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Reframed Tech Series

Moderator

Ghazal Ebrahimi

Senior analyst, Pembina Institute

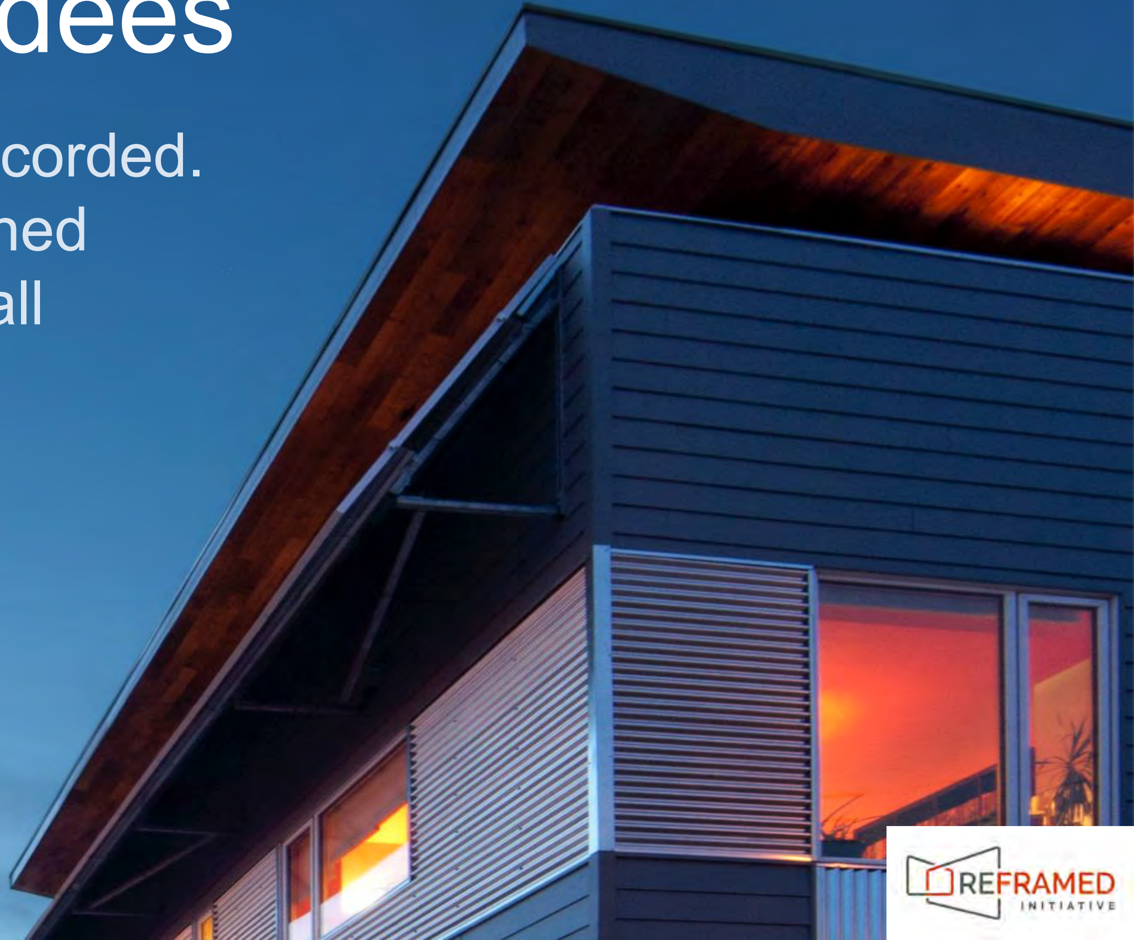
REFRAMED INITIATIVE

Agenda

1. Opening remarks
2. Introductions
3. Presentations
4. Q&A
5. Reframed Lab

Note to attendees

This webinar is being recorded. The video will be published online and shared with all registrants.



REFRAMED INITIATIVE

Introducing the Reframed Initiative

The Reframed Initiative is working with designers, builders, owners, financiers, and policy-makers to scale up deep retrofits.

Together, we can address the housing crunch and climate emergency.

BCNPHA
BC Non-Profit Housing Association

CITY OF VANCOUVER | GREENEST CITY

PEMBINA institute

Deep retrofits are:

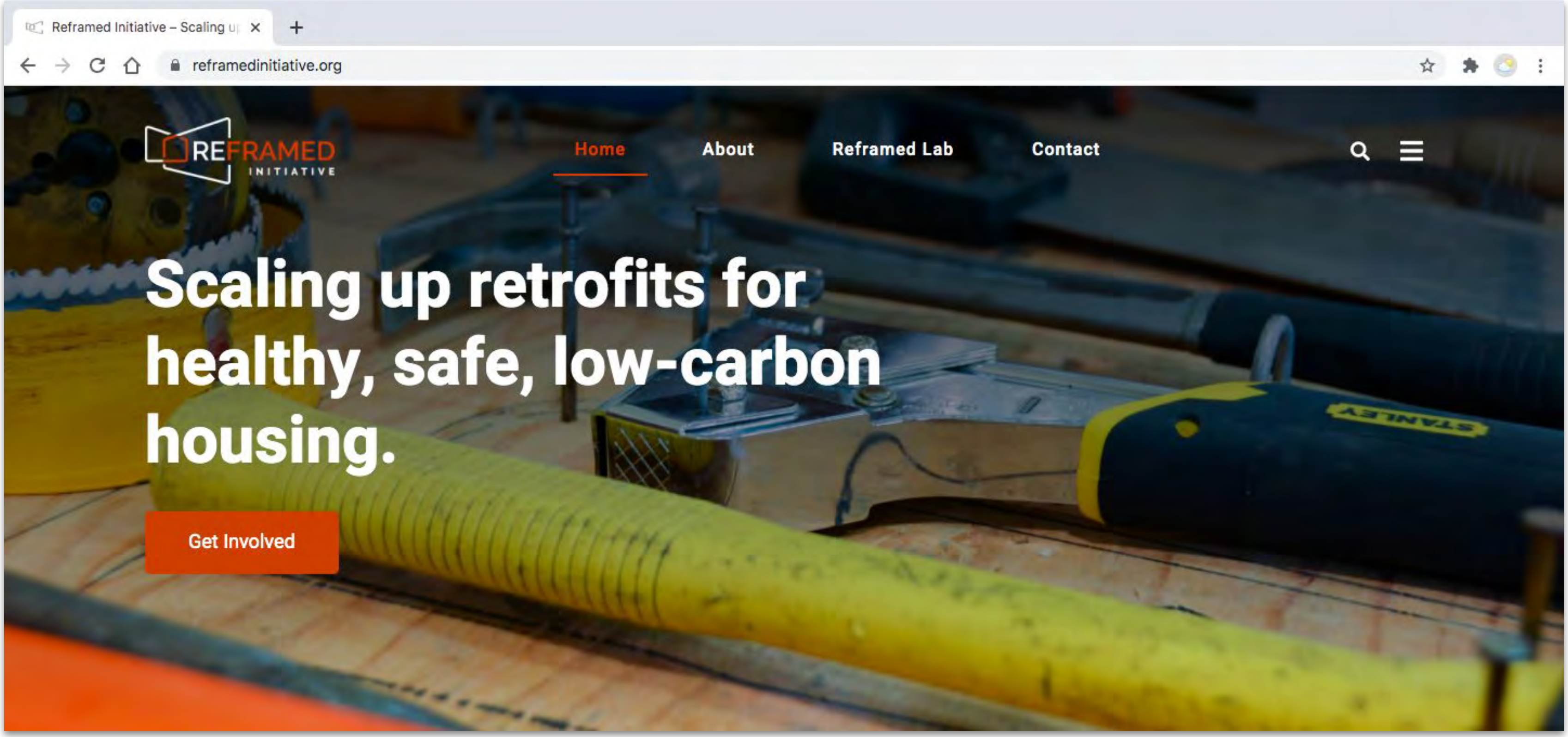
- **Healthy:** cleaner air, improved comfort
- **Resilient:** ready for extreme weather and earthquakes
- **Low-carbon:** use renewable energy and carbon smart materials

REFRAMED INITIATIVE

Let's scale up solutions that:

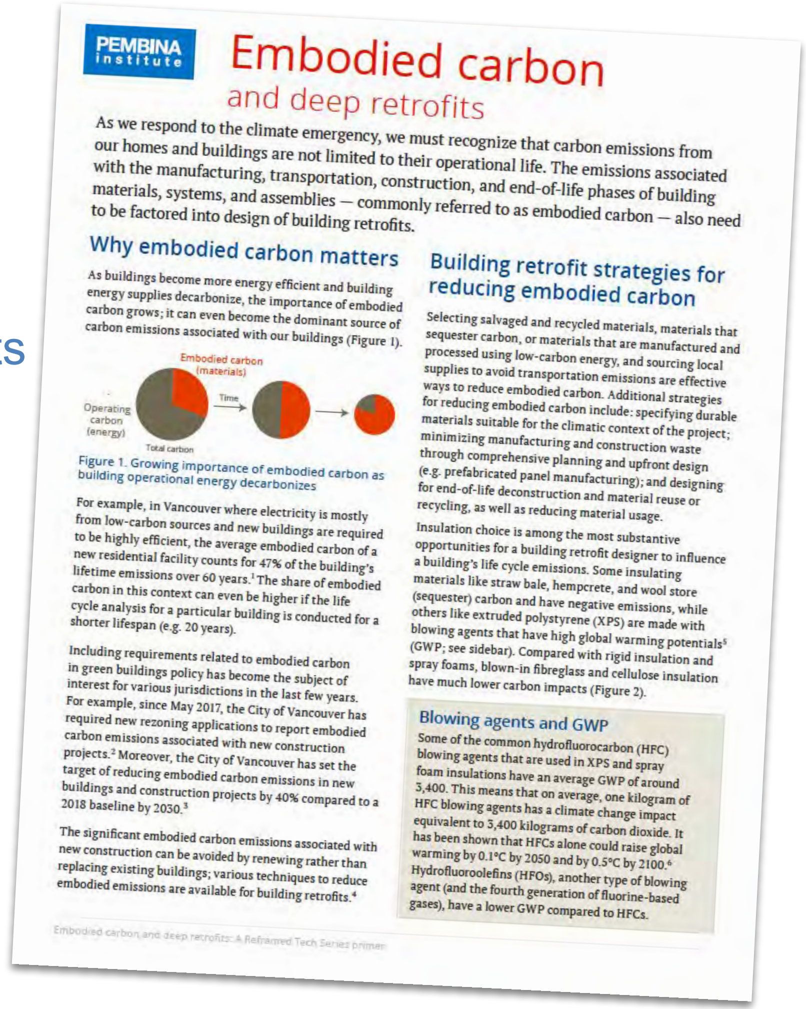
- Keep rent affordable
- Minimize disruption to tenants
- Return value to owners and investors

Learn more: reframedinitiative.org



New primer

DOWNLOAD:
pembina.org/pub/embodied-carbon-retrofits



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Embodied carbon
and deep retrofits

As we respond to the climate emergency, we must recognize that carbon emissions from our homes and buildings are not limited to their operational life. The emissions associated with the manufacturing, transportation, construction, and end-of-life phases of building materials, systems, and assemblies — commonly referred to as embodied carbon — also need to be factored into design of building retrofits.

Why embodied carbon matters

As buildings become more energy efficient and building energy supplies decarbonize, the importance of embodied carbon grows; it can even become the dominant source of carbon emissions associated with our buildings (Figure 1).

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

For example, in Vancouver where electricity is mostly from low-carbon sources and new buildings are required to be highly efficient, the average embodied carbon of a new residential facility counts for 47% of the building's lifetime emissions over 60 years.[1] The share of embodied carbon in this context can even be higher if the life cycle analysis for a particular building is conducted for a shorter lifespan (e.g. 20 years).

Including requirements related to embodied carbon in green buildings policy has become the subject of interest for various jurisdictions in the last few years. For example, since May 2017, the City of Vancouver has required new rezoning applications to report embodied carbon emissions associated with new construction projects.[2] Moreover, the City of Vancouver has set the target of reducing embodied carbon emissions in new buildings and construction projects by 40% compared to a 2018 baseline by 2030.[3]

The significant embodied carbon emissions associated with new construction can be avoided by renewing rather than replacing existing buildings; various techniques to reduce embodied emissions are available for building retrofits.[4]

Building retrofit strategies for reducing embodied carbon

Selecting salvaged and recycled materials, materials that sequester carbon, or materials that are manufactured and processed using low-carbon energy, and sourcing local supplies to avoid transportation emissions are effective ways to reduce embodied carbon. Additional strategies for reducing embodied carbon include: specifying durable materials suitable for the climatic context of the project; minimizing manufacturing and construction waste through comprehensive planning and upfront design (e.g. prefabricated panel manufacturing); and designing for end-of-life deconstruction and material reuse or recycling, as well as reducing material usage.

Insulation choice is among the most substantive opportunities for a building retrofit designer to influence a building's life cycle emissions. Some insulating materials like straw bale, hempcrete, and wool store (sequester) carbon and have negative emissions, while others like extruded polystyrene (XPS) are made with blowing agents that have high global warming potentials[5] (GWP; see sidebar). Compared with rigid insulation and spray foams, blown-in fibreglass and cellulose insulation have much lower carbon impacts (Figure 2).

Blowing agents and GWP

Some of the common hydrofluorocarbon (HFC) blowing agents that are used in XPS and spray foam insulations have an average GWP of around 3,400. This means that on average, one kilogram of HFC blowing agents has a climate change impact equivalent to 3,400 kilograms of carbon dioxide. It has been shown that HFCs alone could raise global warming by 0.1°C by 2050 and by 0.5°C by 2100.[6] Hydrofluoroolefins (HFOs), another type of blowing agent (and the fourth generation of fluorine-based gases), have a lower GWP compared to HFCs.

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EMBODIED CARBON

THE BLINDSPOT OF THE BUILDINGS INDUSTRY

Reframed Tech Series:
Embodied Carbon and Deep Retrofits
July 22, 2020

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Embodied Carbon

Emissions from Construction Materials

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Environmental Impacts from Cradle to Grave

Extraction, Transportation, Manufacturing, Construction, Operation, End of Life

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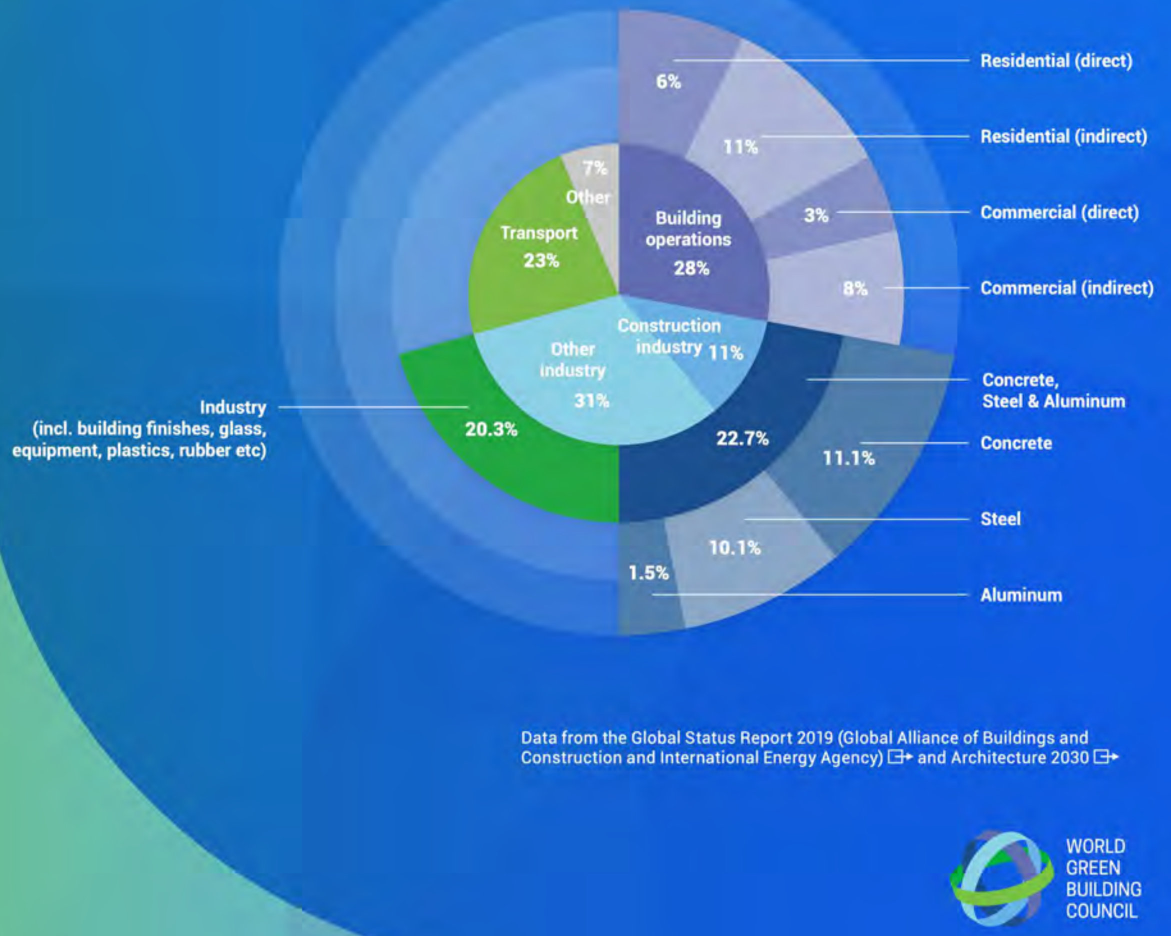


Operational Carbon of Buildings = 28% Global CO2 Emissions

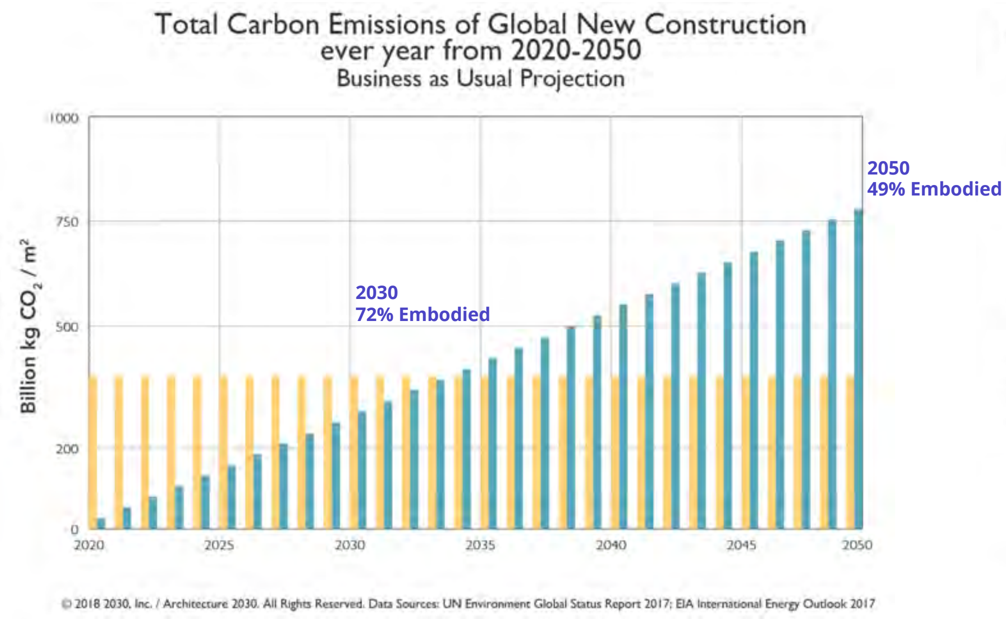
Embodied Carbon in Construction = 11% Global CO2 Emissions

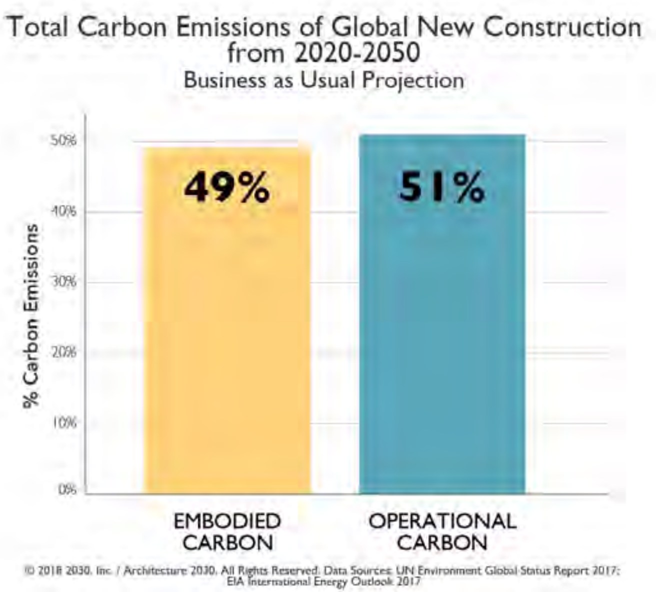
Concrete, Steel, & Aluminum = 22.7% Global CO2 Emissions

"If the building and construction sector were to drastically shift demand towards low carbon options for these materials, this would require a transformation in the manufacturing processes of the supply chain. This would affect the total emissions for those materials streams and have an enormous impact on emissions mostly attributed to other sectors through these three materials alone."

(WorldGBC - Advancing Net Zero Status Report 2020)

Embodied Carbon will be responsible for ALMOST HALF of total new construction emissions between now and 2050





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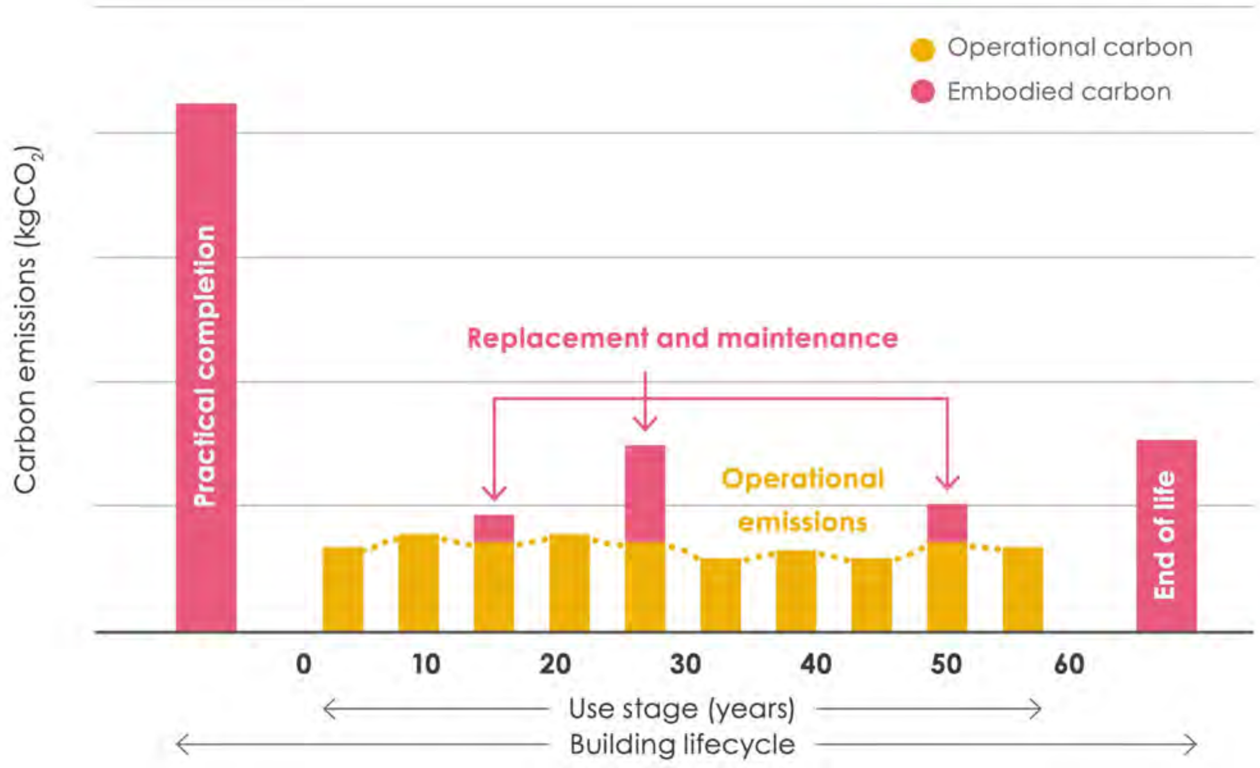
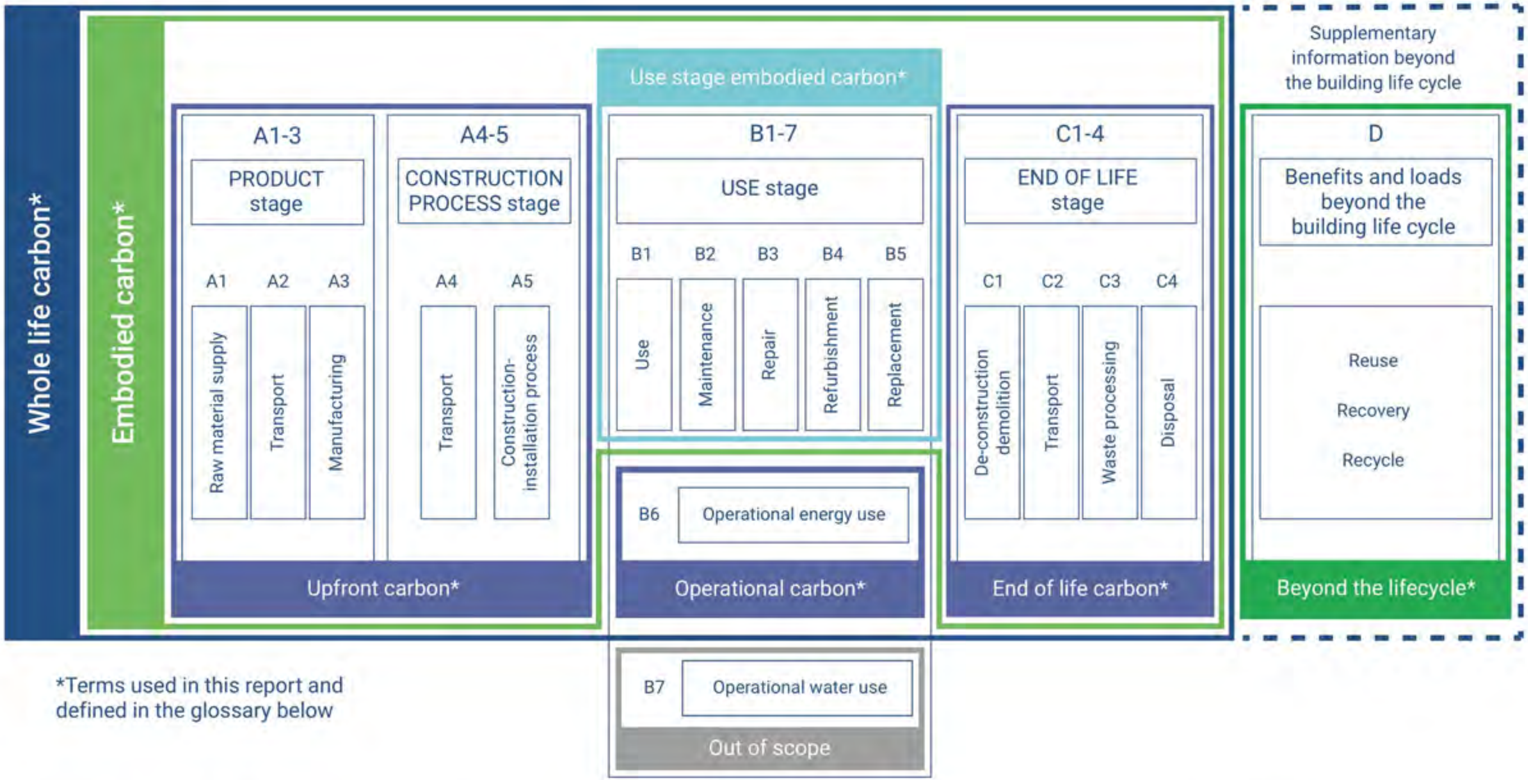
(Source: Architecture 2030 – New Buildings: Embodied Carbon, 2018)

Embodied and Operational Carbon During Building Lifespan



(Source: LETI Embodied Carbon Primer, 2019)

Life Cycle Stages



*Terms used in this report and defined in the glossary below

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

(Source: WorldGBC - Bringing Embodied Carbon Upfront, 2019)

Operational Carbon Intensity Across Canada

Vancouver = 20 $kgCO_2e/m^2/yr$

CoV Rezoning = 3 - 8 $kgCO_2e/m^2/yr$

Toronto = 26 $kgCO_2e/m^2/yr$

Toronto Green Standard = 3 - 20 $kgCO_2e/m^2/yr$

Calgary = 71 $kgCO_2e/m^2/yr$

Ottawa = 31 $kgCO_2e/m^2/yr$

Montreal = 28 $kgCO_2e/m^2/yr$

Halifax = 59 $kgCO_2e/m^2/yr$

(Source: CaGBC – Making the Case for Building to Zero Carbon, 2019)

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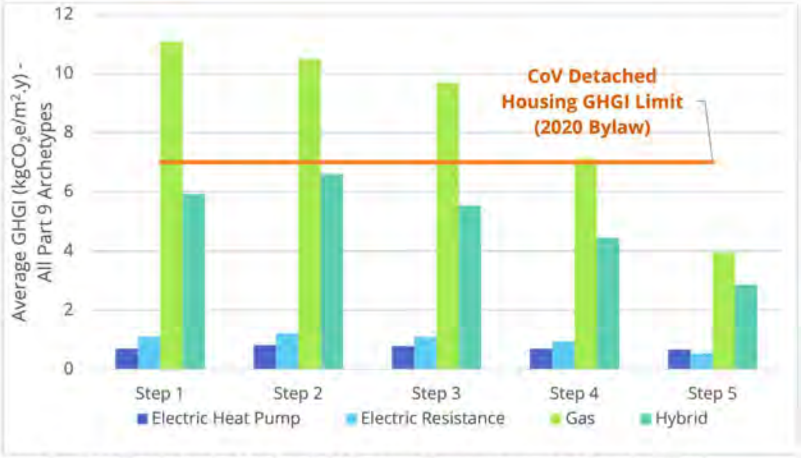
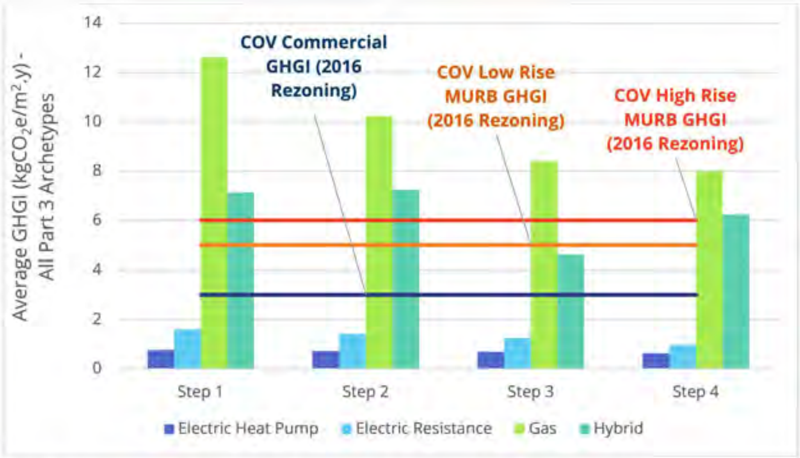
Operational Carbon (kgCO2e/m2·yr)
BC Step Code GHGI (Electric vs Natural Gas)



Part 9 - GHG Intensity by Mechanical System (average across all archetypes)



Part 3 - GHG Intensity by Mechanical System (average across all archetypes)

Part 9 – Houses & Small Buildings (<600m^2)

Electric: <1.5 kgCO2e/m2 per year

Gas: 4 – 11 kgCO2e/m2 per year

Part 3 – Large and Complex Buildings (>600m^2)

Electric: <2 kgCO2e/m2 per year

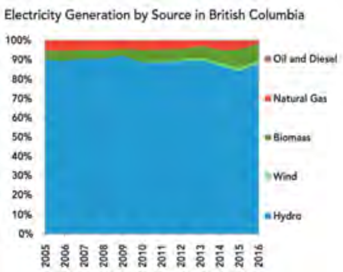
Gas: 4 – 13 kgCO2e/m2 per year

(Source: Integral Group - Implications of the BC Energy Step Code on GHG Emissions, 2019)

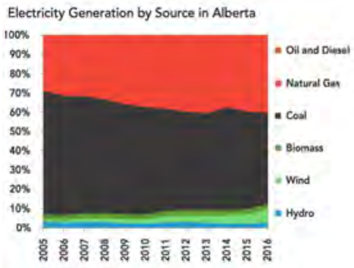
Canadian Provincial Electricity Grid Mix

(g CO_2 / kWh)

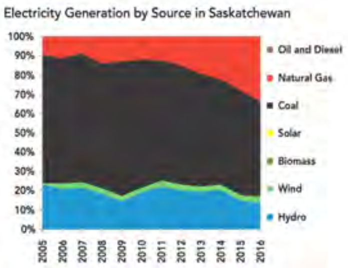
British Columbia
12.9



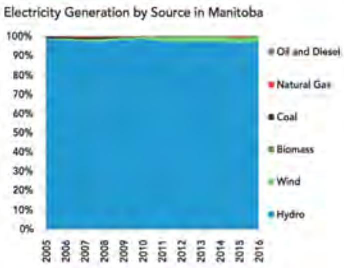
Alberta
790.0



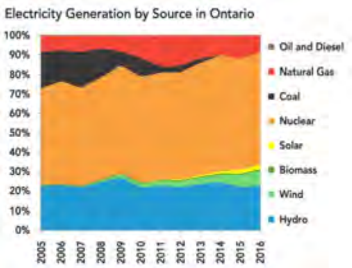
Saskatchewan
660.0



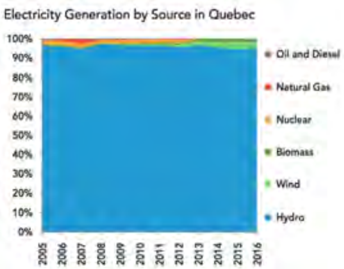
Manitoba
3.4



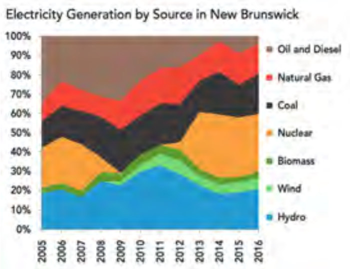
Ontario
40.0



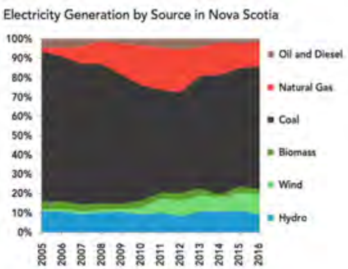
Quebec
1.2



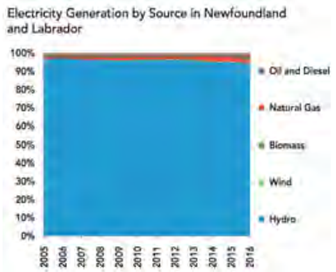
New Brunswick
280.0



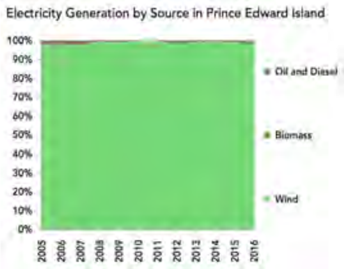
Nova Scotia
600.0



Newfoundland
32.0



Prince Edward Island
20.0



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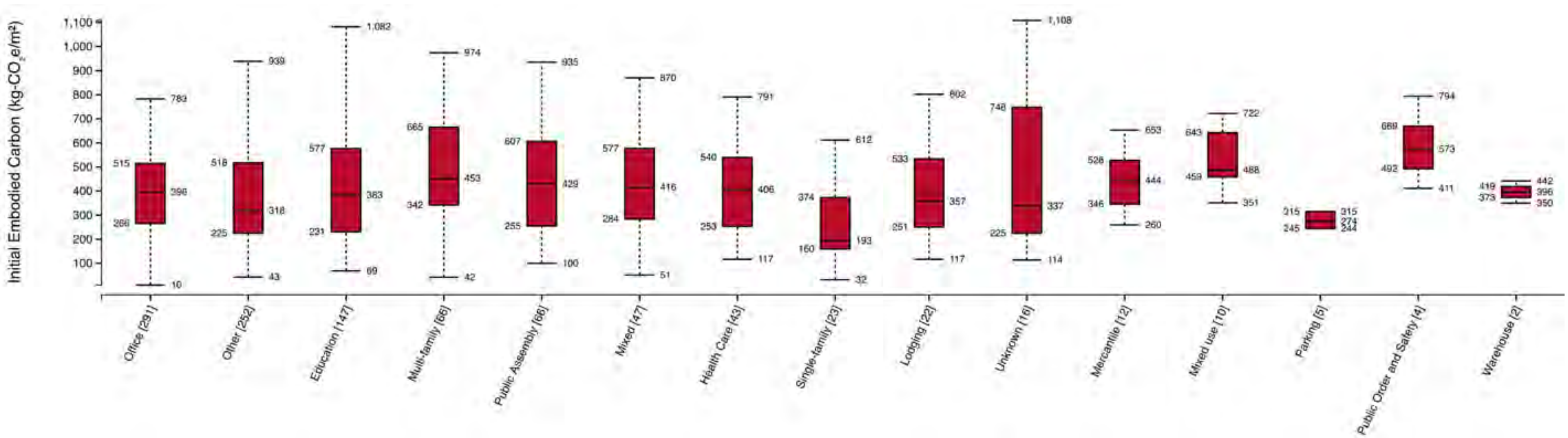
(Source: NEB – Canada's Renewable Power Landscape, Energy Market Analysis 2017)

Embodied Carbon (kgCO2e/m2)

CLF Embodied Carbon Benchmark of 1000 WB-LCAs Globally



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(Source: Carbon Leadership Forum – Embodied Carbon Benchmark Study 2017)

City of Vancouver – Rezoning

LCA calculations required for most City of Vancouver Rezoning projects

Pathway A

Some projects require LCA

CaGBC ZCB Standard v2

Must report and offset embodied carbon emissions. Can also meet "Impact and Innovation" requirement through 20% reduction in embodied carbon.

ILFI Zero Carbon Certification

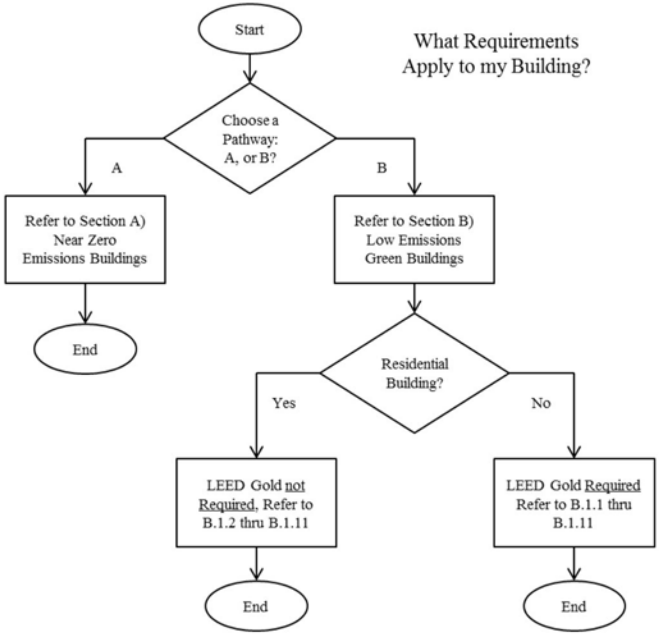
10% reduction in embodied carbon and offset emissions. Max embodied carbon cap at 500 kgCO2e/m2.

ILFI Living Building – Energy Petal

20% reduction in embodied carbon and offset emissions.

Passive House Certified

CHBA Net Zero Homes Standard



Pathway B

All projects require LCA

B.6.2 Requirements for Calculating Embodied Emissions.

Projects pursuing Pathway B **must report** on preliminary embodied emissions calculations through LCA, updated at 3 phases:

1. Rezoning Application
2. Building Permit
3. Occupancy Permit

LEED Gold

Additionally, non-residential buildings are also required to achieve LEED Gold. We can help achieve up to 5 points under LEED v4.1 MRc1 through Whole Building LCA.

PRIOPTA

(Source: CoV Green Buildings Policy for Rezonings, 2019)

Design Strategies for Reducing Embodied Carbon

Glass, Aluminum Insulation, Refrigerants, Mechanical, Interior

Glass

- Glass requires the use of sand and minerals, which are non-renewable natural raw materials.
- **Recycled glass** can have a second use as insulation or aggregate.
- Consideration should be given to coatings, as some processes produce solid waste and emit VOCs.
- The **whole life carbon (WLC)** of any project should be considered: low embodied carbon is a false economy if heat is easily lost in the operational phase.
- **Timber framing is usually the best option**. Timber has a longer life span than polyvinyl chloride (PVC) and a better thermal performance than steel or aluminum. Currently, a very small percentage of PVC is recycled, whilst the vast majority breaks down very slowly in landfill.
- Aluminum cladding of timber frames can reduce maintenance and increase the expected life span of the product, however a balance must be struck between durability and carbon cost.
- Glazing is durable but recycling, particularly of laminated glass, can be problematic; adopting standard sizes can therefore ease the re-use of the product at the end of expected life stage.
- Glass furnaces run permanently during their lifetime (15-18 years), making the introduction of new technologies difficult. These can only be integrated during furnace replacement or upgrade.

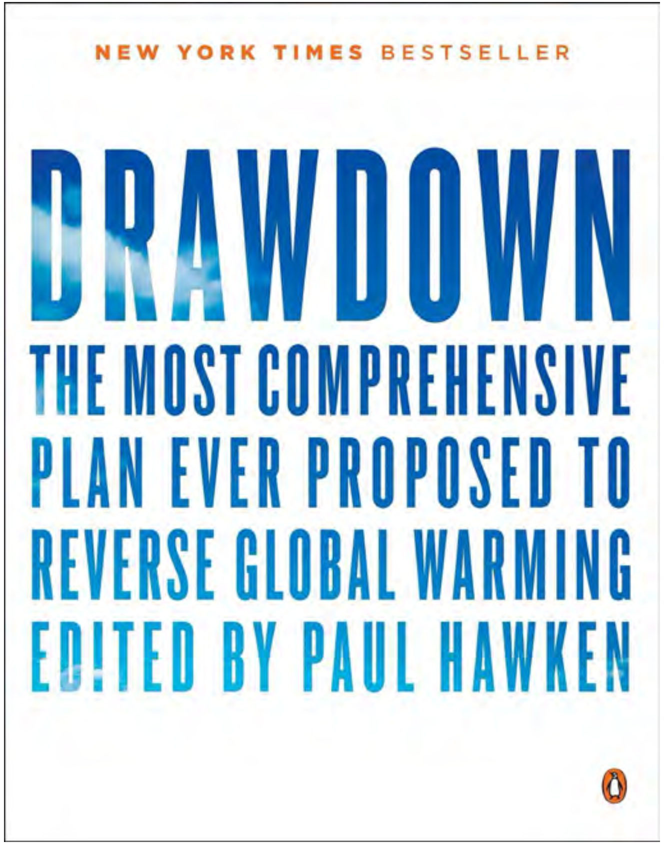
(Source: LETI Embodied Carbon Primer, 2019)

Aluminum

- The production of primary aluminum requires a very high consumption of electricity, almost **10 times** that of steel.
- Should be specified from regions with **low carbon electricity mixes**
- Aluminum is **highly recyclable** and does not deteriorate with re-use. Worldwide, around 75% of all aluminum produced is still in use.
- Recycling uses only around **5% of the energy** needed to produce primary aluminum, but recycled aluminum not enough to meet current demand.
- Most common method of refining aluminum from bauxite – the Bayer process – consumes large amounts of water and creates unwanted residues (120 million tonnes per year). Most of it is stored in holding ponds, as there are virtually no further suitable applications. This is a toxic material that can cause harm to animals and plant life.
- As a result of its high environmental impact, aluminum should be treated as a high-value material and **used sparingly, with re-use in mind**.

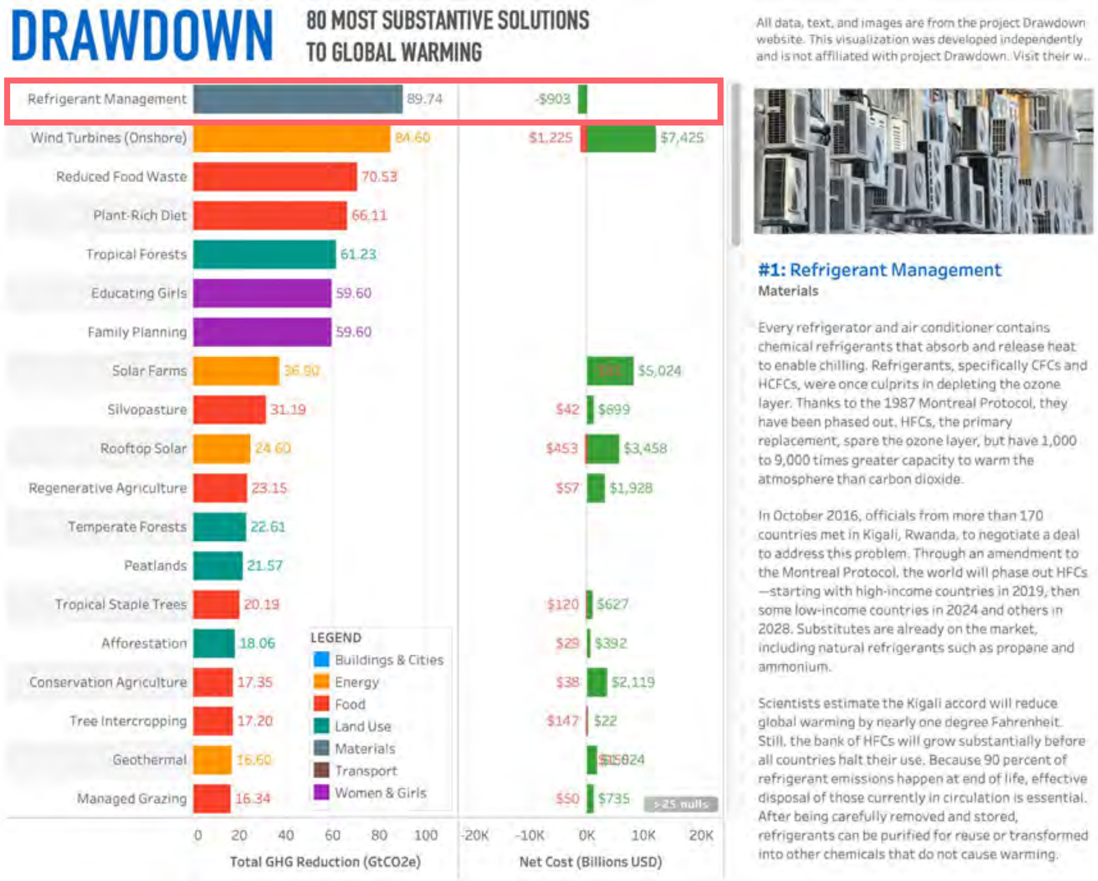
(Source: LETI Embodied Carbon Primer, 2019)

What is the top solution for global warming?



(Source: Drawdown – The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, 2017)

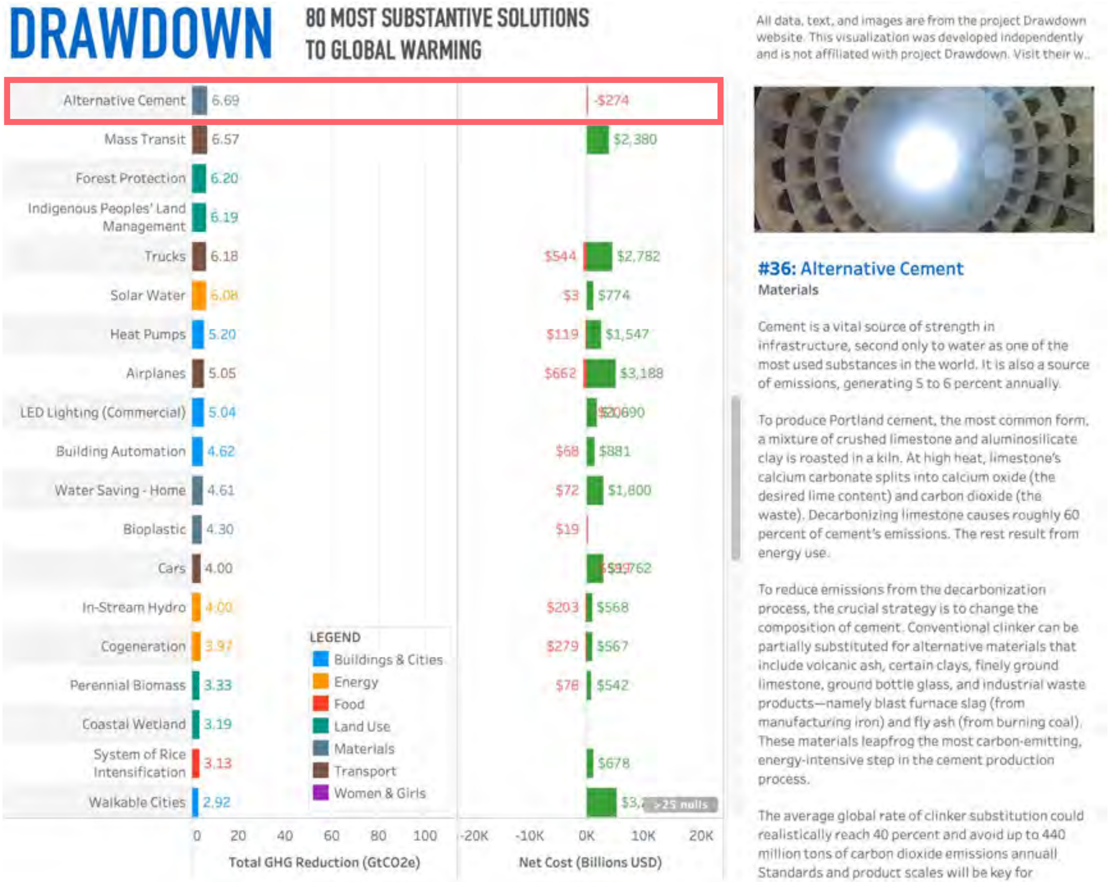
#1 - Refrigerant Management



(Source: Priopta Data Visualization of Drawdown, 2017)

(Data Source: Drawdown – The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, 2017)

#36 - Alternative Cement



(Source: Priopta Data Visualization of Drawdown, 2017)

(Data Source: Drawdown – The Most Comprehensive Plan Ever Proposed to Reverse Global Warming, 2017)

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Refrigerants (GWP20 vs GWP 100)

Methane: 3.0x
GWP100 28
GWP20 84

R-134a 2.7x
GWP100 1,430
GWP20 3,830

R-410a 2.1x
GWP100 2,088
GWP20 4,340

R-32: 3.5x
GWP100 675
GWP20 2,330

Table 1: List of the most commonly used HFCs, HCFCs and low GWP alternatives. (IPCCC Fourth Assessment Report- 2007): Atmospheric lifetime and GWP20 and GWP100

Substance	Application	20 Year GWP	100 Year GWP	Atmospheric Lifetime
HCFC -22	Air-conditioning: most commonly used refrigerant	5,160	1,810	12
HCFC -141b	Insulation foam blowing	2,250	725	9.3
HCFC-142b	Insulation foam blowing	5,490	2,310	17.9
HFC-23	Low temperature refrigerant	12,000	14,800	
HFC-32	Blend component of refrigerants	2,330	675	4.9
HFC-125	Blend component of refrigerants	6,350	3,500	29
HFC-134a	Refrigerant in domestic refrigerators, mobile air-conditioning, stationary air-conditioning, blend component of refrigerants, foam blowing agent, aerosol propellant	3,830	1,430	14
HFC-143a	Blend component of refrigerants	5,890	4,470	52
HFC -152a	Blend component of refrigerants, foam blowing agent, possible future refrigerant	437	124	1.4
HFC-227ea	Refrigerant	5,310	3,220	
HFC-245fa	Foam blowing agent Possible future refrigerant	3,380	1030	7.6
HFC-365mfc	Foam blowing agent Possible future refrigerant	2,520	794	8.6
HFC-404a	Refrigerant blend: a leading alternative to HCFC-22 in air-conditioning	6010	3922	34.2
HFC-410 a	Refrigerant blend: a leading alternative to HCFC-22 in air-conditioning, transport refrigeration	4340	2088	
HFC-407c	Refrigerant blend: a leading retrofit alternative to HCFC-22 in air-conditioning, transport refrigeration	4115	1774	
CO2	Refrigerant, foam blowing agent	1	1	
Hydrocarbons	Refrigerant, foam blowing agent	<3	<3	
Ammonia	Refrigerant	0	0	

The lifetime of HFCs ranges from 1.4 years (HFC-152a) to 52 years (HFC-143a), the average lifetime is 21.7 years. The average GWP of these HFCs, calculated over 20 years is 4582, and 2362 over 100 years. [viii]

(Source: The Benefits of Basing Policies on the 20 Year GWP of HFCs, 2011)

XPS & Spray Foam - Blowing Agent Emissions (Module B & C)

Data Source	Insulation Type	A1-A3	A4	A5	B1	C2	C4	Total (A-C) (kgCO2e/m2) RSI=1 (R-5.68)
Dow Styrofoam EPD 2014	XPS (HFC) - Styrofoam	34.43	0.19		27.20		33.30	95.30
Owens Corning Foamular EPD 2018	XPS (HFC) - 100 psi	39.05	0.27	0.00	50.99	0.04	13.18	103.53
Owens Corning Foamular EPD 2018	XPS (HFC) - 60 psi	28.65	0.20	0.00	37.41	0.03	9.67	75.95
Owens Corning Foamular EPD 2018	XPS (HFC) - 40 psi	23.43	0.16	0.00	30.60	0.02	7.91	62.13
Owens Corning Foamular EPD 2018	XPS (HFC) - 25 psi	20.17	0.14	0.00	26.34	0.02	6.81	53.48
Owens Corning Foamular EPD 2018	XPS (HFC) - 15 psi	16.93	0.12	0.00	22.11	0.02	5.71	44.89
Jackson EPD 2015 (Germany CML)	XPS (HFO)	13.00	0.65	-		0.09	0.28	14.02
SPFA Industry Average EPD 2018	Spray Foam (HFC) - 2K-LP	3.21	0.10	7.05	15.20	0.00	10.20	35.76
SPFA Industry Average EPD 2018	Spray Foam (HFC) - Closed Cell	3.31	0.12	3.82	7.73	0.00	5.20	20.19
SPFA Industry Average EPD 2018	Spray Foam (HFO) - Closed Cell	3.47	0.12	0.53	-	0.00	0.04	4.16
SPFA Industry Average EPD 2018	Spray Foam (HFC) - Roofing	3.83	0.16	5.10	10.40	0.00	6.96	26.46
SPFA Industry Average EPD 2018	Spray Foam (HFO) - Roofing	4.05	0.16	0.69	-	0.00	0.06	4.96

Comparison of Insulation GWP

	Data Source	Insulation Type	Total (A-C) (kgCO2e/m2) RSI=1 (R-5.68)	Global Warming Potential A-C (kgCO2e/m2) R-5	R-10	R-15	R-20	R-25	R-30	R-35	R-40	R-45	R-50	R-55	R-60
	Dow Styrofoam EPD 2014	XPS (HFC) - Styrofoam	95.3	83.9	167.8	251.7	335.7	419.6	503.5	587.4	671.3	755.2	839.2	923.1	1,007.0
	Owens Corning Foamular EPD 2018	XPS (HFC) - 100 psi	103.5	91.2	182.3	273.5	364.7	455.8	547.0	638.2	729.3	820.5	911.7	1,002.8	1,094.0
	Owens Corning Foamular EPD 2018	XPS (HFC) - 60 psi	76.0	66.9	133.8	200.6	267.5	334.4	401.3	468.2	535.0	601.9	668.8	735.7	802.5
HFC	Owens Corning Foamular EPD 2018	XPS (HFC) - 40 psi	62.1	54.7	109.4	164.1	218.8	273.5	328.3	383.0	437.7	492.4	547.1	601.8	656.5
	Owens Corning Foamular EPD 2018	XPS (HFC) - 25 psi	53.5	47.1	94.2	141.3	188.4	235.5	282.5	329.6	376.7	423.8	470.9	518.0	565.1
	Owens Corning Foamular EPD 2018	XPS (HFC) - 15 psi	44.9	39.5	79.0	118.6	158.1	197.6	237.1	276.7	316.2	355.7	395.2	434.8	474.3
	Jackson EPD 2015 (Germany CML)	XPS (HFO)	14.0	12.3	24.7	37.0	49.4	61.7	74.1	86.4	98.8	111.1	123.5	135.8	148.1
	SPFA Industry Average EPD 2018	Spray Foam (HFC) - 2K-LP	35.8	31.5	63.0	94.5	126.0	157.4	188.9	220.4	251.9	283.4	314.9	346.4	377.9
	SPFA Industry Average EPD 2018	Spray Foam (HFC) - Closed Cell	20.2	17.8	35.5	53.3	71.1	88.9	106.6	124.4	142.2	160.0	177.7	195.5	213.3
HFO	SPFA Industry Average EPD 2018	Spray Foam (HFO) - Closed Cell	4.2	3.7	7.3	11.0	14.7	18.3	22.0	25.7	29.3	33.0	36.6	40.3	44.0
	SPFA Industry Average EPD 2018	Spray Foam (HFC) - Roofing	26.5	23.3	46.6	69.9	93.2	116.5	139.8	163.1	186.4	209.7	233.0	256.3	279.6
	SPFA Industry Average EPD 2018	Spray Foam (HFO) - Roofing	5.0	4.4	8.7	13.1	17.5	21.9	26.2	30.6	35.0	39.3	43.7	48.1	52.5
	EPS-IA Industry Avg. 2017	EPS	2.5	2.2	4.4	6.6	8.8	11.1	13.3	15.5	17.7	19.9	22.1	24.3	26.5
	Athena Impact Estimator	EPS	1.9	2.4	4.8	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0	26.3	28.7
	Dow TUFF-R EPD 2014	Polyiso - TUFF-R	4.2	3.7	7.3	11.0	14.6	18.3	22.0	25.6	29.3	32.9	36.6	40.3	43.9
	Dow THERMAX EPD 2014	Polyiso - THERMAX	6.1	5.4	10.8	16.1	21.5	26.9	32.3	37.7	43.0	48.4	53.8	59.2	64.6
	Athena Impact Estimator	Polyiso	1.3	1.1	2.2	3.3	4.5	5.6	6.7	7.8	8.9	10.0	11.1	12.3	13.4
	BASF Neopor 2018	GPS - Neopor	1.7	1.5	3.0	4.6	6.1	7.6	9.1	10.7	12.2	13.7	15.2	16.8	18.3
Other	PIMA Industry Avg. 2015	Polyiso - Roof	2.8	2.5	4.9	7.4	9.9	12.3	14.8	17.3	19.7	22.2	24.7	27.1	29.6
	PIMA Industry Avg. 2015	Polyiso - Wall	2.3	2.0	4.1	6.1	8.2	10.2	12.3	14.3	16.3	18.4	20.4	22.5	24.5
	NAIMA Industry Avg. 2013	Mineral Wool Loose Fill	1.4	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.5	13.8	15.0
	NAIMA Industry Avg. 2018	Mineral Wool Board - Light Density	4.0	3.5	7.0	10.6	14.1	17.6	21.1	24.7	28.2	31.7	35.2	38.8	42.3
	NAIMA Industry Avg. 2018	Mineral Wool Board - Heavy Density	9.0	8.0	15.9	23.9	31.9	39.8	47.8	55.7	63.7	71.7	79.6	87.6	95.6
	OC EcoTouch PINK Fiberglas 2018	Fiberglass Batt - Unfaced	0.5	0.4	0.9	1.3	1.8	2.2	2.7	3.1	3.6	4.0	4.4	4.9	5.3
	CertainTeed Blown Fiberglass 2019	Open Attic	1.4	1.0	1.9	2.9	3.9	4.8	5.8	6.7	7.7	8.7	9.6	10.6	11.6
	CIMA/CIMAC Industry Avg. 2019	Cellulose Loose Fill	0.7	0.6	1.2	1.9	2.5	3.1	3.7	4.3	5.0	5.6	6.2	6.8	7.4

- XPS and Spray Foam insulation typically use **HFC** blowing agents, which have very high Global Warming Potential (GWP).
- **HFO** blowing agents have much GWP values. Spray foam using HFO has **~1/5th** the embodied carbon compared to HFC.
- Whole Building LCA tools have shown XPS GWP values that are **~10 times** lower than manufacturer-specific EPDs from Dow and Owens Corning. This may be due to use of old European XPS data which doesn't have HFC blowing agents and/or not accurately accounting for HFC blowing agent emissions during operation and end of life (Module B and C). This means that past WB-LCA results for projects using XPS and Spray Foam have underestimated these emissions and can significantly increase the total whole building GWP.

Refrigerant Leaks

Example: 500 sf NYC apartment, 1 ton heat pump, COP 2.5, 2.9lbs refrigerant

Impact of Refrigerant Leakage per Year on Heating CO_2 Intensity

Refrigerant leakage rate per year	Pounds CO_2e per square foot per year due to building emissions and refrigerant leakage
0%	1.0
1%	1.2
5%	1.6
10%	2.2 (comparable to a gas hydronic system = approximately 2.0)
25%	3.8 (comparable to a median electric baseboard = approximately 4.2)
40%	5.8 (comparable to a median steam building = approximately 6.2)

Source: BuildingGreen, Inc., based on data supplied by Robin Neri and Marc Zuluaga, Steven Winter Associates

4.9 kgCO2e/m2

5.9 kgCO2e/m2

7.8 kgCO2e/m2

10.7 kgCO2e/m2

18.6 kgCO2e/m2

28.3 kgCO2e/m2

Refrigerant leaks can come from initial charging (adding refrigerants), defective equipment, installation, repairs, corrosion, damage, recharging, and improper disposal.

Commercial chillers leak up to 15%, Residential and light commercial systems up to 10%, higher for complicated split systems.

58.6 kgCO2e/m2 (100% leakage, 12 lbCO2e/sf)

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(Source: The Cost of Comfort: Climate Change and Refrigerants – BuildingGreen, 2017)

Embodied Carbon of Mechanical Systems

Results for Passive House

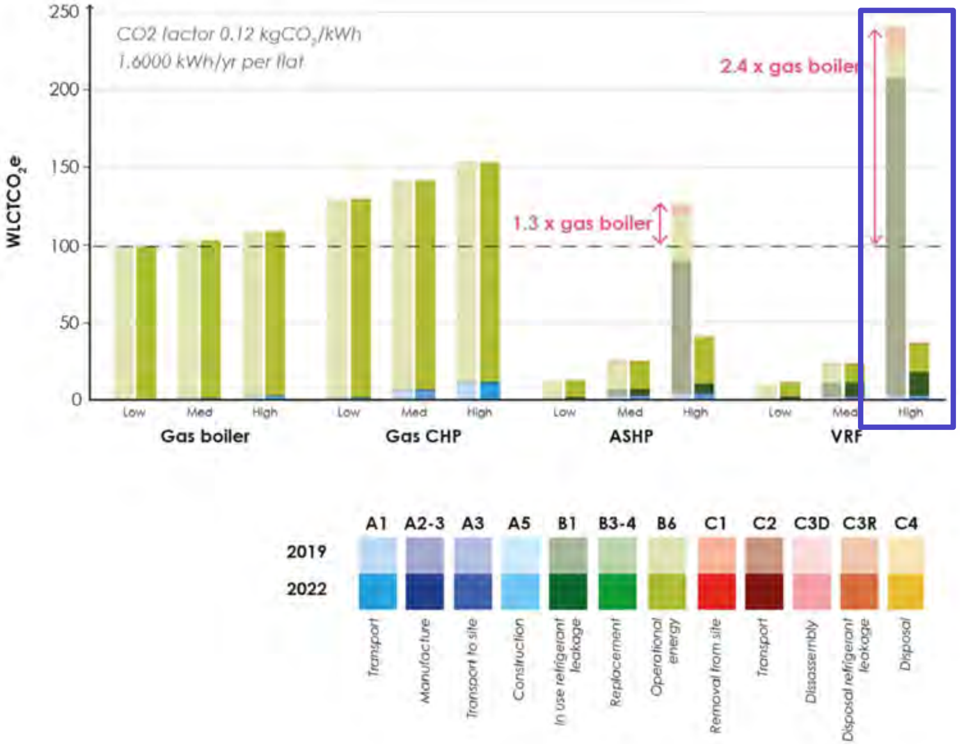

Figure A.6.4.2 – Study results for the whole life carbon of heat generation equipment by Elementa consulting

Refrigerant GWP and Leakage Rate Assumptions

Table 6: Assumptions on refrigerants; installation in 2019

	Heat pumps			VRF		
	Low	Med	High	Low	Med	High
GWP	1	150	2088	1	150	2088
Annual leakage/ End of life recovery	1%/ 99%	3.8%/ 98%	6%/ 90%	1%/ 99%	6%/ 90%	10%/ 85%

Table 8: Assumptions on refrigerants for installations after 2022

Assumptions on refrigerants for installations after 2022						
	Heat pumps			VRF		
	Low	Med	High	Low	Med	High
GWP	150	150	150	150	150	150
Annual leakage/ End of life recovery	1%/99%	3.8%/98%	6%/90%	1%/99%	6%/90%	10%/85%

(Source: LETI Embodied Carbon Primer, 2019 & Whole Life Carbon of Heat Generation Equipment, Clara Bagenal George et al, 2019)

Mech, Elec, Plumbing (MEP)

Tenant Improvement (TI)

MEP - Embodied Carbon Ranges:

Mechanical **28 – 60** $kgCO_2e/m^2$

Electrical **5 – 16** $kgCO_2e/m^2$

Plumbing **6 – 7** $kgCO_2e/m^2$

MEP - High Impact Items:

- Air-handling units (AHUs) and other large, heavy units
- Galvanized sheet metal for ductwork
- Light fixtures
- Cast iron piping for wastewater and ventilation
- Refrigerants (more data is needed)

Refrigerants - Estimate:

Refrigerants **38** $kgCO_2e/m^2$

(R-410a, 40% loss, 15yr replacement)

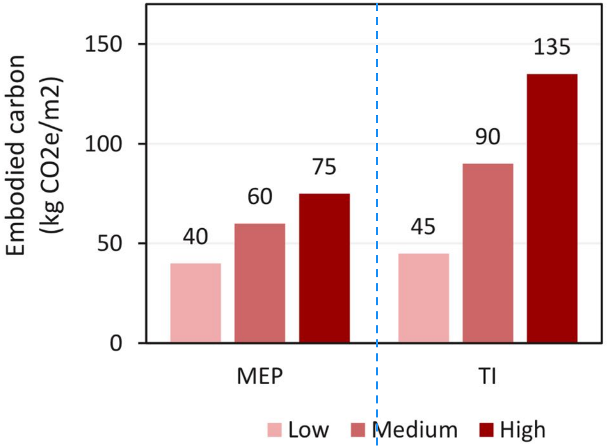

Figure 2. Embodied carbon estimates for MEP and TI at low, medium, and high estimate levels.

TI - High Impact Items:

- Cubicles
- Furniture
- Flooring – Dependent on Type
- Ceiling Panel Suspension System

(Source: LCA for Low Carbon Construction: Mechanical, Electrical, and Plumbing in Commercial Office Buildings, 2019)

MEP & TI - Lifecycle Embodied Carbon (60 years)

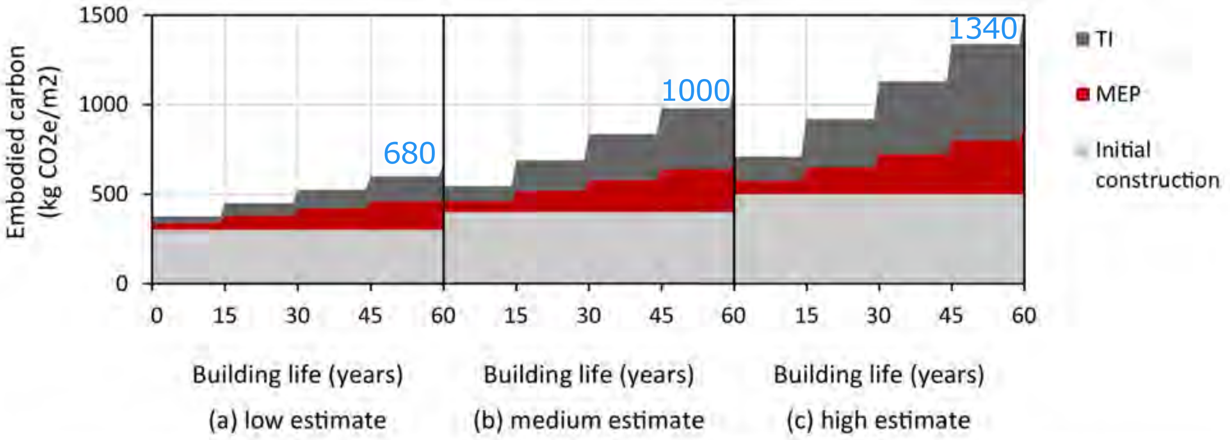

Figure 4. Cumulative embodied carbon impacts of initial construction, MEP, TI, and use (operational) at low, medium, and high estimate levels over 60 years.

Table 1. Initial embodied carbon impacts at low, medium, and high estimate levels.

	Embodied carbon (kg CO_2e/m^2)		
Component	**Low estimate**	**Medium estimate**	**High estimate**
Initial MEP	40	60	75
Initial TI	45	90	135
Initial construction	300	400	500
Initial construction + MEP+TI	385	550	710
Initial + (MEP+TI) x 4	680	1000	1340

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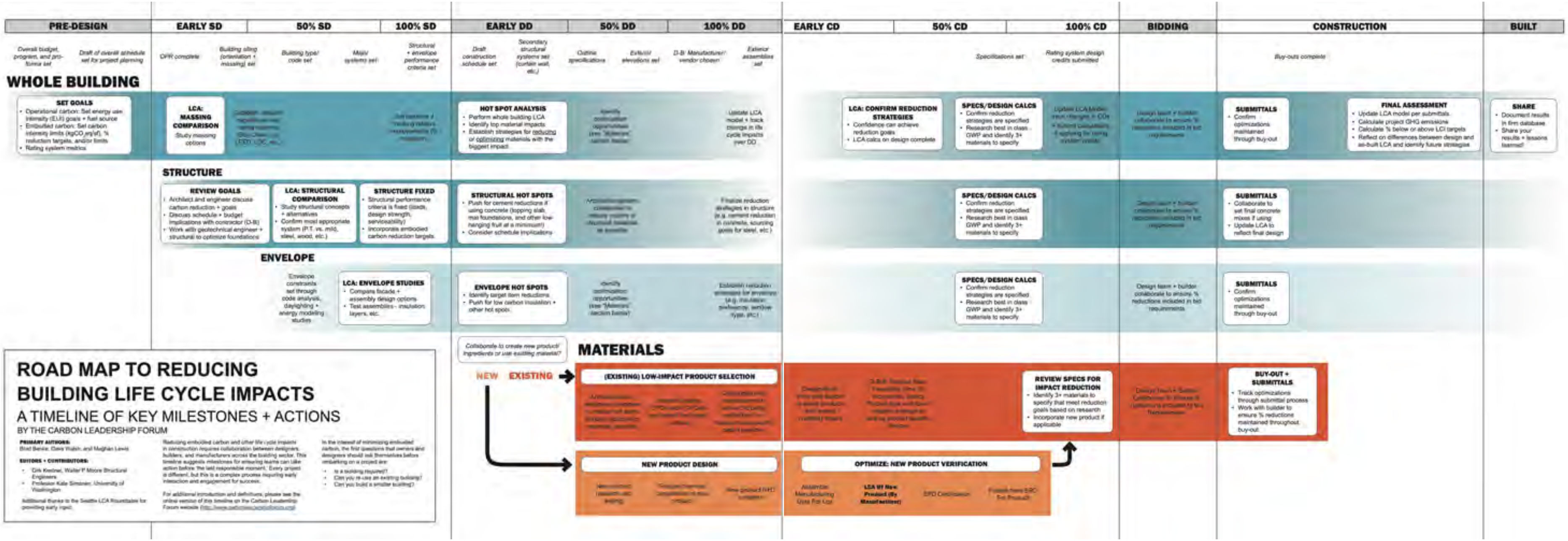
(Source: LCA for Low Carbon Construction: Mechanical, Electrical, and Plumbing in Commercial Office Buildings, 2019)

Reduce Embodied Carbon – Timeline of Key Milestones and Actions



(Source: [CLF – Roadmap to Reducing Building Life Cycle Impacts]())

PRIOPTA

Our Mission

Drive Radical Reductions in Embodied Carbon Globally

Email: anthony@priopta.com

Connect: LinkedIn

Website: www.priopta.com

Reframed: Embodied Carbon

Lindsay Rasmussen, Assoc. AIA, CPHC®
Program Manager | Architecture2030

Reframed Tech Series: Embodied Carbon & Deep Retrofits

HOW DO WE REDUCE EMBODIED CARBON?

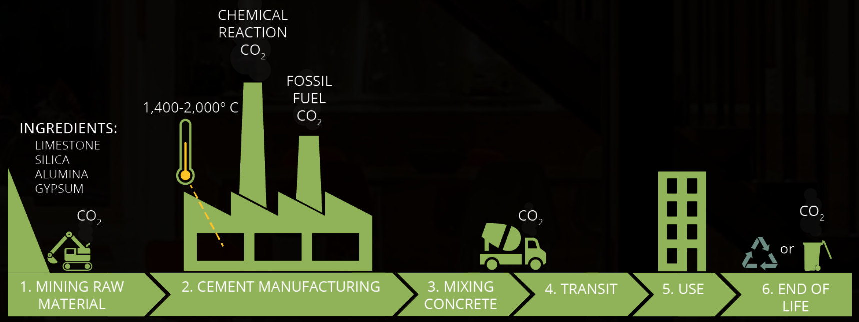
Reducing **Embodied Carbon** in Design and Policy

Prescriptive Path

- USE DRY KILN WITH PREHEATER AND PRECALCINER
- UTILIZE CARBON INJECTION

Performance Path

CARBON IMPACTS OF CONCRETE



EPDs & WHOLE BUILDING LCAS

Taking a **Performance Path Approach** to Embodied Carbon reduction

The Stellar Apartments

PASSIVE HOUSE

EARTH ADVANTAGE

PHASE ONE
COMPARE ENERGY CONSUMPTION

VS

VS

PHASE TWO
COMPARE OPERATIONAL TO EMBODIED

Comparison

PHASE THREE | COMPARE EMBODIED CARBON OF PHNW PROJECTS

Stellar

CH2

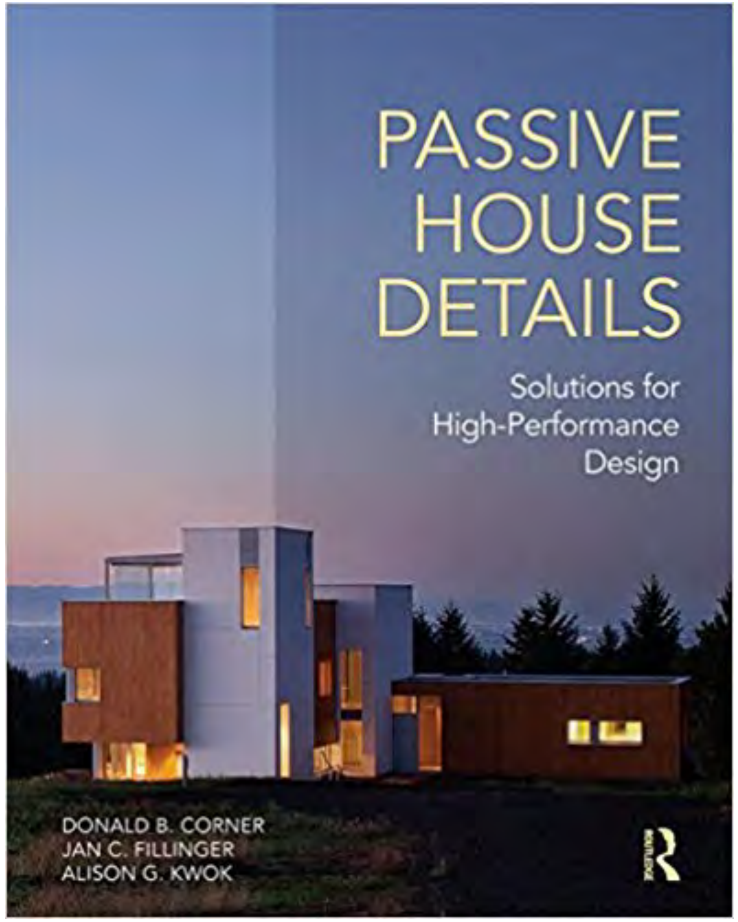
Orchards Phase I

Orchards Phase II

San Juan

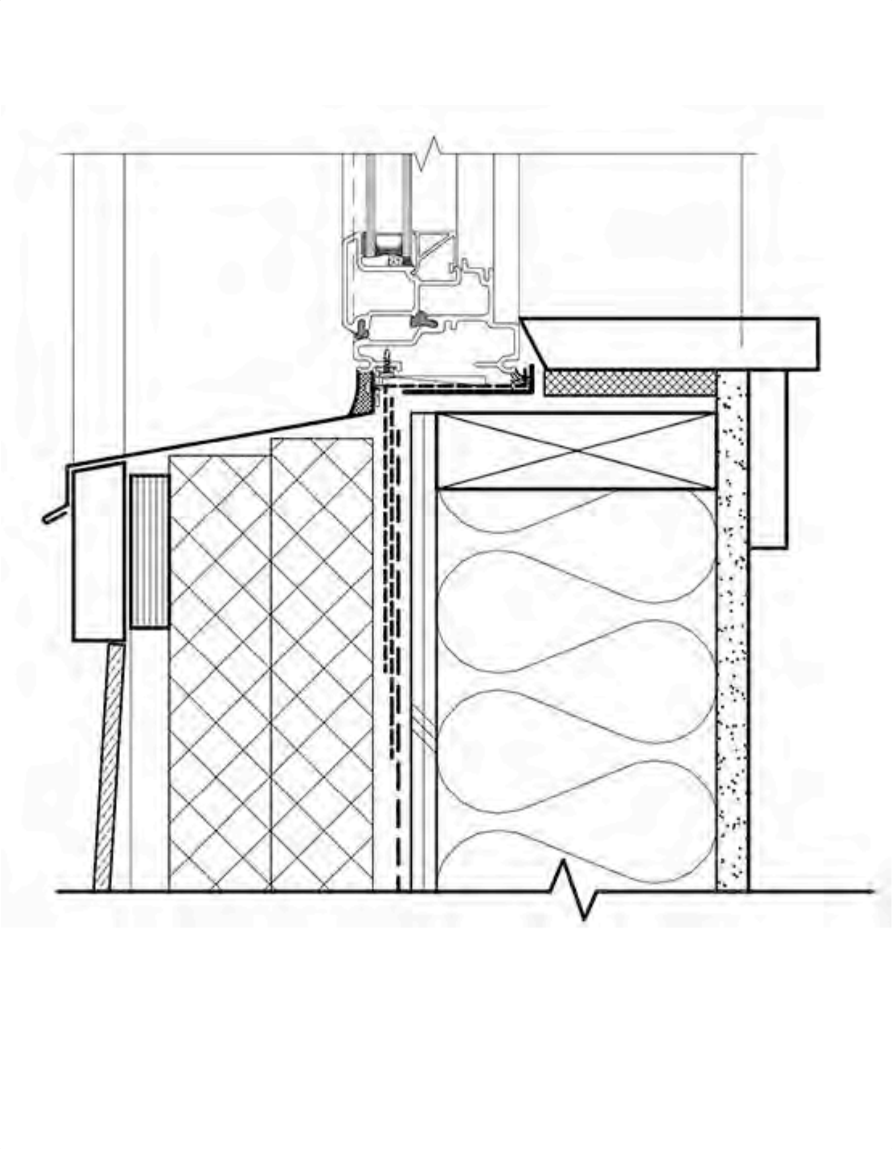
Skidmore

Methodology



CASE STUDY ONE – STELLAR

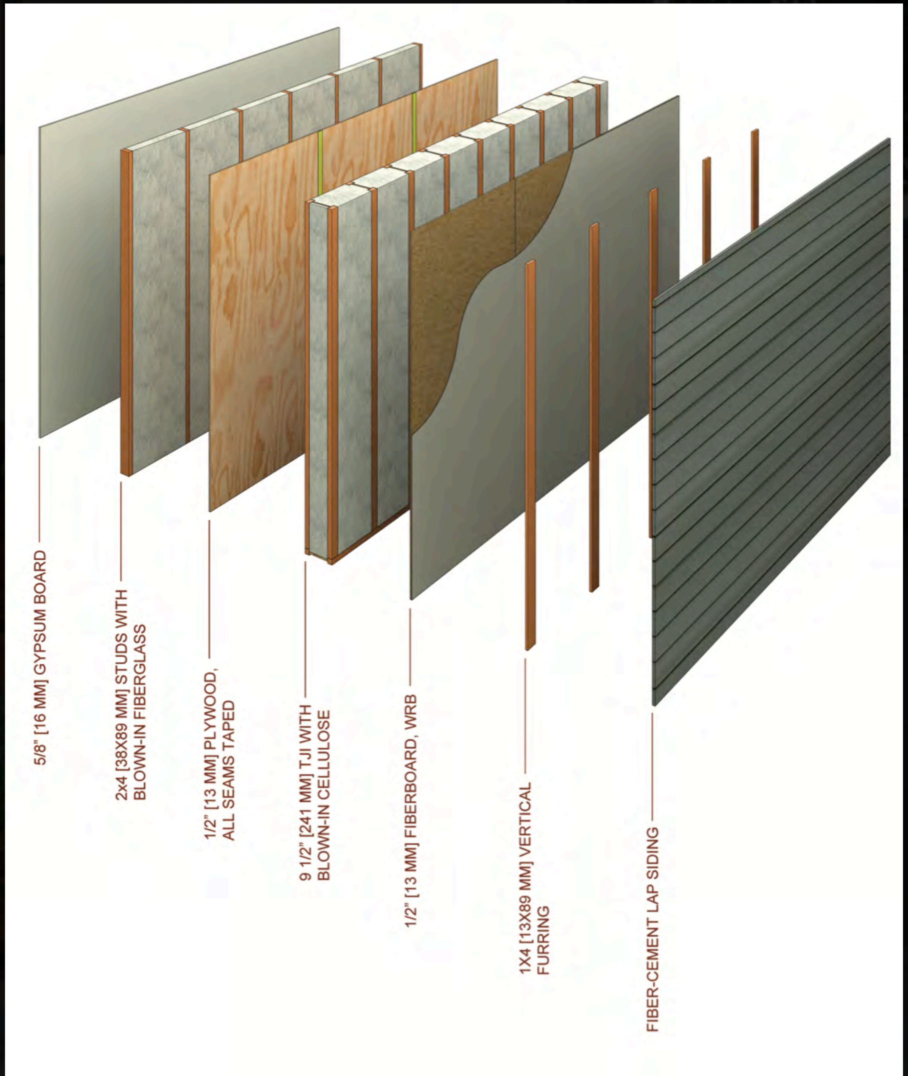
Eugene, Oregon
Bergsund DeLaney
Architecture and Planning
CPHC: Win Swafford
2014
5,034 sf




615

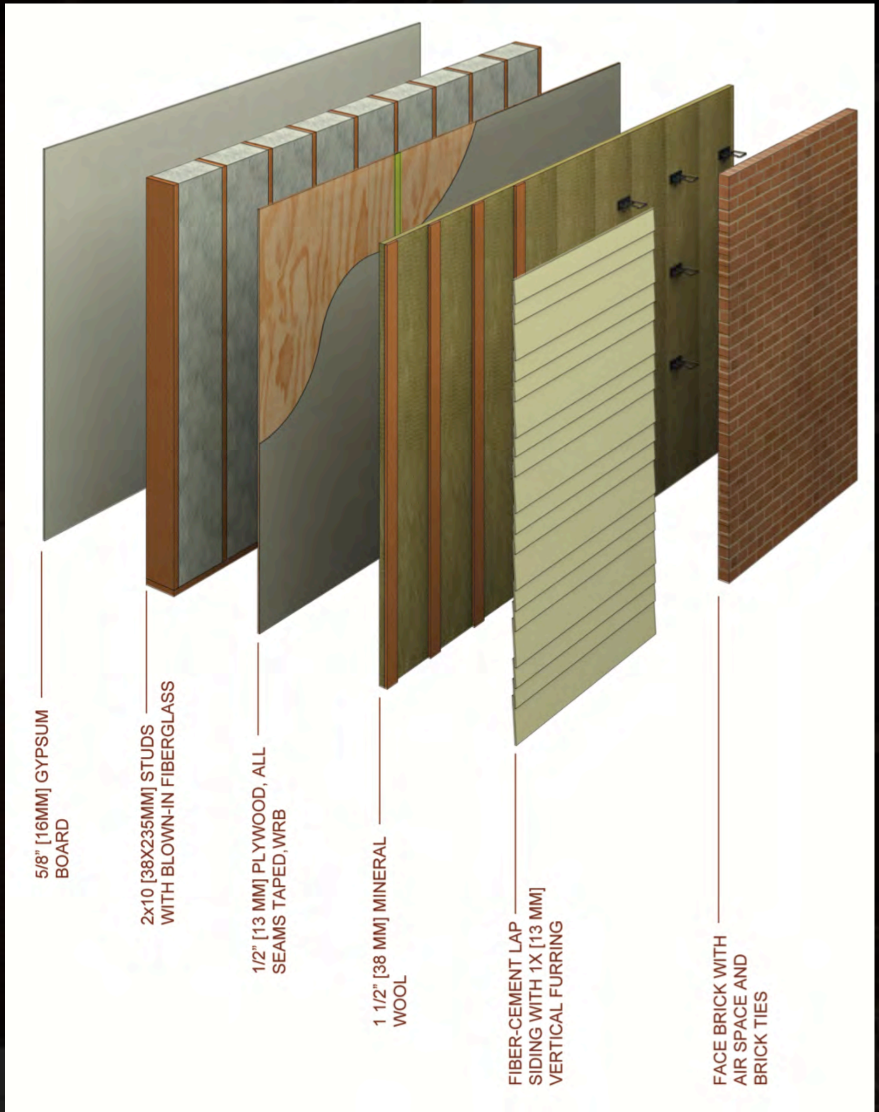
CASE STUDY TWO – CH2

Portland, Oregon
PDX Living, LLC
CPHC: Rob Hawthorne
2014
1,670 sf



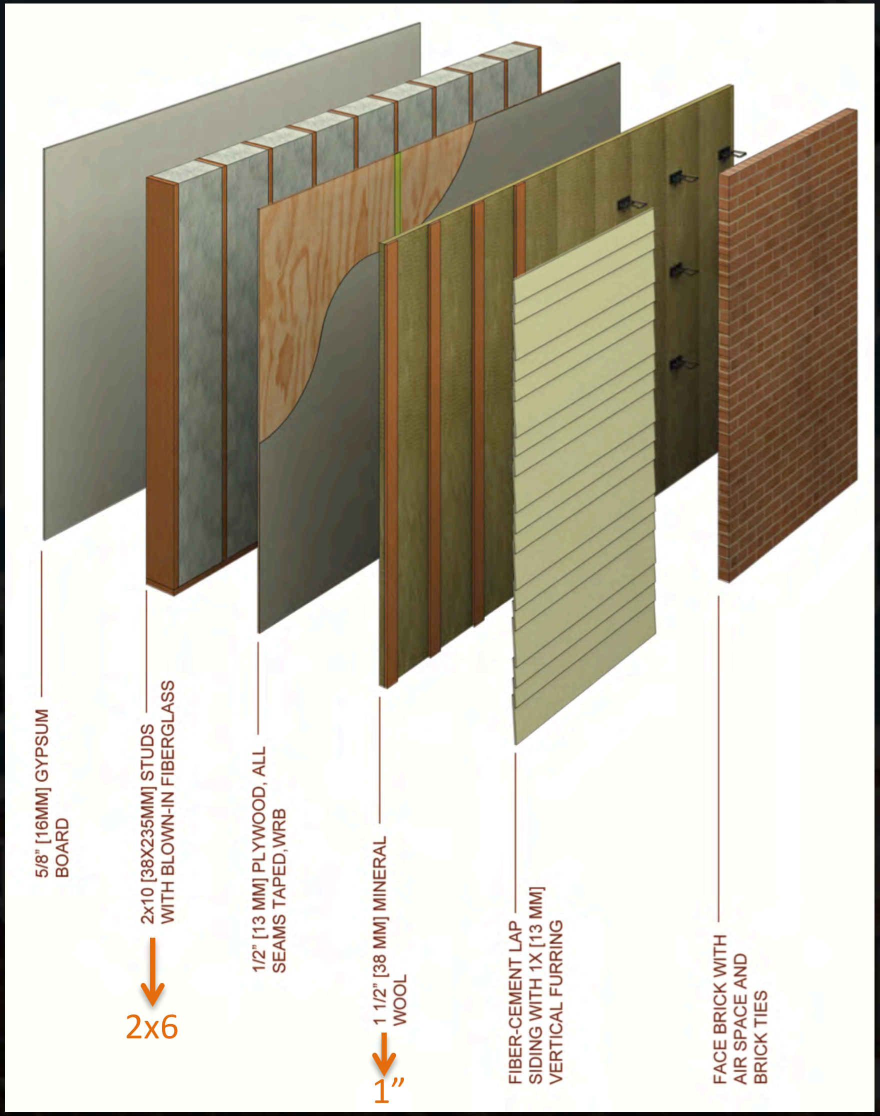
CASE STUDY THREE – ORCHARDS I

Portland, Oregon
Ankrom Moisan Architects
CPHC: Dylan Lamar
2016
56,421 GSF



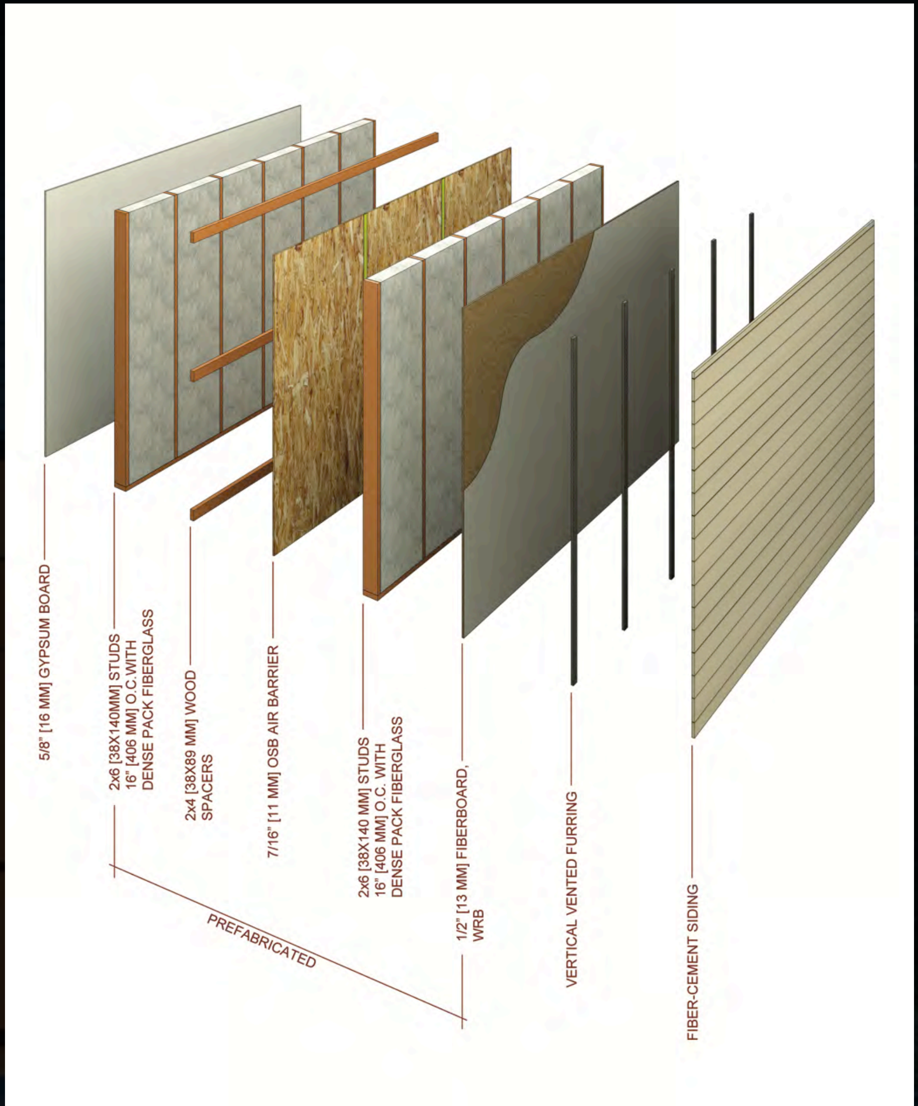
CASE STUDY FOUR – ORCHARDS II

Portland, OR
Arkrom Moisan Architects
CPHC: Lisa White
Fall 2018
49,886 sf



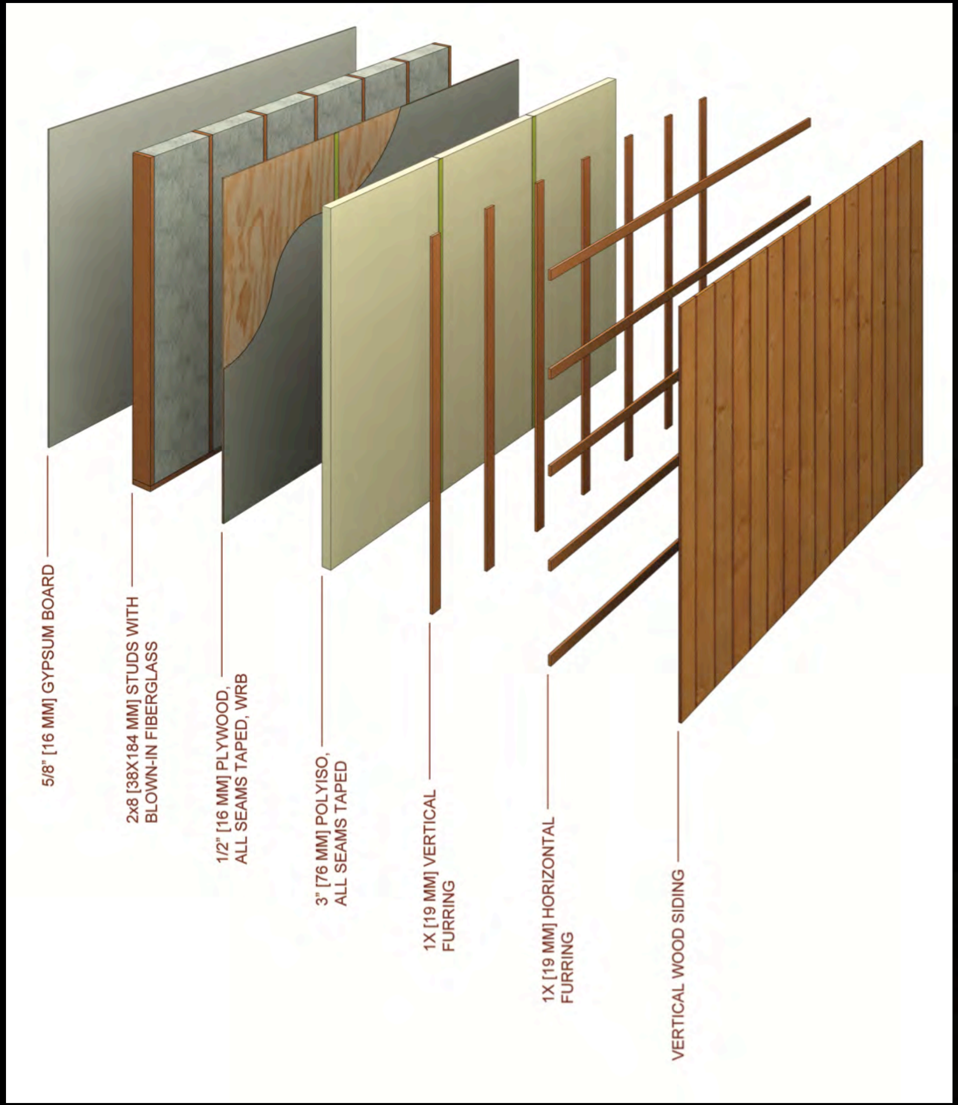
CASE STUDY FIVE – SAN JUAN

San Juan Islands, Washington
Artisans Group
CPHC: Tessa Smith
2013
1,800 SF



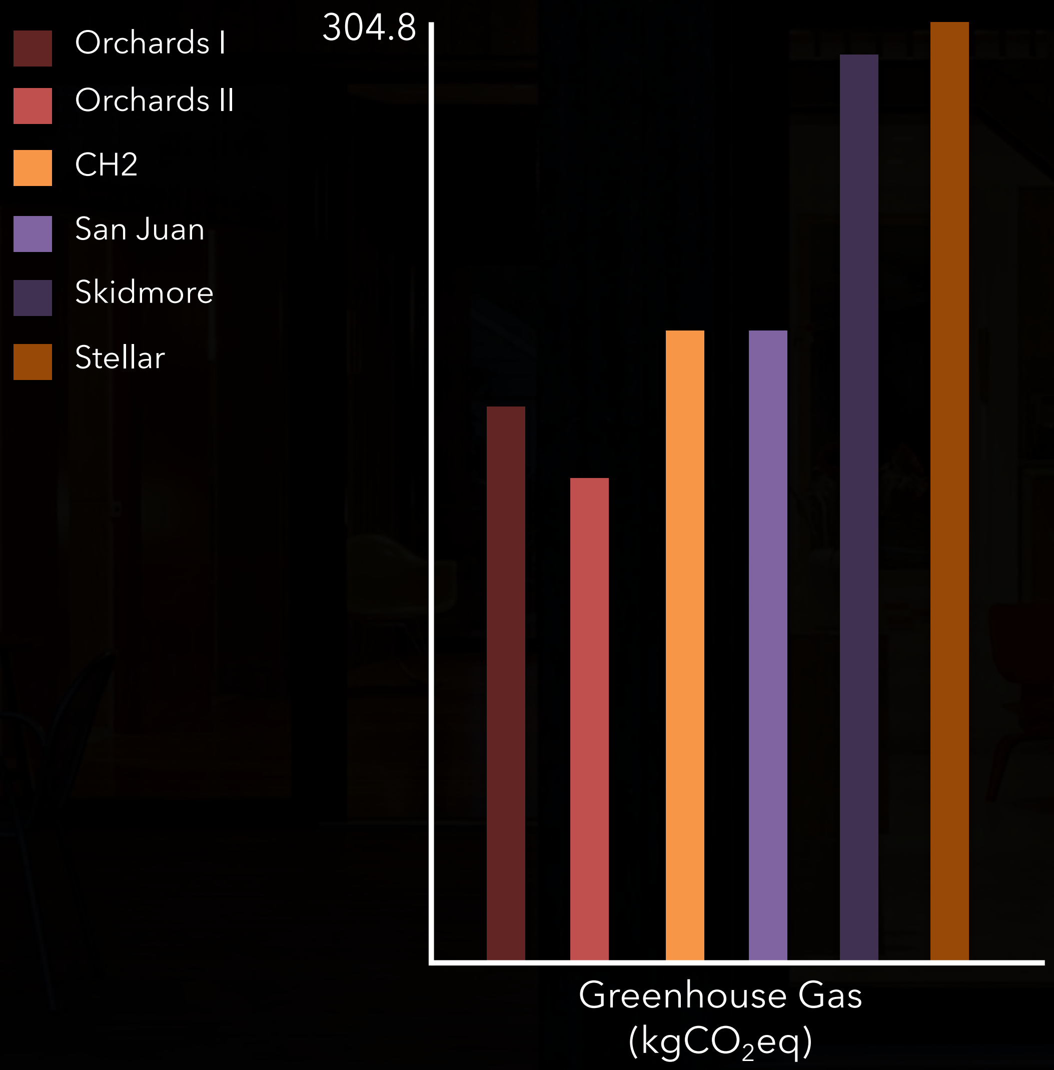
CASE STUDY SIX – SKIDMORE

Portland, Oregon
In Situ Architecture
CPHC: Jeff Stern
2013
1,965 GSF

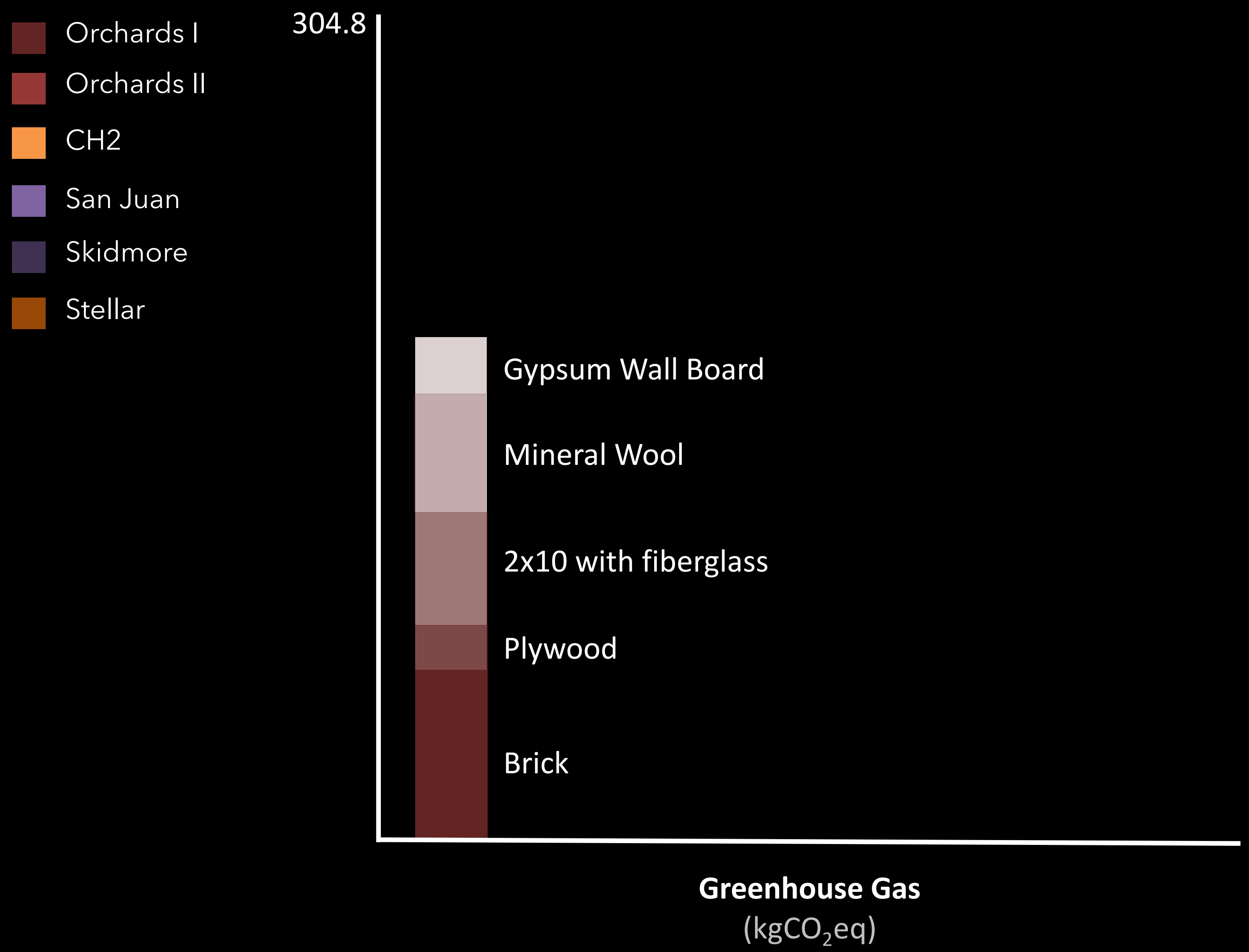


HOW DID THEY COMPARE?

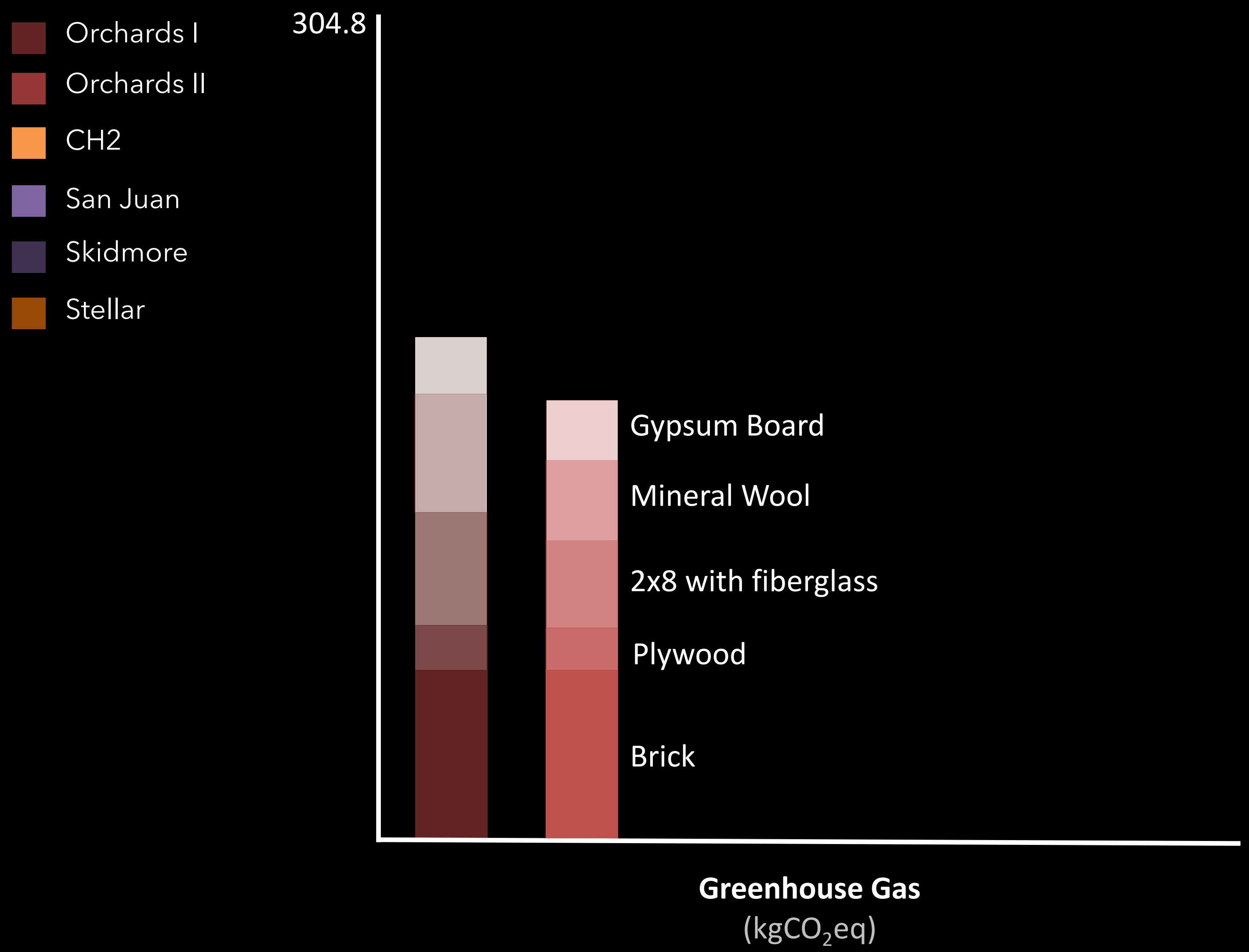
EMBODIED CARBON COMPARISON



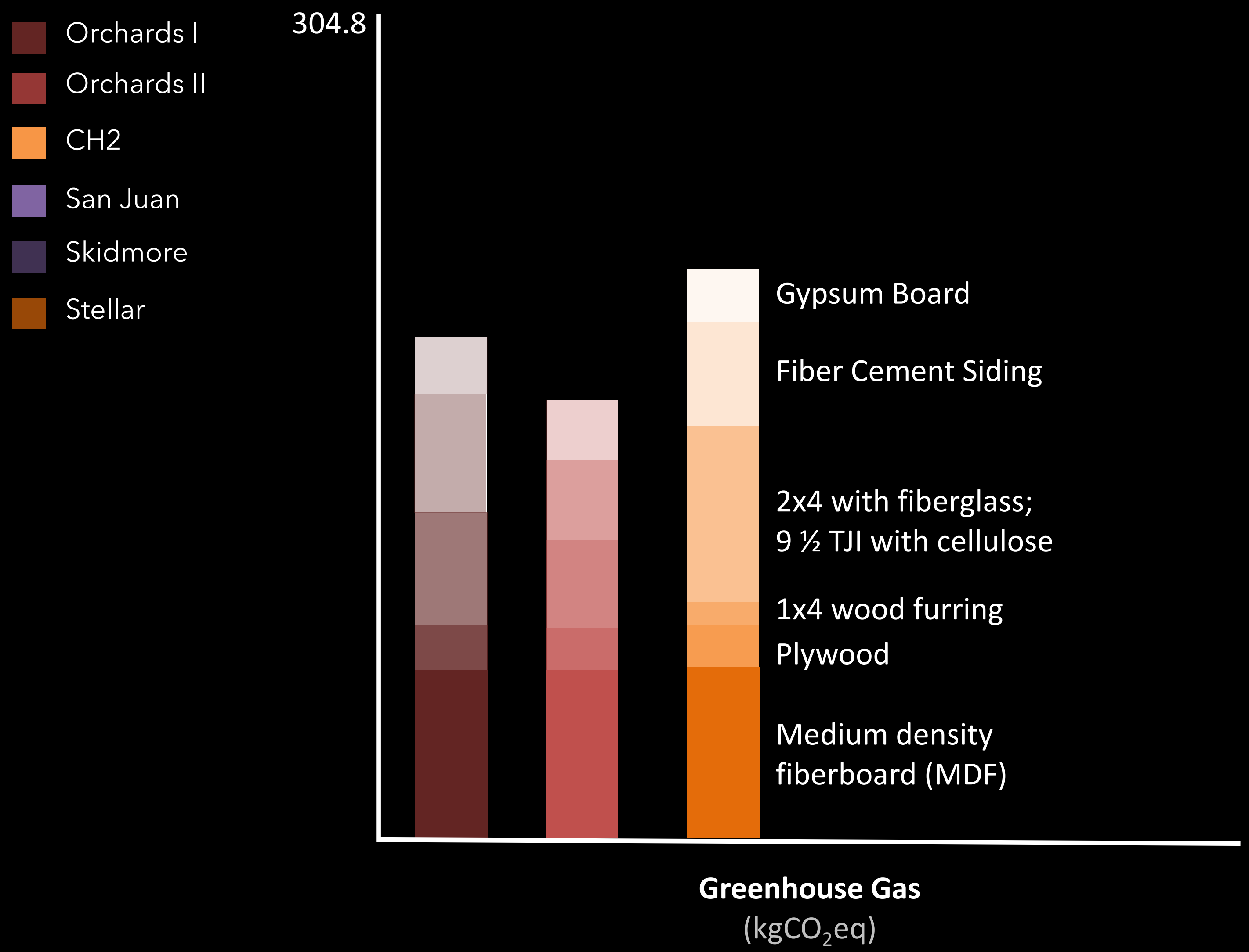
EMBODIED CARBON COMPARISON



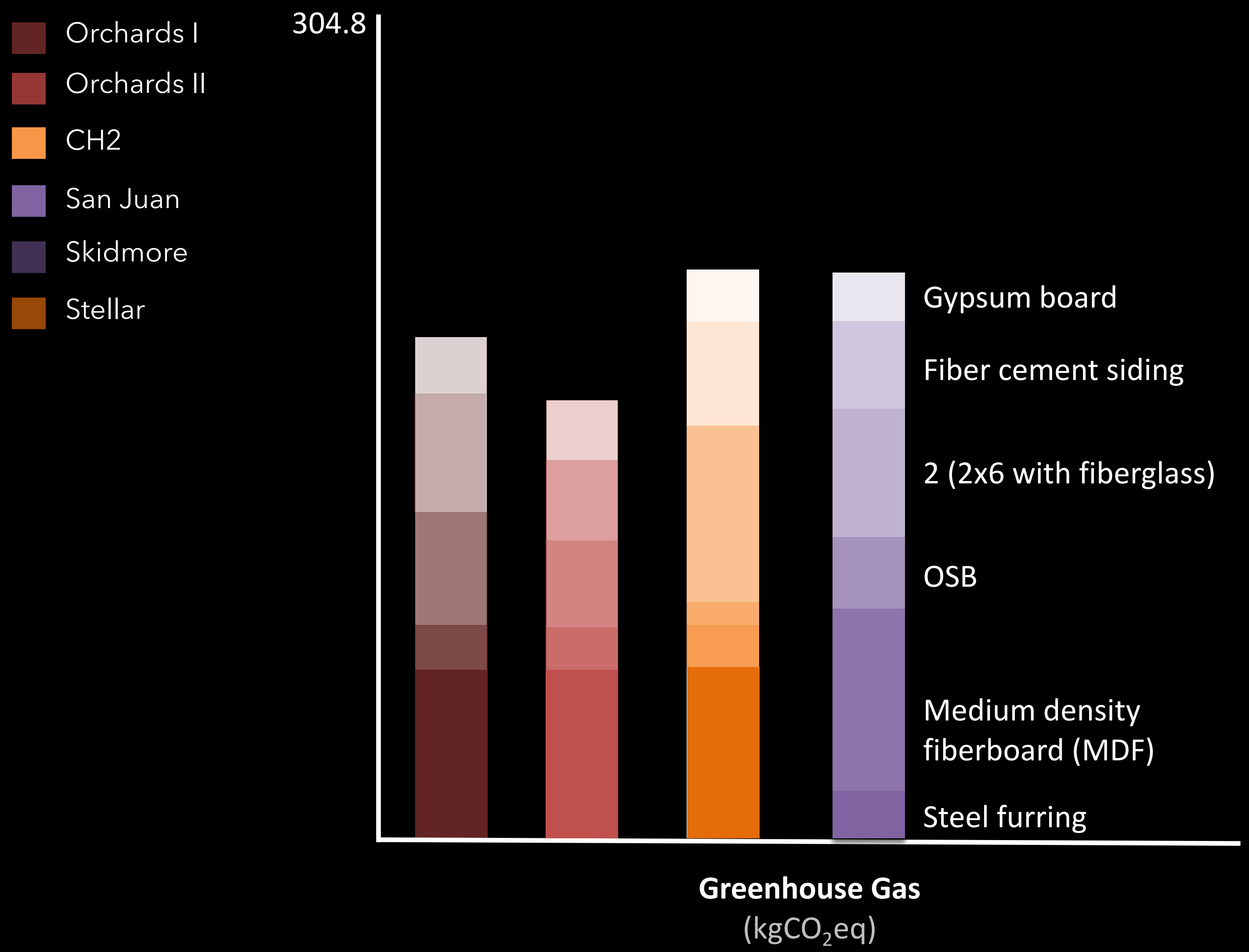
EMBODIED CARBON COMPARISON



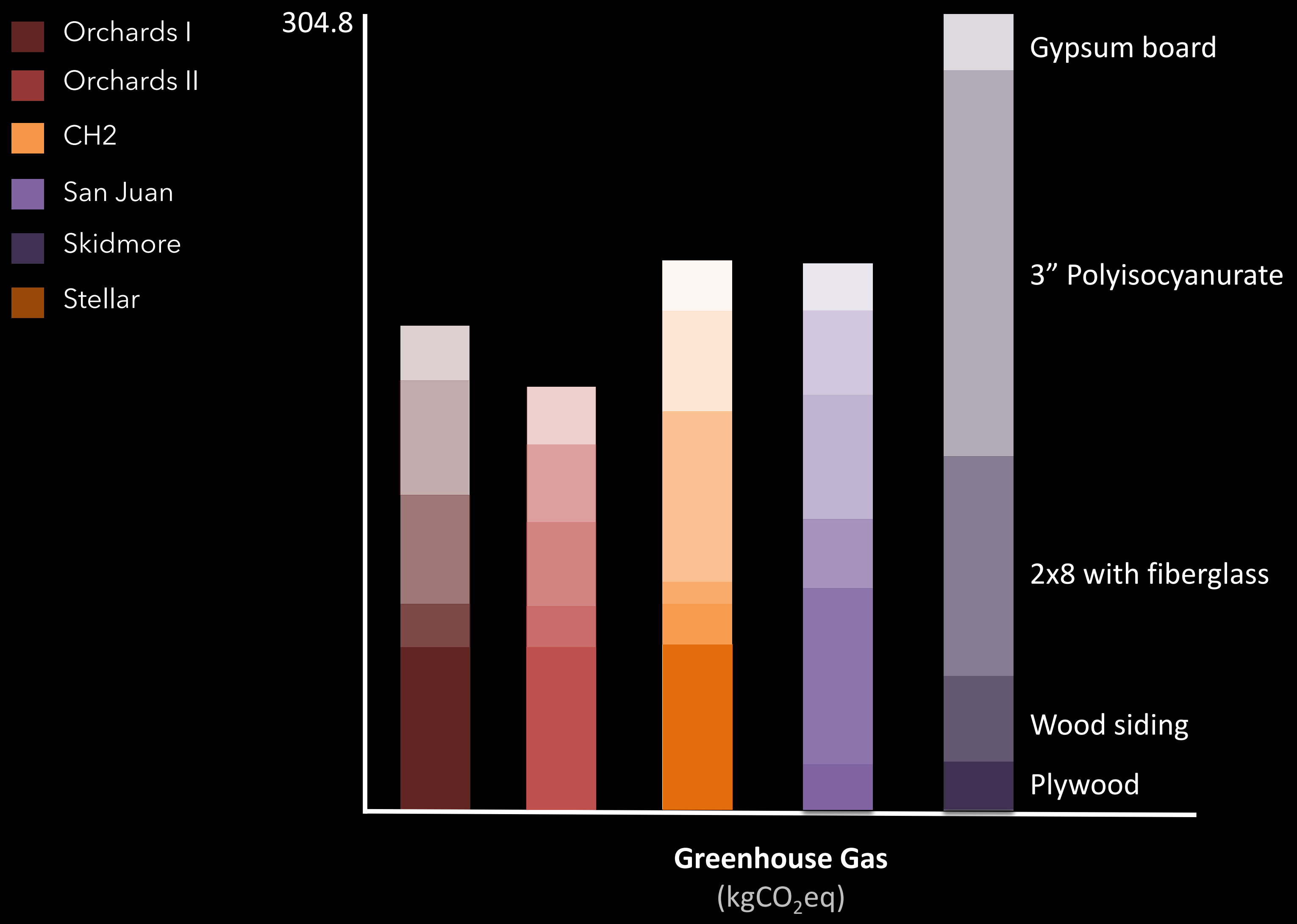
EMBODIED CARBON COMPARISON



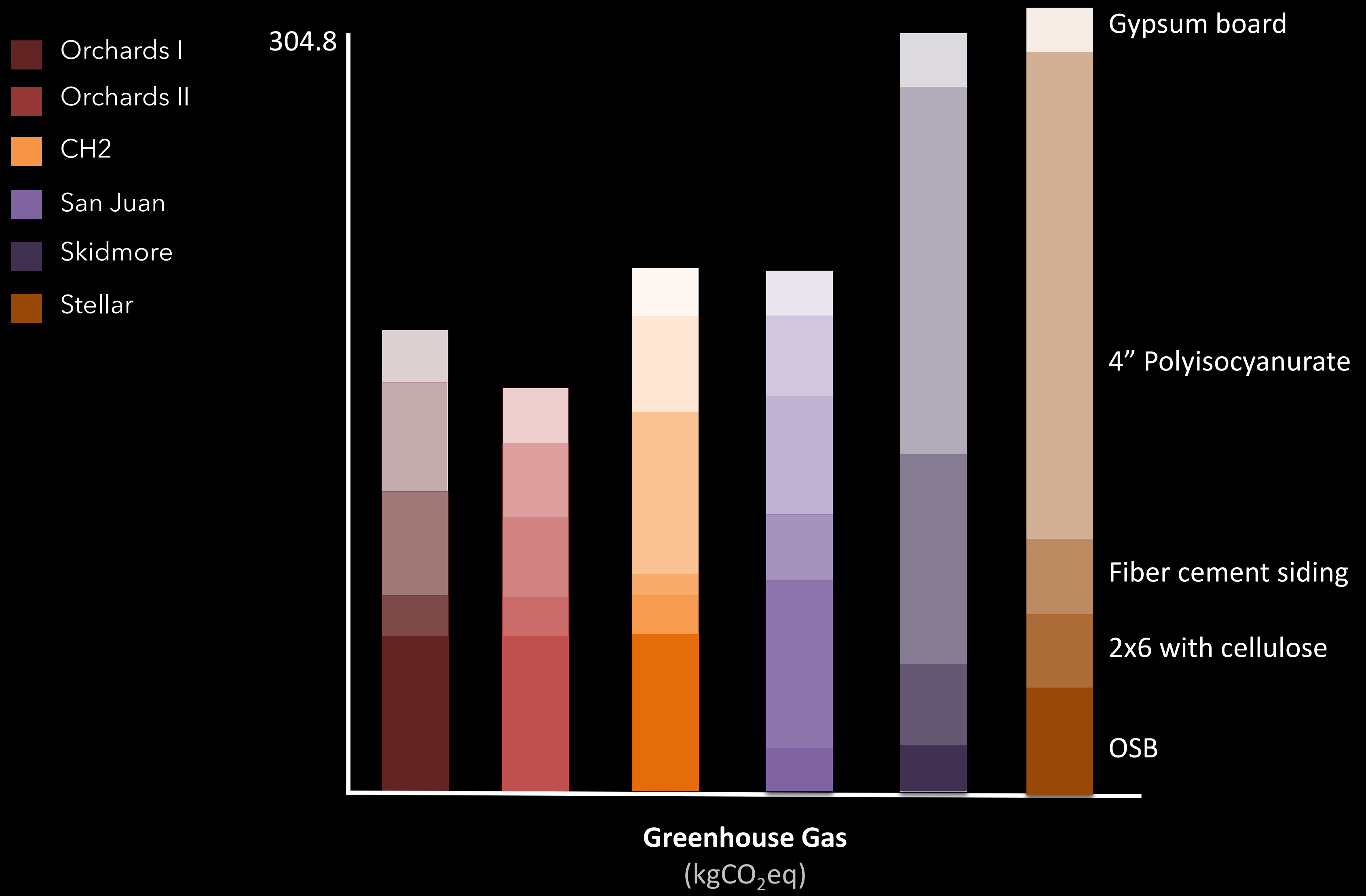
EMBODIED CARBON COMPARISON



EMBODIED CARBON COMPARISON



EMBODIED CARBON COMPARISON



Conclusions

Blown-in cellulose and fiberglass have lower embodied carbon impacts than rigid insulation

Polyiso and mineral wool were major contributors. However, if rigid insulation is necessary, choose mineral wool over Polyiso, EPS or XPS.

This study only addressed wall assemblies; it's equally important to address roof and floor enclosures.

Acknowledgements

Alison Kwok, University of Oregon

Kieran Timberlake: Tally® educational license

Architecture and construction firms: sharing construction drawings

NetZED Laboratory: Stellar Apartment study

WHAT ABOUT A PRESCRIPTIVE PATH APPROACH TO EMBODIED CARBON REDUCTION?

CARBON SMART
MATERIALS PALETTE™

architecture 2030

ACTIONS FOR REDUCING EMBODIED

HIGH-IMPACT MATERIALS

Predominant building materials with high-impact potential for emissions reductions

CONCRETE

STEEL

WOOD

INSULATION

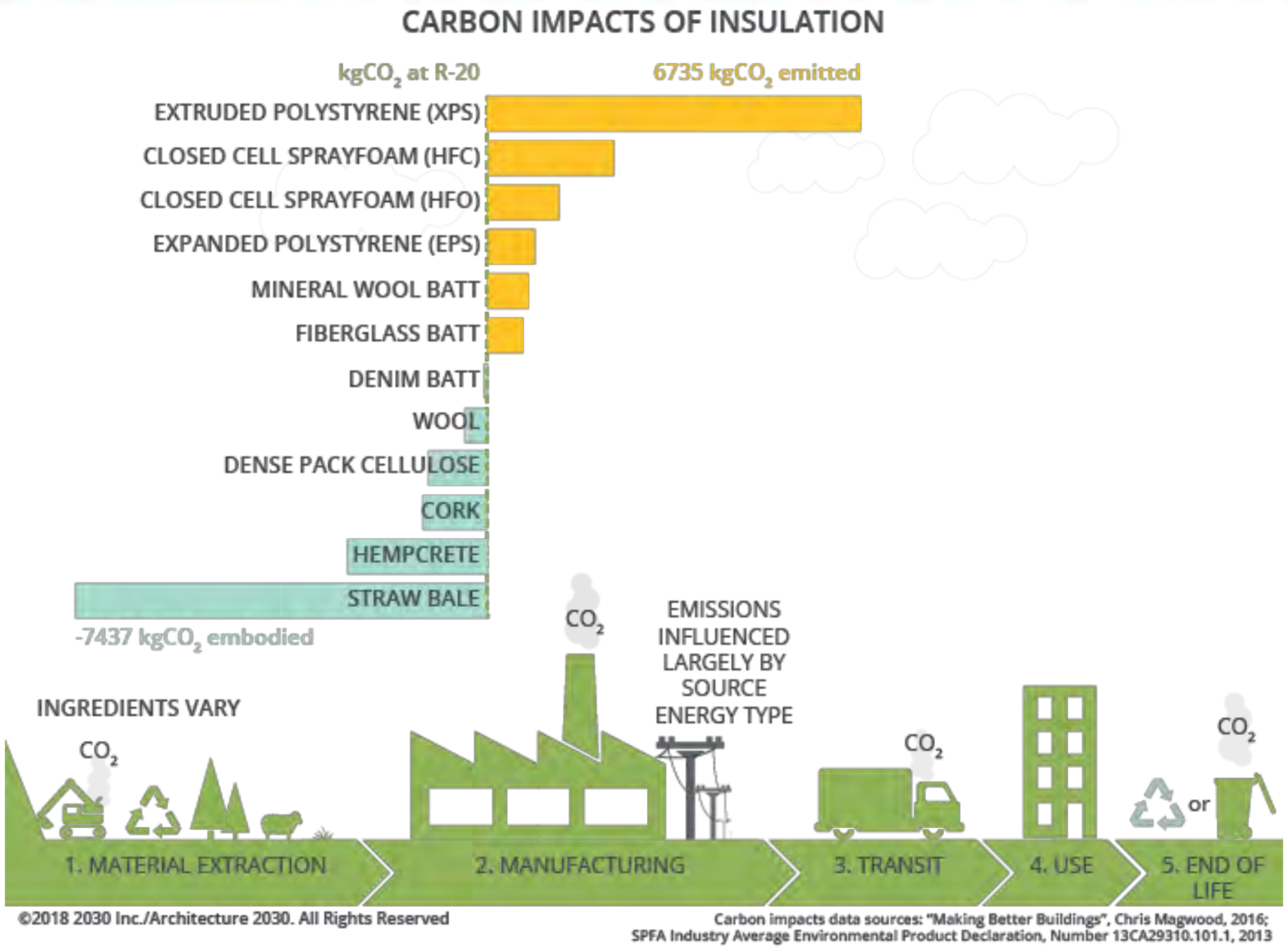
CARPET

GYPSUM BOARD

CARBON-SMART MATERIALS

architecture 2030

INSULATION



CARBON IMPACT OF INSULATION

Insulation choices greatly affect the carbon footprint of the building in terms of embodied carbon and operational carbon emissions. Insulation can be either a significant contributor to the embodied carbon footprint of the building, or a carbon sink, depending on the choice of materials used. When selecting insulation, operational performance considerations (thermal performance, climatic requirements, air leakage rates, moisture resistance) should be balanced with embodied carbon targets.

Using natural materials and blown-in applications are the best way to reduce the embodied carbon of insulation.

CARBON SMART ATTRIBUTES FOR INSULATION

Specify insulation materials that naturally sequester carbon

Materials such as wood, straw, clay-straw, hemp, cork, and sheep's wool naturally sequester carbon and store if over their useful life. Using these materials can reduce the carbon footprint of your building.

Specify blown-in insulation instead of rigid and spray foams insulation

Blown-in fiberglass and cellulose insulation have a significantly lower embodied carbon impact than rigid insulation and spray foams. Also, if not properly installed (tacked to studs or rafters), some batt insulations can slump over time and spray foam can crack with building movement or settling, creating a thermal bridge and potentially leading to moisture condensation and wall assembly degradation. Using high density blown-in (non-foam) insulation (over 3.5 pcf) can help minimize thermal bridging, minimize embodied carbon, and improve the operational performance and lifespan of a building.

Avoid Expanded Polystyrene (EPS), Extruded Polystyrene (XPS), Polyisocyanurate (Polyiso), Structurally Insulated Panel Systems (SIPS) with foam insulation, and spray foam, where climate allows

All of the insulations listed above are petroleum-based products that require significant energy to manufacture resulting in a high-embodied carbon footprint. Where climate and project requirements allow, specify lower carbon alternatives.

DESIGN GUIDANCE

Specify different insulations for different uses

Exterior rigid insulation is often used as a layer of continuous insulation to prevent thermal bridging and provide air-tightness if used as an air barrier (with taped seams). However, due to its significant carbon footprint, use rigid insulation sparingly. In a wall assembly, consider mineral wool as a lower-carbon alternative to XPS, EPS, and Polyiso. Under the slab, consider EPS over XPS.

Protect insulation from heat and water

Moisture and high temperatures are the biggest threats to the durability of insulation materials. Many foam insulations degrade with exposure to heat, and cellulose and fiberglass insulations are susceptible to water damage from rain, leaks, and/or vapor condensation. Ensure that wall assemblies are adequately designed and that all insulation is installed according to the manufacturer's instructions.

ACKNOWLEDGED CHALLENGES, QUESTIONS & UNKNOWNS

- Though avoiding the use of rigid insulations and spray foams where possible reduces carbon emissions, this is not possible in all climates. In some climates, rigid insulation is required for dew point (condensation) considerations.. However, some recent projects in marine climates have successfully utilized mineral wool instead of rigid insulation[1].
- EPS is better than XPS at this time, though it has a significant embodied carbon impact. A better, lower-carbon alternative should be developed.
- A deeper wall assembly may be necessary when using materials that naturally sequester carbon.
- Use of recycled content is largely driven by availability – try to use recycled content when locally available to avoid emissions from raw material manufacturing and transportation.
- Embodied carbon footprints (within EPDs) are available for several naturally low-carbon or carbon sequestering materials. However, further research should be completed to ensure that the Life Cycle Assessments for these products account for agricultural practices.

RESOURCES

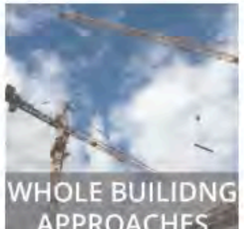
1 | Orchards at Orenco Phase I and II

Other Resources:

Table of embodied energy or primary energy of materials, Enrique Azpilicueta Astarloa, PhD,

Making Better Buildings, Chris Magwood, 2016

SEE ALSO



CARBON SMART CONCRETE

Use cement content as a proxy for GWP

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 a maximum cement content, or the required compressive strength at a specific age.

CARBON SMART STEEL

Specify steel with high recycled content

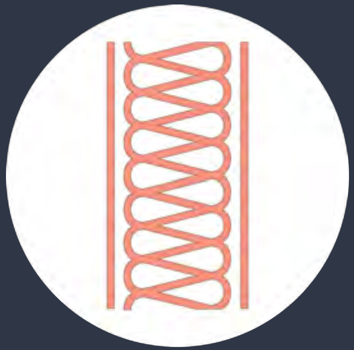
Virgin steel can have an embodied carbon footprint that is up to five times greater than high-recycled content steel. EAFs use an average of 93% recycled content, where BOFs use an average of 25% recycled content. Use high-recycled content steel whenever possible.

CARBON SMART STEEL

Power EAFs with carbon-free renewable energy

Basic oxygen furnaces (BOFs) burn coal or natural gas to create steel. EAFs are powered by electricity and therefore have the ability to be powered using renewable energy sources.

CARBON SMART INSULATION



Use natural materials and blown-in applications

Many insulation materials exist that naturally sequester carbon and store it for the life of the building.

Blown-in fiberglass and cellulose have significantly lower embodied carbon impacts than rigid insulation and spray foam. Blown-in also reduces slump that can lead to thermal bridging, moisture condensation, and assembly degradation.

CARBON SMART WOOD

Specify timber from climate smart forests

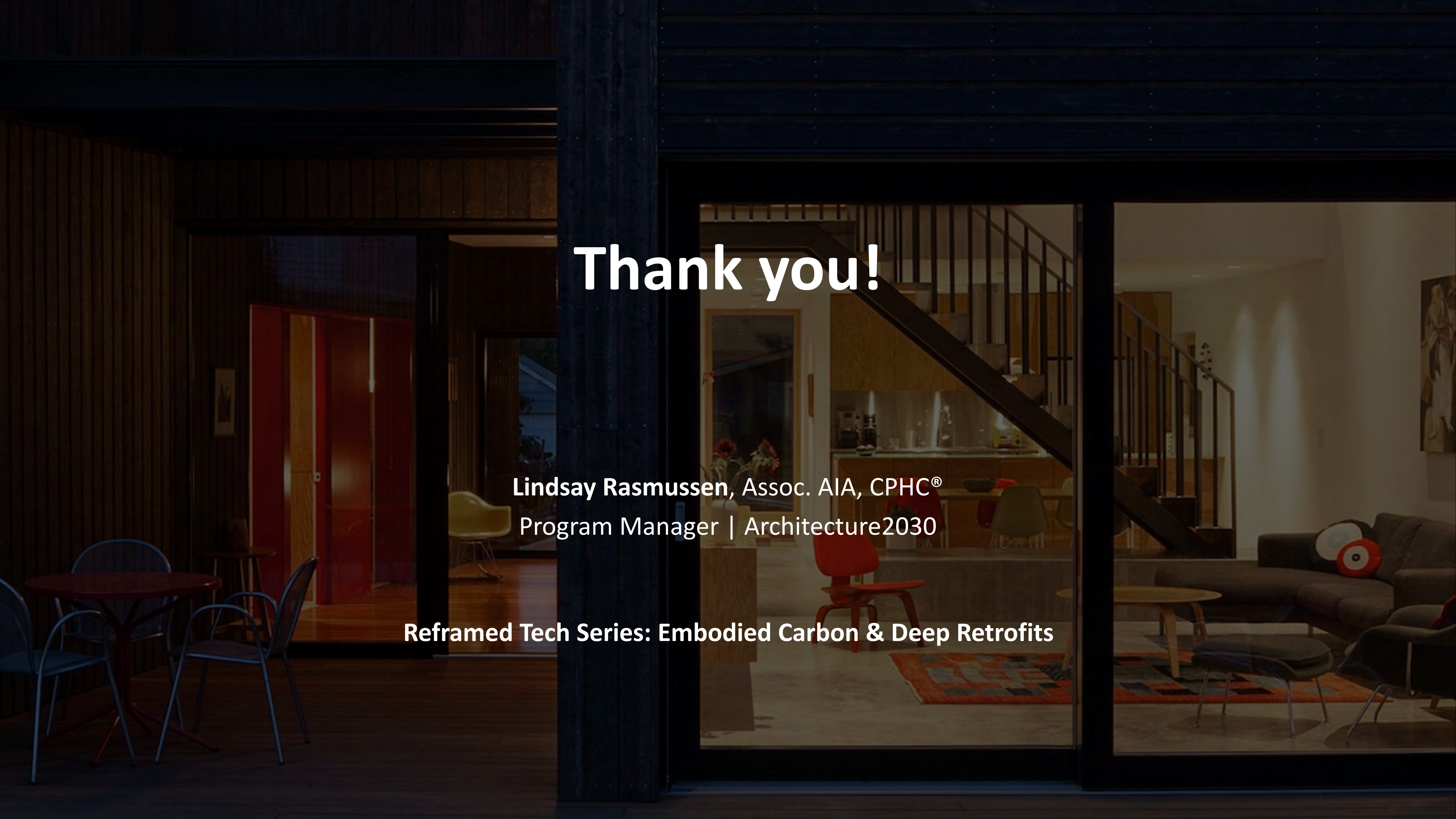
Forest management practices can greatly influence the carbon footprint of a wood product. Climate smart forestry includes using longer rotation periods, protecting water quality and aquatic habitats, tightly restricting the use of chemicals, and safeguarding old growth forests and habitat of threatened and endangered species.

CARBON SMART WOOD

Specify locally harvested and manufactured wood products

Transportation emissions can be a large percentage of a wood product's embodied carbon impact. Specifying local wood reduces transportation emissions, allows more transparency into forest practices and grid mix.

materialspalette.org



Thank you!

Lindsay Rasmussen, Assoc. AIA, CPHC®
Program Manager | Architecture2030

Reframed Tech Series: Embodied Carbon & Deep Retrofits

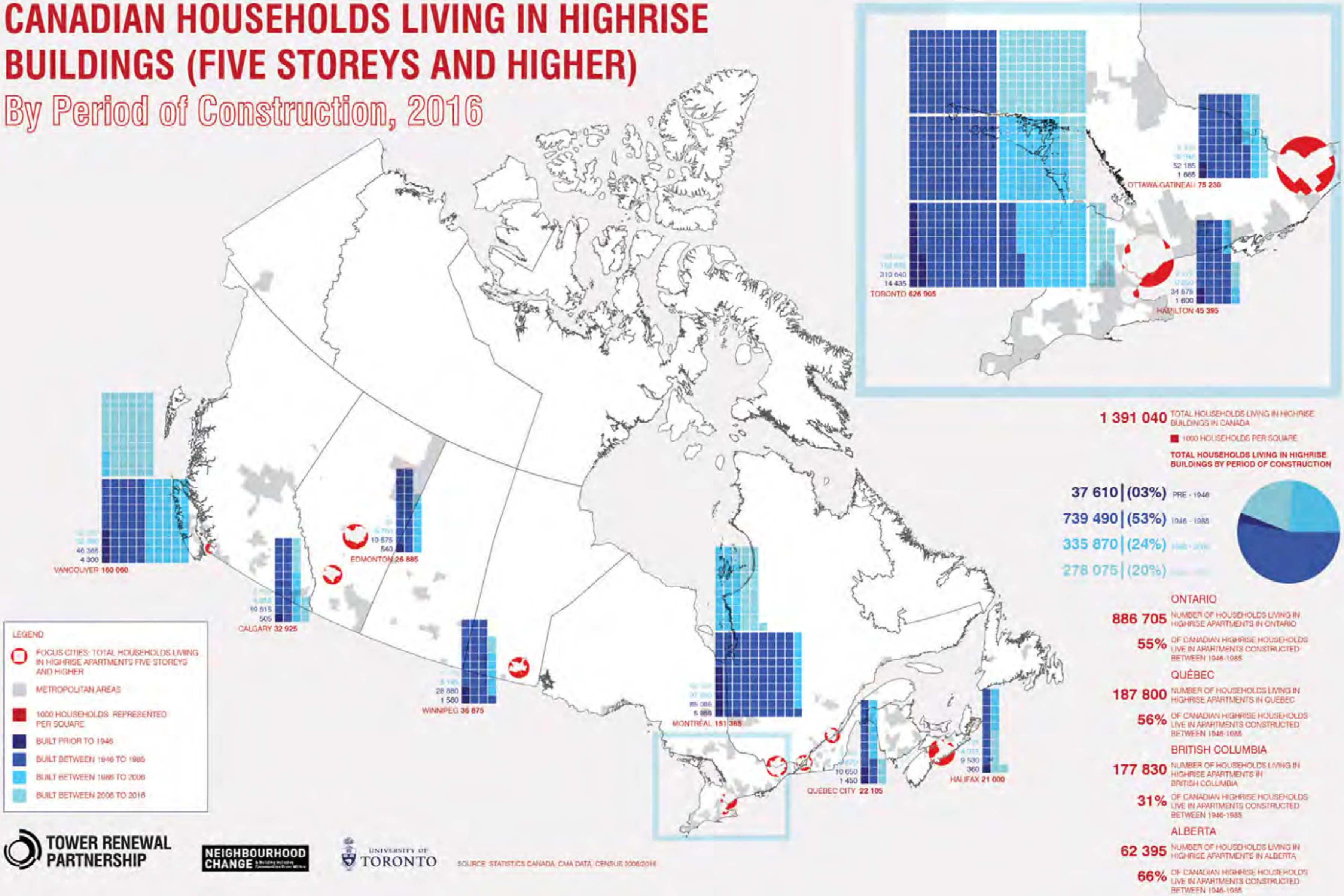
KEN SOBLE TOWER **ENERPHIT**

ERA
TOWER RENEWAL PARTNERSHIP
ENTUITIVE
REINBOLD engineering group
JMV CONSULTING


GREENWIN
TOWER RENEWAL
PARTNERSHIP

CANADIAN HOUSEHOLDS LIVING IN HIGHRISE BUILDINGS (FIVE STOREYS AND HIGHER)

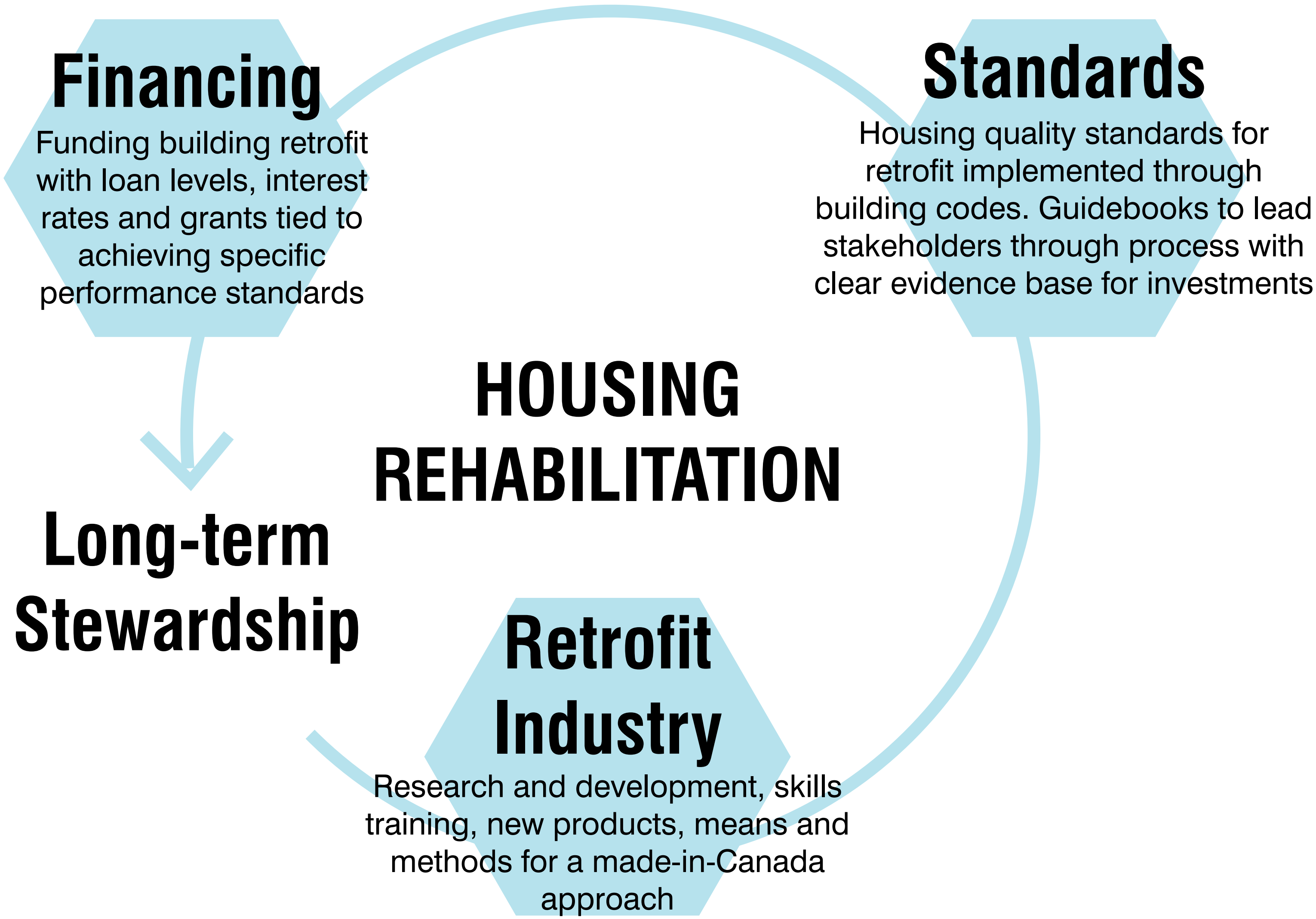
By Period of Construction, 2016

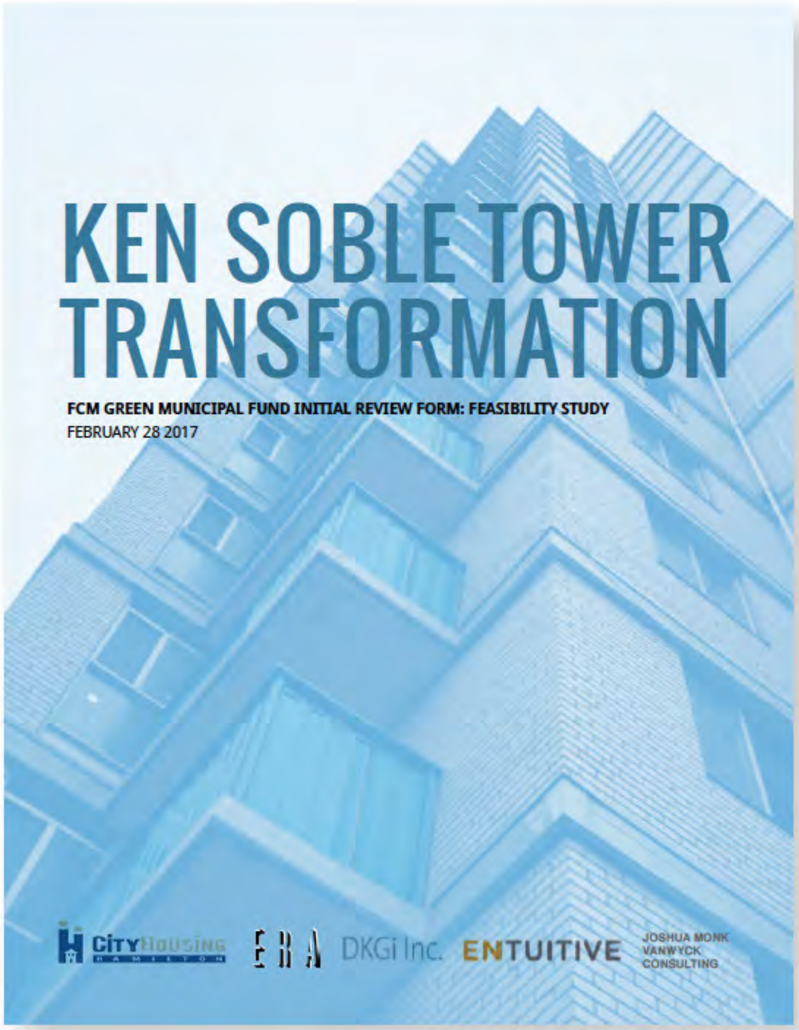


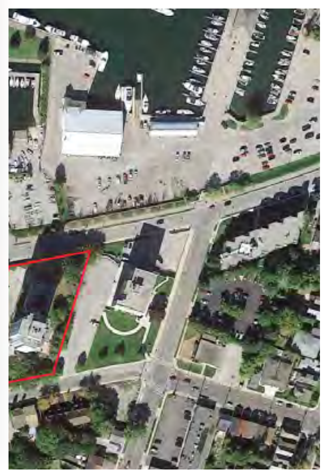
TOWER RENEWAL PARTNERSHIP NEIGHBOURHOOD CHANGE UNIVERSITY OF TORONTO

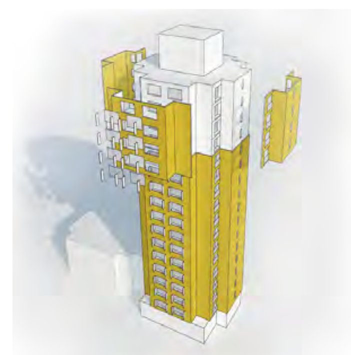
SOURCE: STATISTICS CANADA, CMA DATA, CENSUS 2006/2016

TOWER RENEWAL PARTNERSHIP









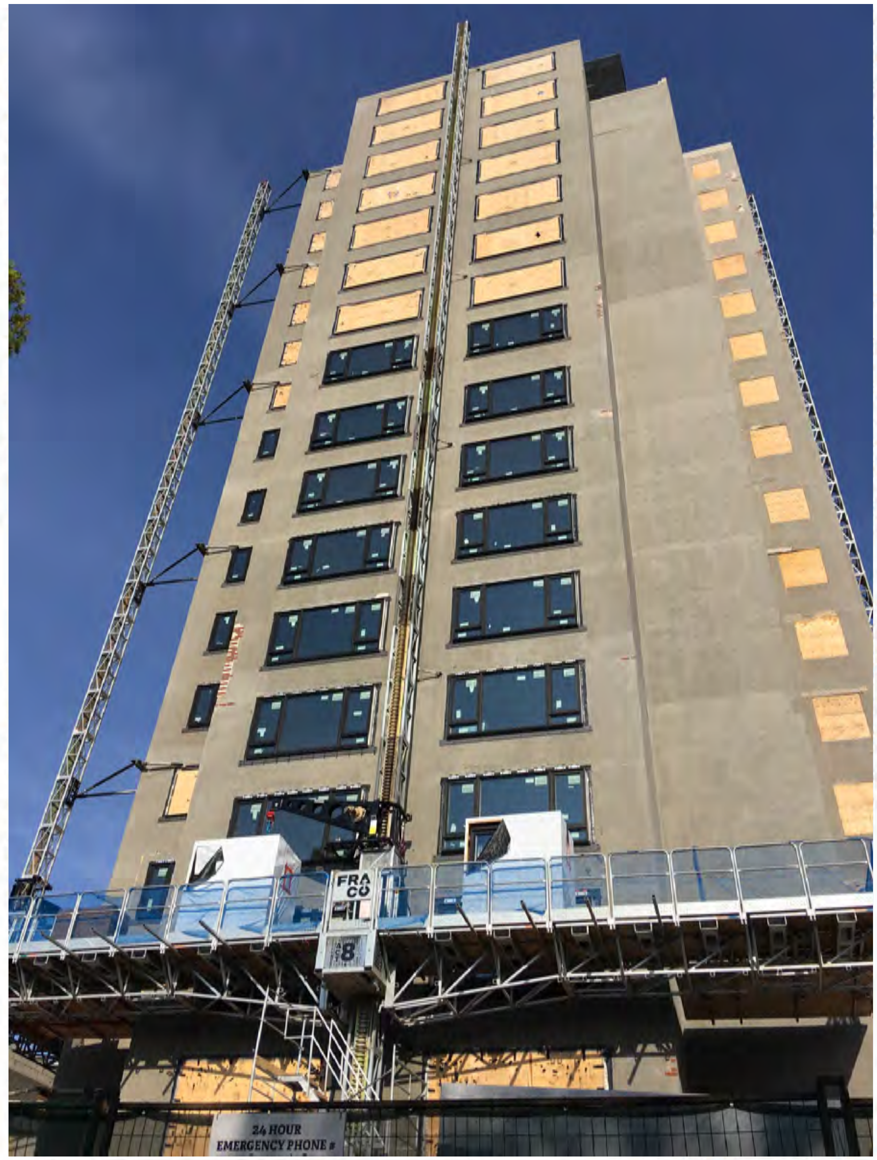
High Performance Building Envelope

New Community Spaces & Partnerships

TOWER RENEWAL PARTNERSHIP

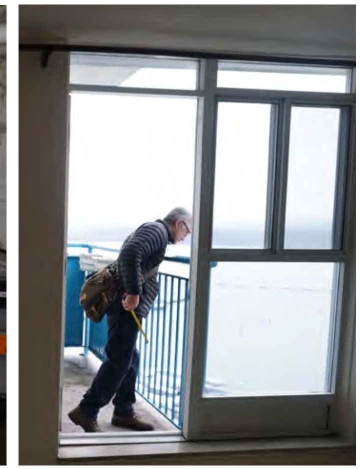
500 MACNAB **1967**

500 MACNAB **2020**



KEY CHALLENGES

- Deteriorating envelopes
- Lack of insulation
- Inadequate ventilation
- Mould and hazardous materials
- Lack of thermal control
- End of life systems



OVERVIEW ENERPHIT & ASSET RENEWAL

KEN SOBLE TOWER TRANSFORMATION

SYSTEMS

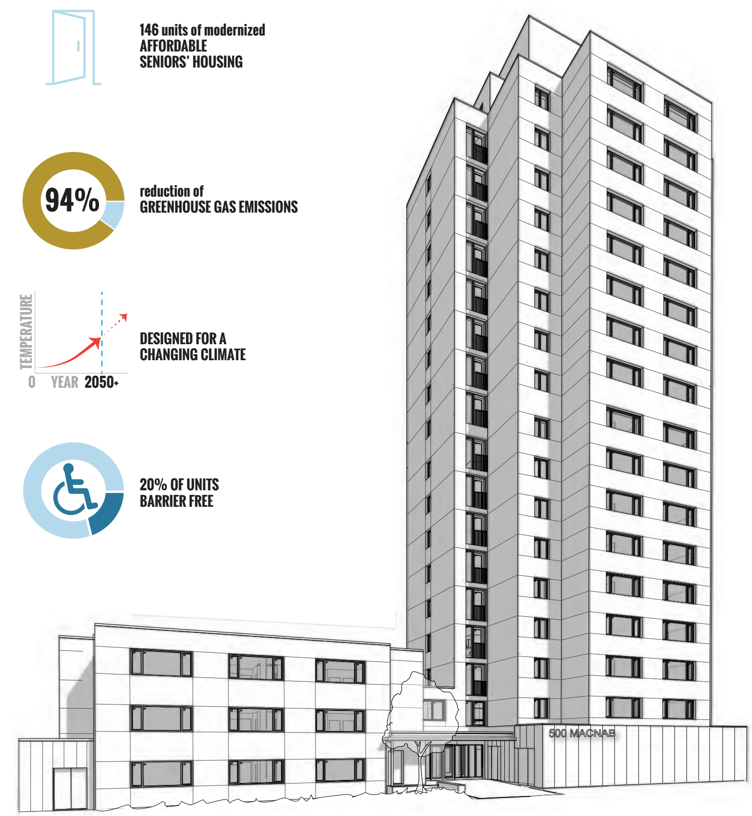
Centralized HVAC with Cooling
Riser Replacements for Most Systems
Full Building Sprinklering

ENVELOPE

R38 Effective Overcladding
Passive House Windows
0.6ACH @ 50Pa Airtightness

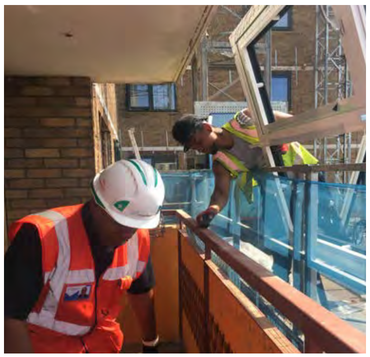
MODERNIZATION

Accessibility Upgrades
New Community Room and Solarium
Interior Upgrades to Support Aging-in-Place
Rain Gardens and Green Gathering Spaces



TOWER RENEWAL PARTNERSHIP

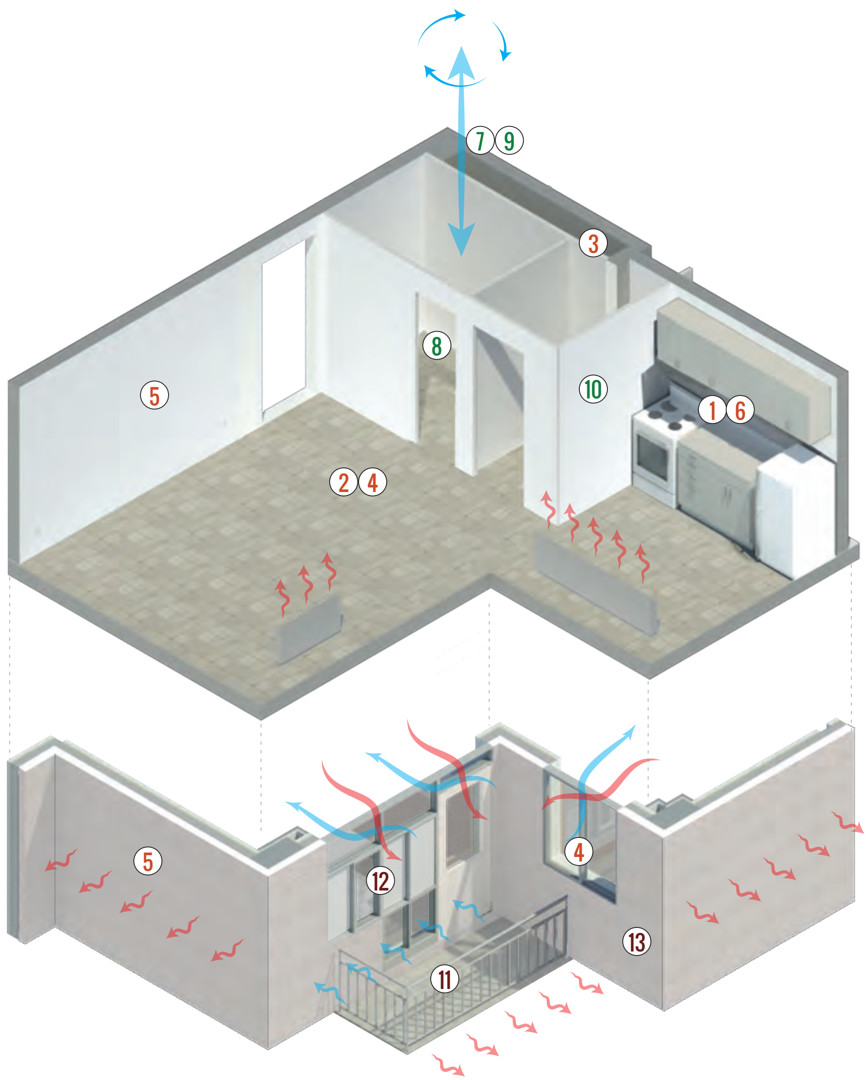
LINKING HOUSING QUALITY OUTCOMES TO RETROFITS




- Tenant comfort
- Thermal controls
- Adequate ventilation
- Life safety measures
- Community connectivity
- Climate resilience

TOWER RENEWAL PARTNERSHIP

500 MACNAB **BASE CONDITIONS**



INTERIORS

1. Deteriorated fixture, millworks and appliances
2. Deteriorated flooring
3. Holes in fire separations between units
4. Asbestos containing materials
5. Mould remediation required in all interior walls
6. Pervasive pests

SYSTEMS

7. Deteriorated central ductwork
8. Deteriorated plumbing
9. Inadequate ventilation
10. Deteriorated electrical system

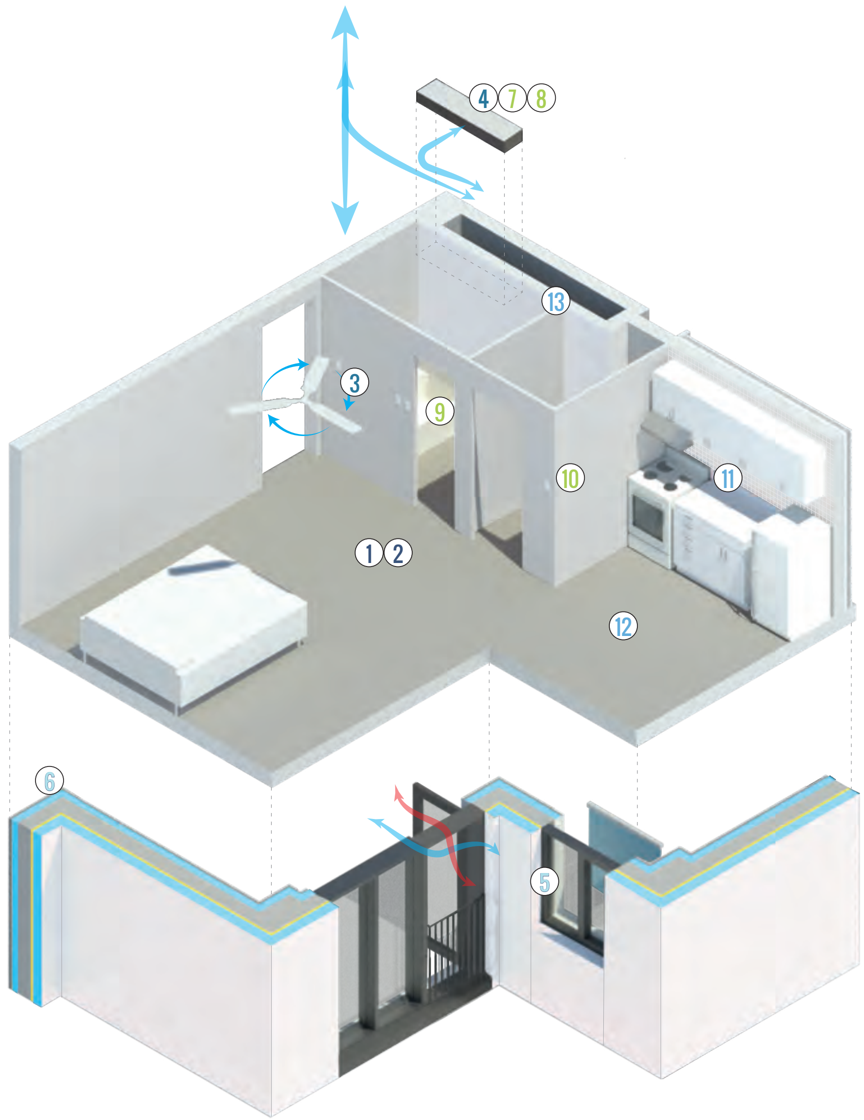
ENVELOPE

11. Deteriorated balcony slab edge
12. Deteriorated windows
13. Masonry repairs required
14. Deteriorated roof

TOWER RENEWAL PARTNERSHIP

ERA

500 MACNAB **PASSIVE HOUSE RENEWAL**



LIFE SAFETY

1. Sprinklers
2. New fire alarm system

COMFORT

3. Ceiling fans
4. Central low energy cooling

ENVELOPE

5. Triple glazed windows
6. Thermally continuous and airtight envelope with exterior and Interior Insulation

SYSTEMS

7. Direct ducting for fresh air supply in units with
8. Heat recovery
9. New plumping system
10. Modernized electrical system

UNITS

11. New kitchen
12. New flooring
13. Repair of walls for continuous fire separations between units

BUILDING AMENITY

14. New community space at base and penthouse
15. New laundry facility
16. Modernized landscape

STATE OF REPAIR

17. All state of repair issues addressed to achieve 30 year plus asset renewal

TOWER RENEWAL PARTNERSHIP

ERA

500 MACNAB **PASSIVE HOUSE RENEWAL: ACCESSIBILITY UNITS**

ACCESSIBILITY

Ⓐ 20% of units fully accessible with new washrooms and kitchens meeting CSA standard

LIFE SAFETY

① Sprinklers

② New fire alarm system

COMFORT

③ Ceiling fans

④ Central low energy cooling

ENVELOPE

⑤ Triple glazed windows

⑥ Thermally continuous and airtight envelope with exterior and Interior Insulation

SYSTEMS

⑦ Direct ducting for fresh air supply in units with

⑧ Heat recovery

⑨ New plumping system

⑩ Modernized electrical system

UNITS

⑪ New kitchen

⑫ New flooring

⑬ Repair of walls for continuous fire separations between units

BUILDING AMENITY

⑭ New community space at base and penthouse

⑮ New laundry facility

⑯ Modernized landscape

STATE OF REPAIR

⑰ All state of repair issues addressed to achieve 30 year plus asset renewal

TOWER RENEWAL PARTNERSHIP

ERA

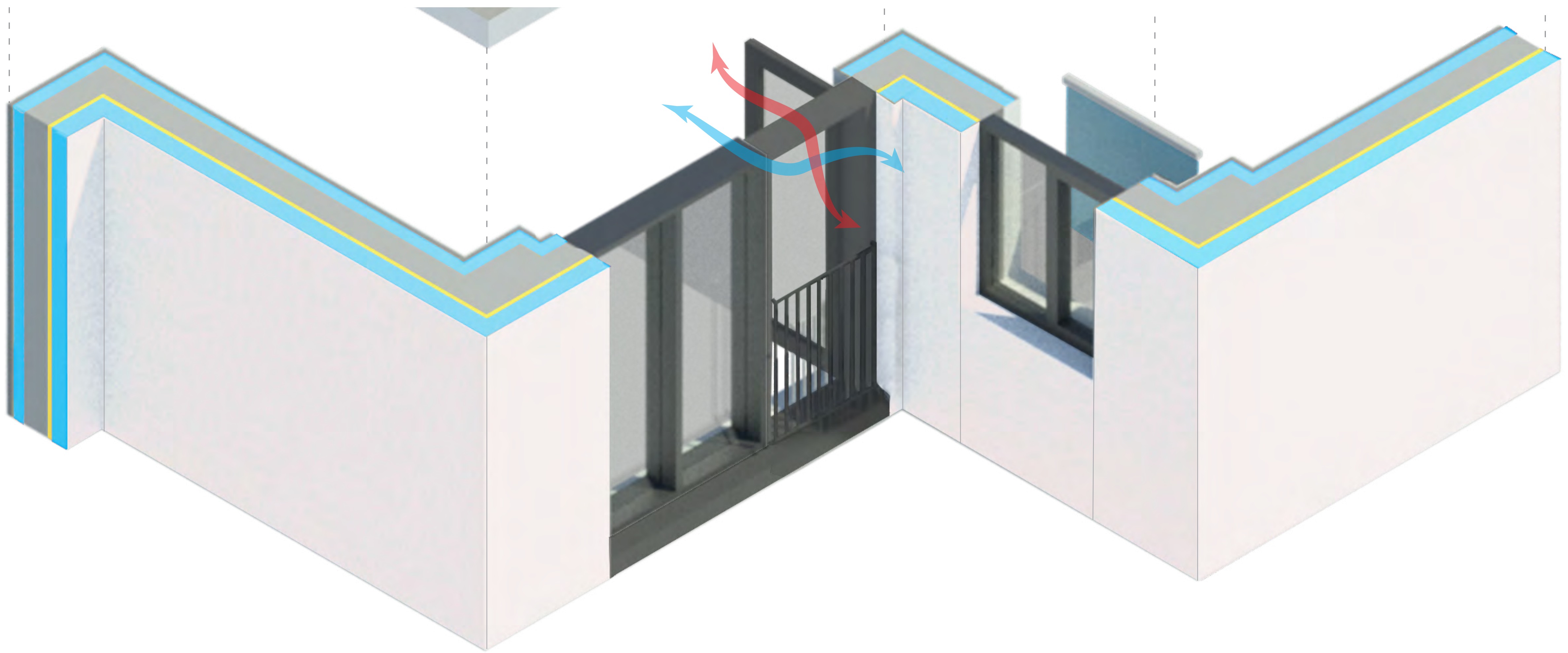
FACADE APPROACH

AIRTIGHT (0.6 ACH @50KPA)

R38-EFFECTIVE

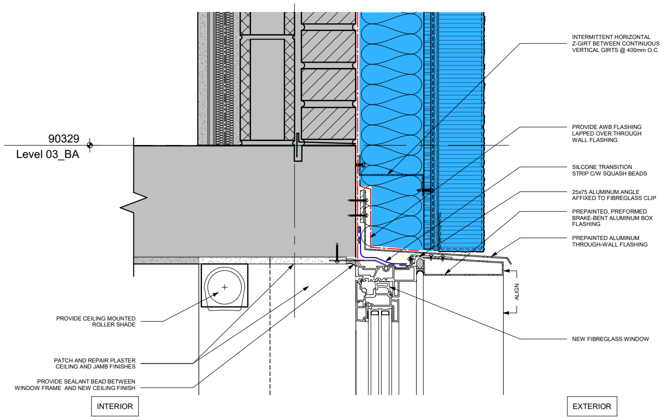
LOW-CARBON

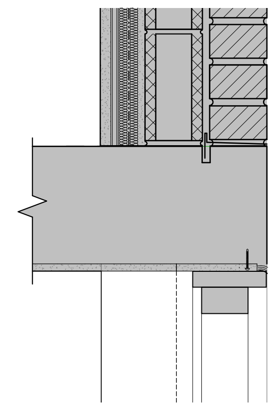
NON-COMBUSTIBLE

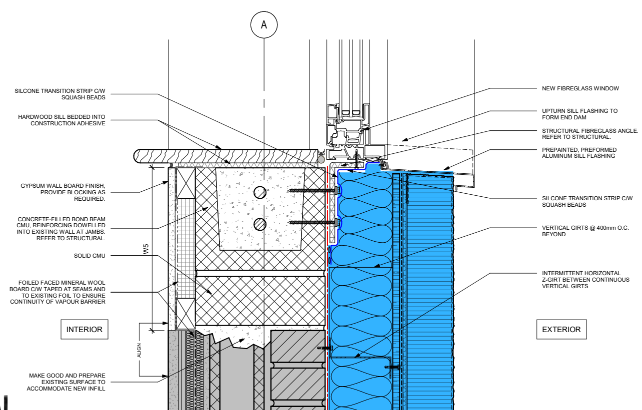


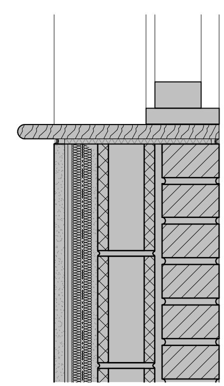
FACADE APPROACH R38 EFFECTIVE

KEN SOBLE TOWER TRANSFORMATION



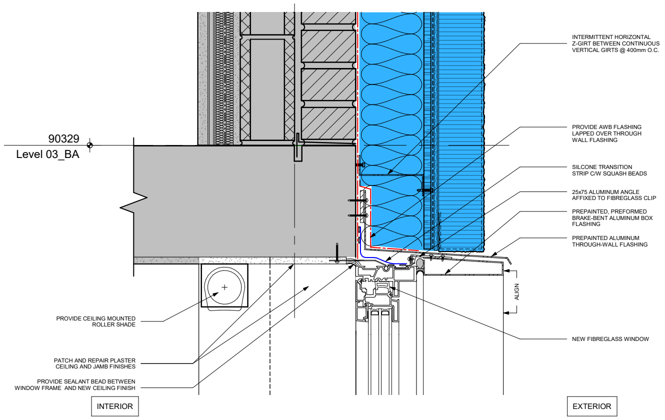


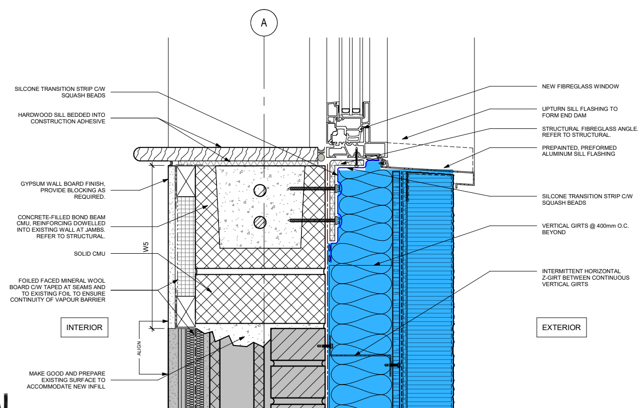




TOWER RENEWAL PARTNERSHIP

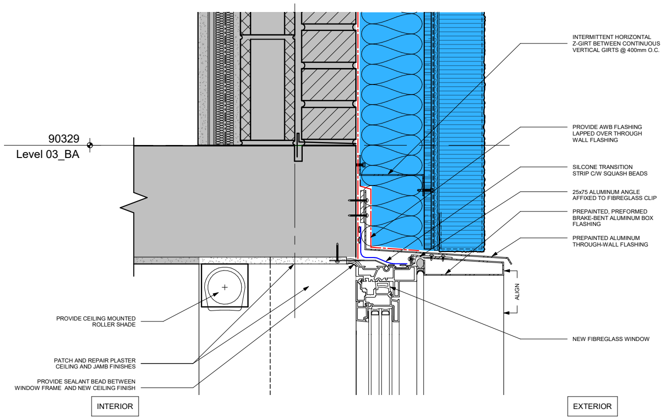
FACADE APPROACH R38 EFFECTIVE

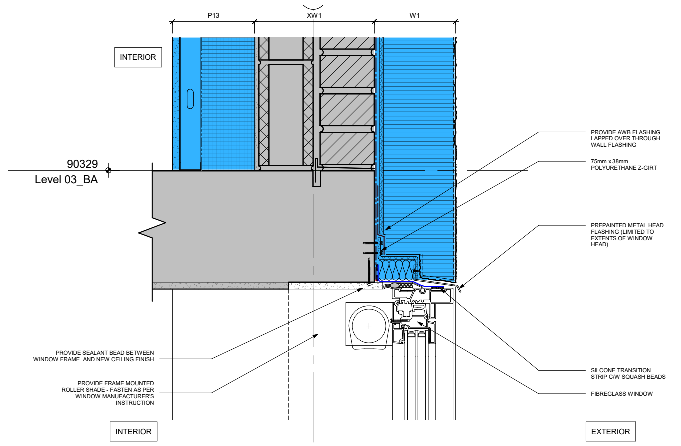


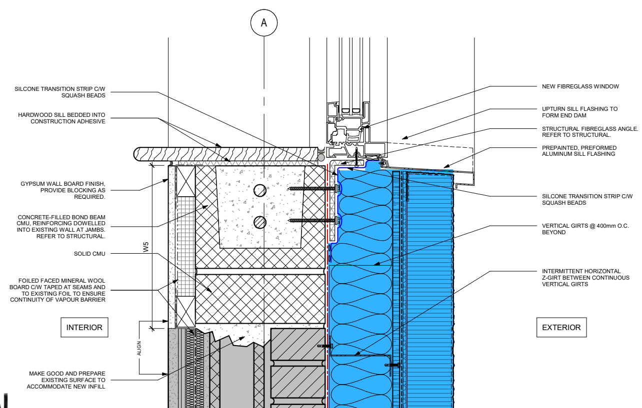


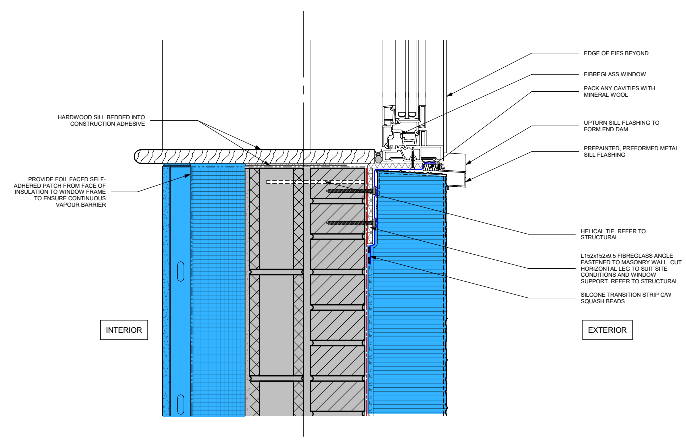
FACADE APPROACH R38 EFFECTIVE

KEN SOBLE TOWER TRANSFORMATION







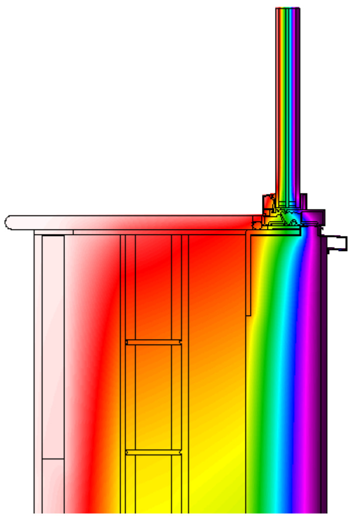


TOWER RENEWAL PARTNERSHIP

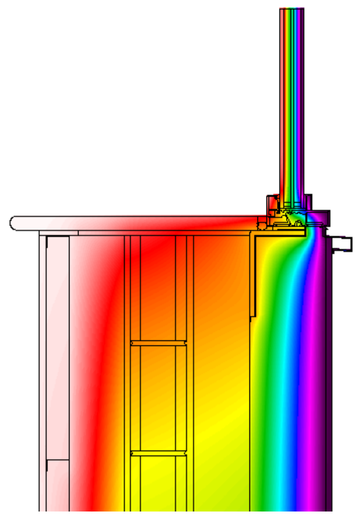
THERMAL BRIDGING WINDOW SILL DETAIL

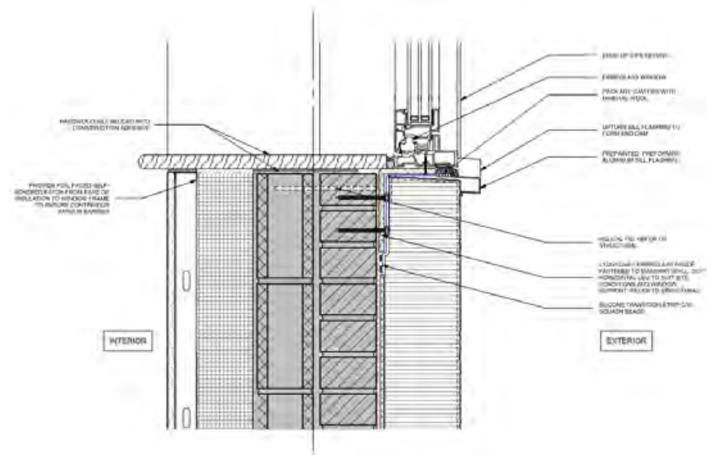
KENSOBLE TOWER TRANSFORMATION

Fiberglass Angle



Steel Angle

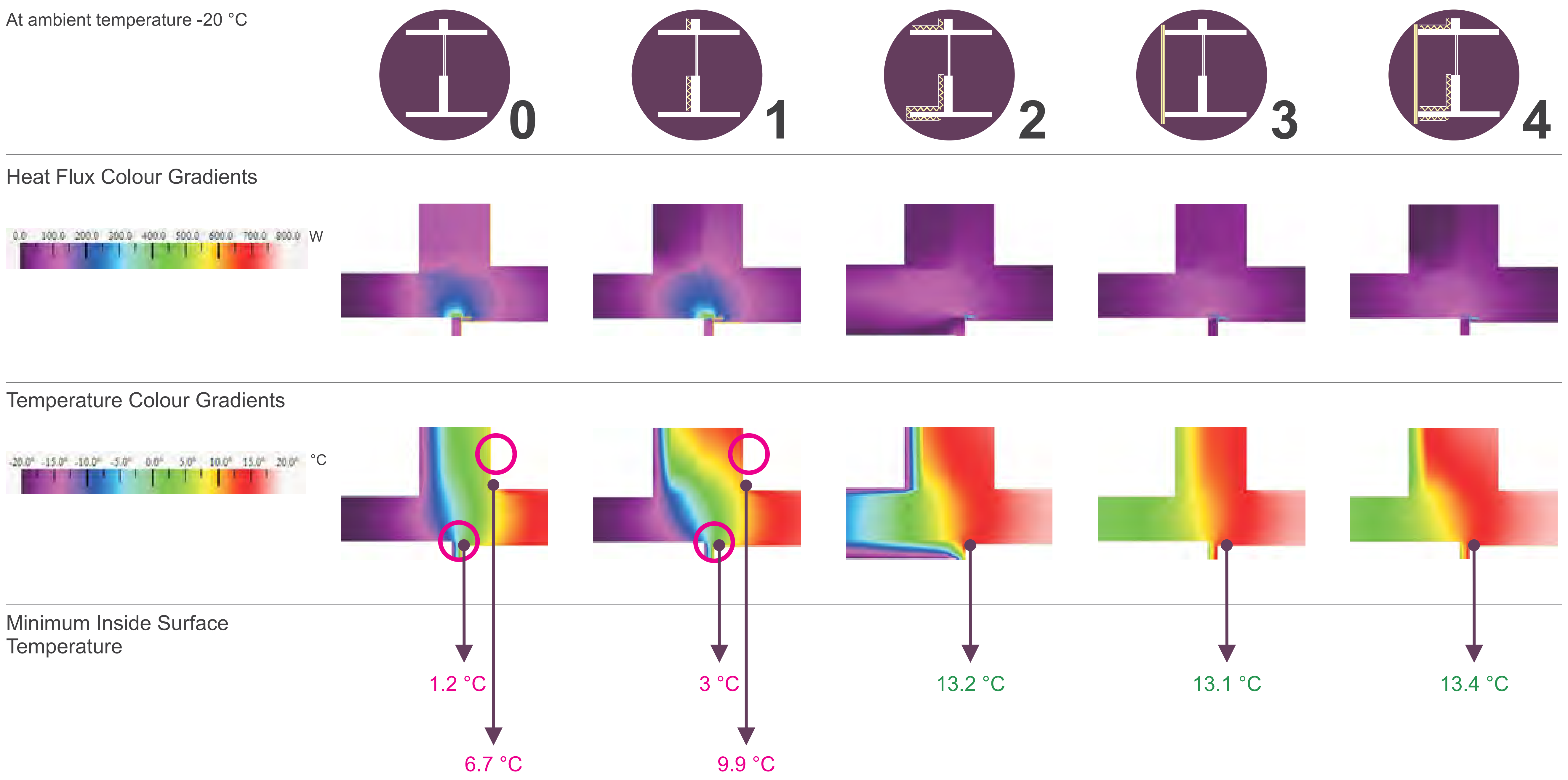




	Psi- Value (W/mK)	Heating Demand (kWh/m²a)
Window Sill Detail - Steel Angle	0.114	
Window Sill Detail - Fiberglass Angle	0.086	-0.16

TOWER RENEWAL PARTNERSHIP

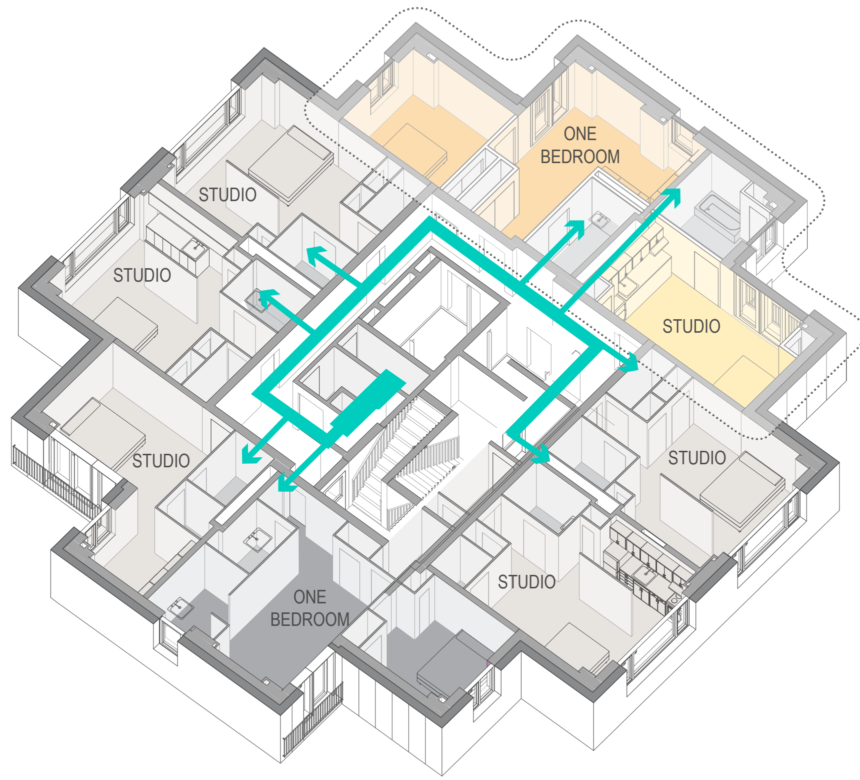
THERMAL BRIDGING




6234-02
CRATE 17

Modernized Ventilation Systems

- New Air Handling Units with Heat Recovery
- Direct Ducting into Suites
- Sealing Corridor Doors
- Electrical VAV 'Booster' In-Suite
- Modernized Exhaust Risers



TOWER RENEWAL PARTNERSHIP

OVERHEATING A PASSIVE HOUSE CHALLENGE

KEN SOBLE TOWER TRANSFORMATION

DYNAMIC THERMAL COMFORT MODELLING

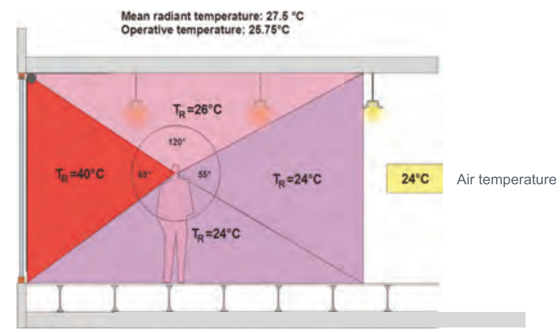
EXTREME WEATHER DAYS

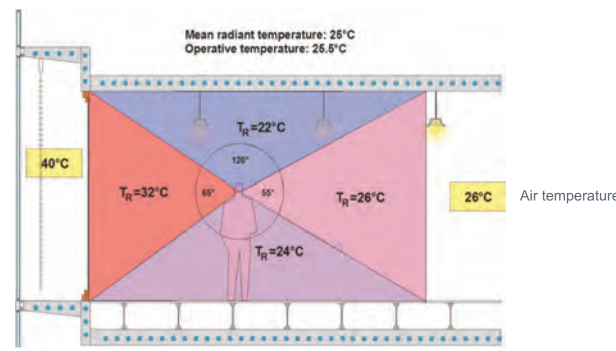
Operative Temperature vs. Air Temperature

Thermal Comfort

What we experience and perceive as thermal comfort in a building is influenced by both the air temperature and the mean radiant temperature. The mean radiant temperature accounts for the temperature of the surfaces to which a person is exposed. Balancing the operative temperature can create more comfortable spaces in a building.

The examples to the right illustrate the importance of balancing the operative temperature and not just the air temperature. People would feel the same level of comfort in both cases. Even though the air temperature in the example in the bottom right is warmer (26°C) than the example in the top right (24 °C), their operative temperature is around the same (25.5 °C). In the first example, since the surfaces are warmer, the air temperature needs to be cooler to provide the same level of comfort as the bottom room.





IMG: TRANSSOLAR

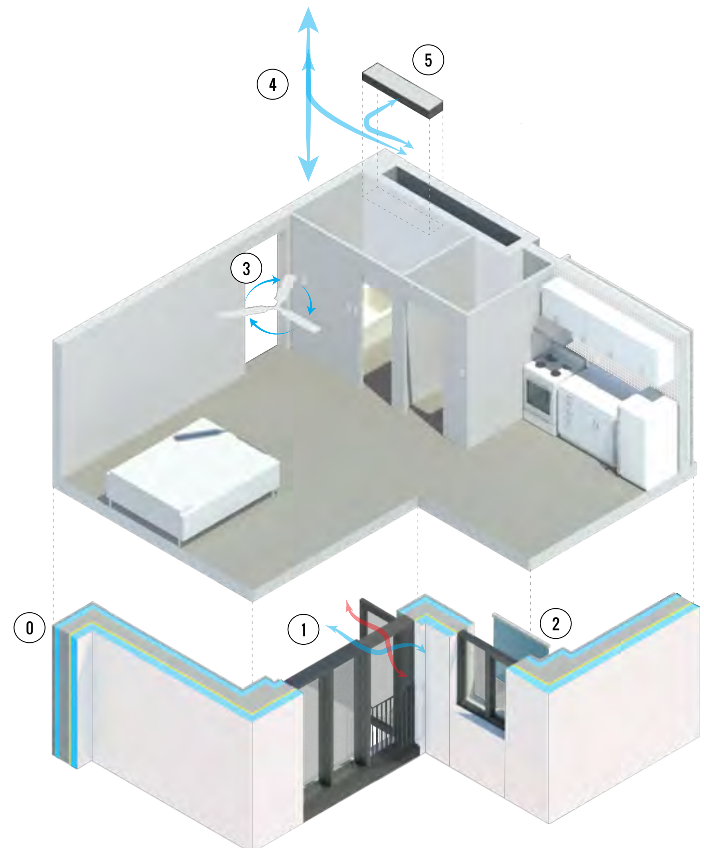
TOWER RENEWAL PARTNERSHIP

COOLING MULTI-STAGE SYSTEM

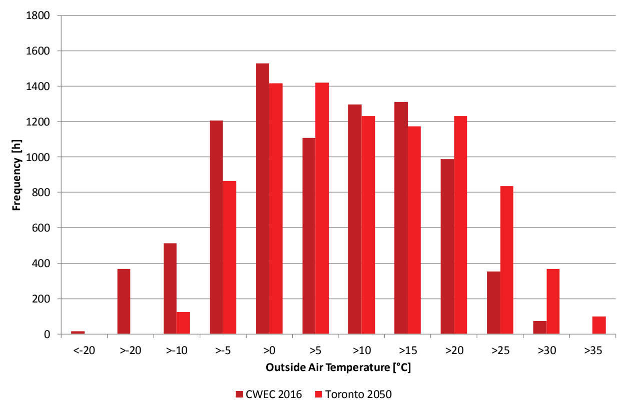
0 1 2 3 4 5

Passive — *Active*

0. R38 Effective Envelope
1. Glazing with a low Solar Heat Gain Coefficient
2. Low emissivity interior shades
3. Ceiling fans to circulate air within units
4. Lightly tempered air delivered through a centralized ventilation system
5. Decentralized cooling 'boost' through a Variable Air Volume Unit activated by in-suite controls



COOLING APPROACHES



Tmean_2016 = 8.3 °C → Tmean_2050 = 13.0 °C

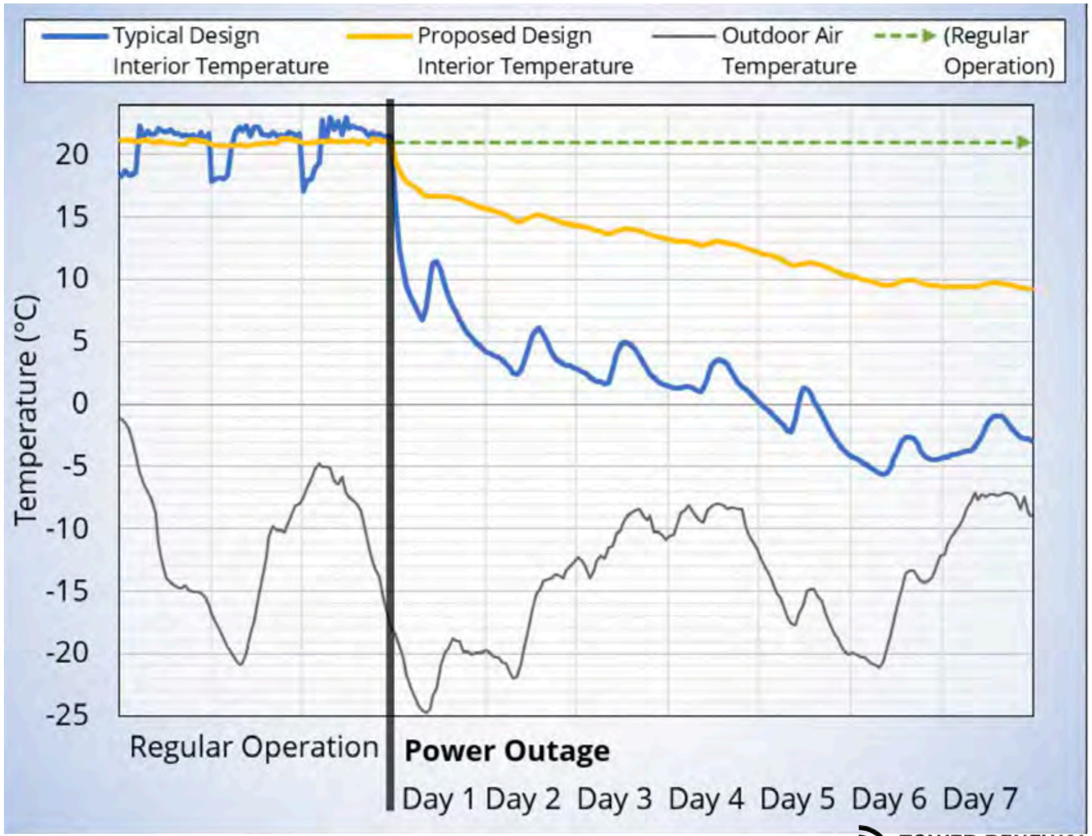
	slightly cool	comfortable	slightly warm	warm
	-1.5>PMV>-0.5	-0.5>PMV>0.5	0.5>PMV>1.5	1.5>PMV>2.5
VAR2B g34 CWEC Hamilton	0	8760	0	0
VAR2B g36 CWEC Hamilton	0	8760	0	0
VAR2B g40 CWEC Hamilton	0	8759	1	0
VAR2B g34 Toronto 2050	0	8488	272	0
VAR2B g36 Toronto 2050	0	8420	340	0
VAR2B g40 Toronto 2050	0	8333	427	0

- CONSIDER RESILIENCY FOR CLIMATE CHANGE
- EVALUATE HOURLY RESULTS BY PMV COMFORT CRITERIA FOR 2016 WEATHER DATA + 2050 TORONTO CONDITIONS

TOWER RENEWAL PARTNERSHIP

RESILIENCE PASSIVE 'SURVIVABILITY'

RESILIENCE TO EXTREME CLIMATE EVENTS



IMG: UNION GAS SAVINGS BY DESIGN

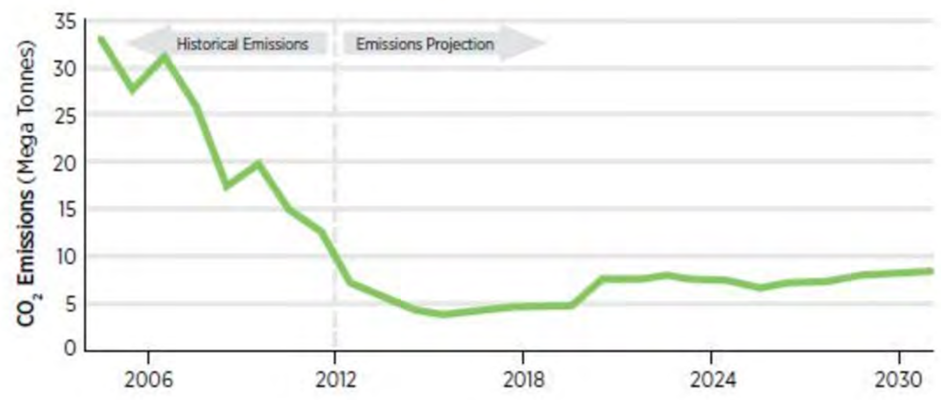
DECISION POINTS EMBEDDED CARBON

DECISION POINTS EMBEDDED CARBON

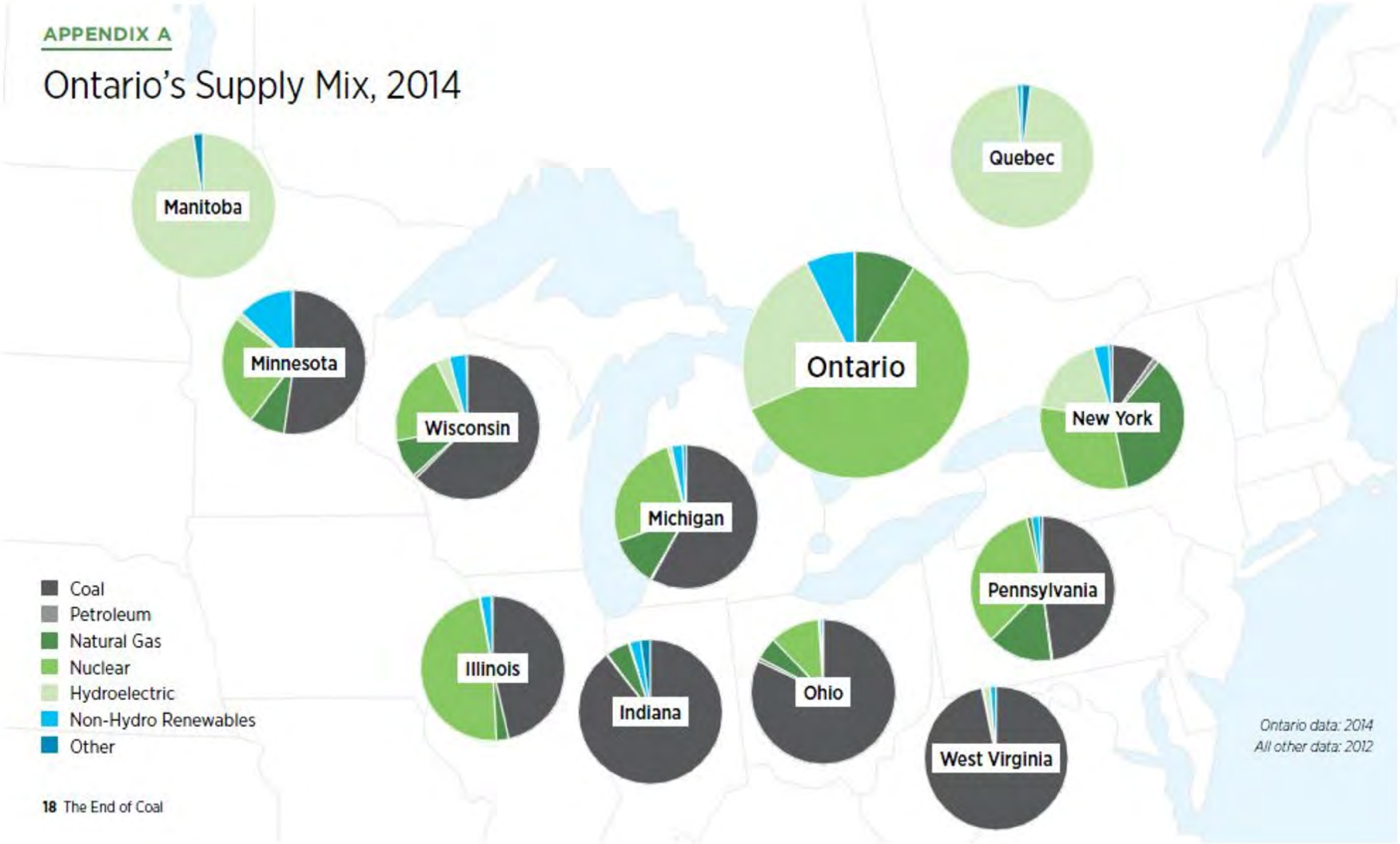
FUEL SWITCHING

Coal Phase Out

Greenhouse Gas Emissions Forecast



Appendix A



DECISION POINTS EMBEDDED CARBON

ENVELOPE

LINKING HOUSING QUALITY TO RETROFITS

STANDARDS* (FOR LARGE BUILDINGS)

	CANADA new	CANADA retrofit	GERMANY new	GERMANY retrofit
HEALTHY SPACE				
Condensation / Mould — mitigated through min. interior surface temperature (12.6oC)	Not Enforced	Not Enforced	Enforced	Enforced
Healthy Ventilation Systems — by mechanical and natural means	Not Enforced	Proposed Change	Enforced	Enforced
Controlled 'Infiltration' — by operable windows or trickle vents	Not Enforced	Not Enforced	Enforced	Enforced
THERMAL COMFORT				
Interior Temperatures — based on dynamic metrics (i.e. operative temperature and adaptive comfort modelling)	Not Enforced	Not Enforced	Enforced	Enforced
Thermostat Control — individual control of thermostats / heaters in each room	Under Consultation	Not Enforced	Enforced	Enforced
Eliminating Thermal Bridging — by implementing continuous insulation and other strategies	Proposed Change	Not Enforced	Enforced	Enforced
Air Tightness — in-situ testing required	Proposed Change	Not Enforced	Enforced	Enforced
Triple-pane Windows / Doors — max U-Value 0.85 W/m2K (installed) (current PH standard for comfort reasons)	Not Enforced	Not Enforced	Enforced	Enforced
Shading Control — for summer cooling	Not Enforced	Not Enforced	Enforced	Enforced
FIRE SAFETY				
Overcladding** — avoiding flammable insulation materials at all building heights	Not Enforced	Not Enforced	Enforced	Enforced
Sprinklers	Enforced	Not Enforced	?	?
ENERGY PERFORMANCE				
Energy Requirements — low energy performance standards	Proposed Change	Proposed Change	Enforced	Enforced
TRACKING AND MONITORING				
Commissioning	Under Consultation	Not Enforced	Enforced	Enforced
Sub-Metering / Energy Tracking / Energy Modelling	Under Consultation	Not Enforced	Enforced	Enforced

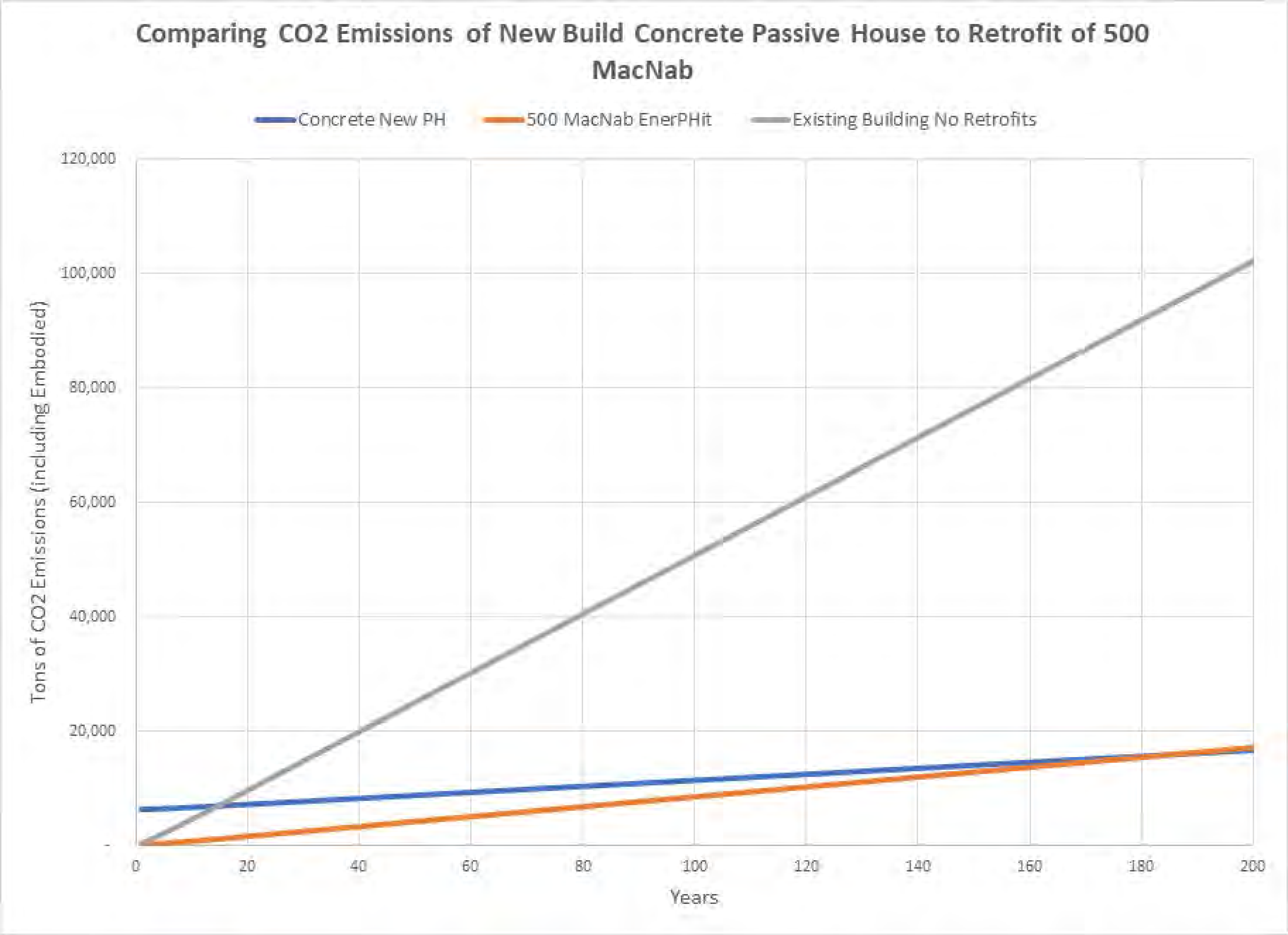
LEGEND: Enforced · Proposed Change · Not Enforced · Under Consultation

* Deep energy currently considered for non-extensive renovations.

** Non-flammable insulation required for six storeys and above in Ontario.

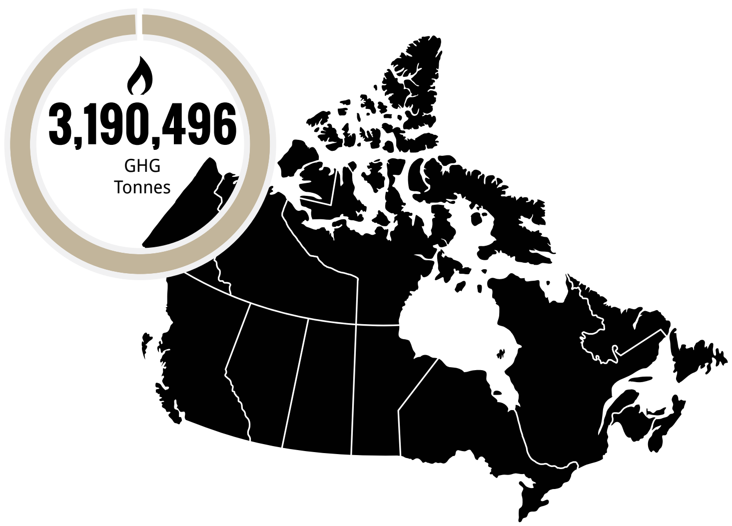
DECISION POINTS EMBEDDED CARBON

DEMOLITION VS RENEWAL


Comparing CO2 Emissions of New Build Concrete Passive House to Retrofit of 500 MacNab
Concrete New PH
500 MacNab EnerPHit
Existing Building No Retrofits
Tons of CO2 Emissions (including Embodied)
120,000
100,000
80,000
60,000
40,000
20,000
-
0
20
40
60
80
100
120
140
160
180
200
Years

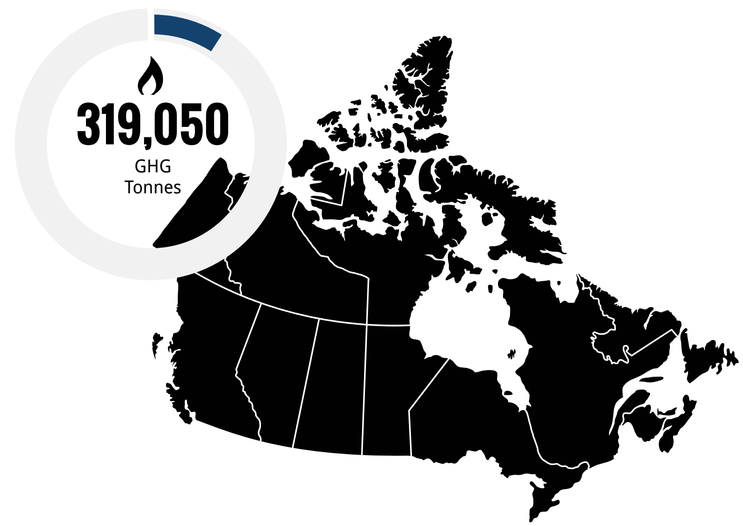

FRA
CO
24 HOUR
EMERGENCY PHONE #

NATIONAL IMPACT



4.11 GHG/Unit

IN CANADA THERE ARE 777,100 HOUSEHOLDS LIVING IN AGING POST-WAR HIGHRISES.
EACH HOUSEDHOLD EMITS 4.11 TONNES GHG/YR*.



0.41 GHG/Unit

FOLLOWING RETROFIT GHG REDUCTION OF 90%

EACH HOUSEHOLD*

** The average based on typical building condition per city of Toronto 2016*

TOWER RENEWAL PARTNERSHIP

MEASURING IMPACT TO SCALE CHANGE

HEALTH IMPACTS ER visits / Attendance at Public Health Services / Heat-Related Thermal Stress / Missed Work

SAFETY FACTORS Home Fire Incidents / Accessibility within Common Areas / Police Calls / Break-Ins

HOUSING QUALITY IMPACTS Outdoor Noise Disruptions / Indoor Air Quality / Elevator Breakdowns

AFFORDABILITY IMPACTS Tenant Turnover / Ability to Pay Utility Bills / Ability to Pay Rent / High-Cost Loans

OPERATIONS Pest Control Incidents / Tenant Complaints / Equipment Maintenance / Repairs and Replacements

ENVIRONMENTAL FACTORS Avoided GHG Emissions / Utility Costs / Avoided Material in Waste Stream

ECONOMIC FACTORS Trades Training / Property Value / Operating Costs / Vacancy Rate / Reserve Fund

KEN SOBLE TOWER **ENERPHIT**

ERA

TOWER RENEWAL PARTNERSHIP

ENTUITIVE

REINBOLD engineering group

JMV CONSULTING

Poll

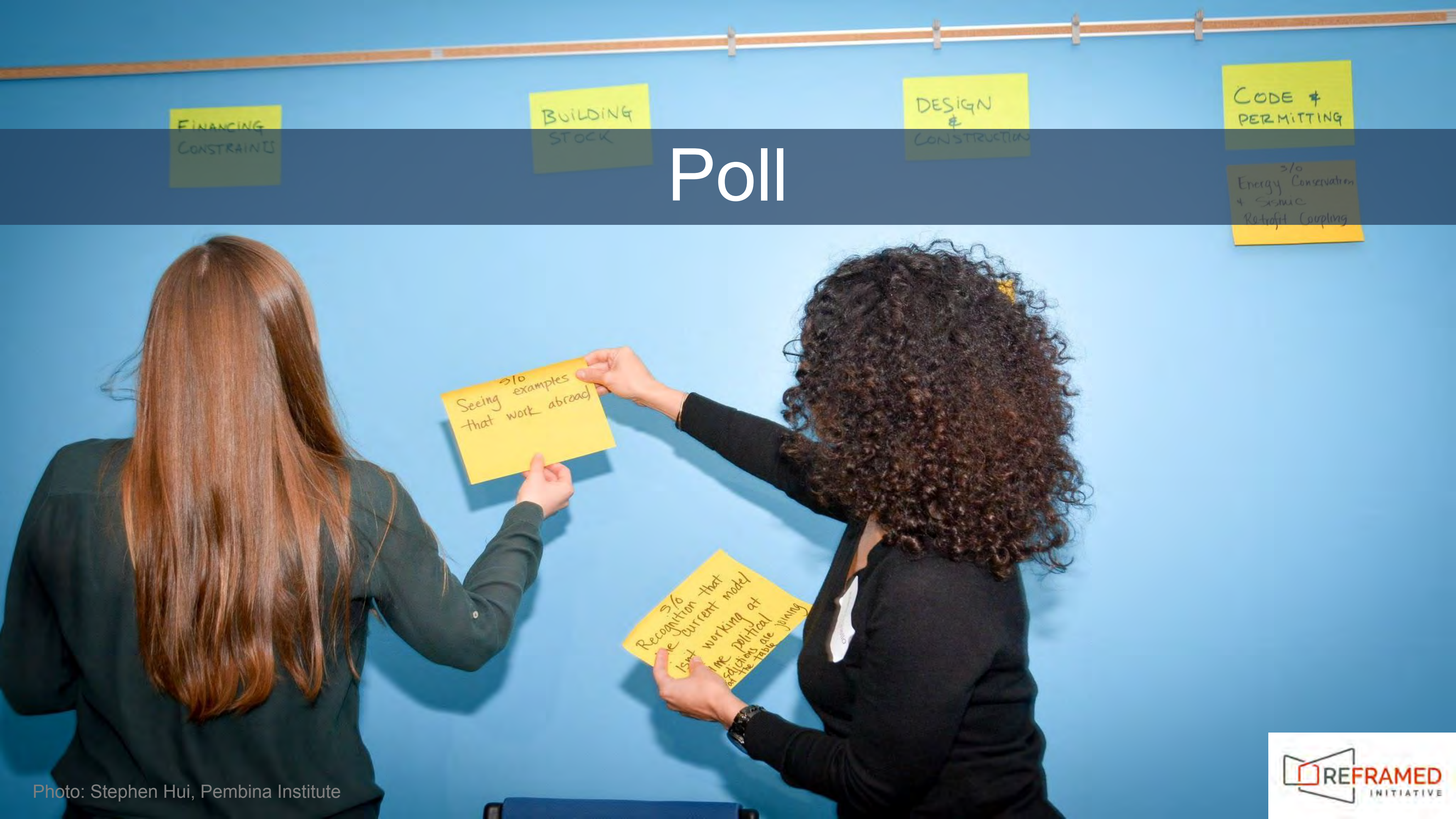


Photo: Stephen Hui, Pembina Institute

REFRAMED INITIATIVE

Questions

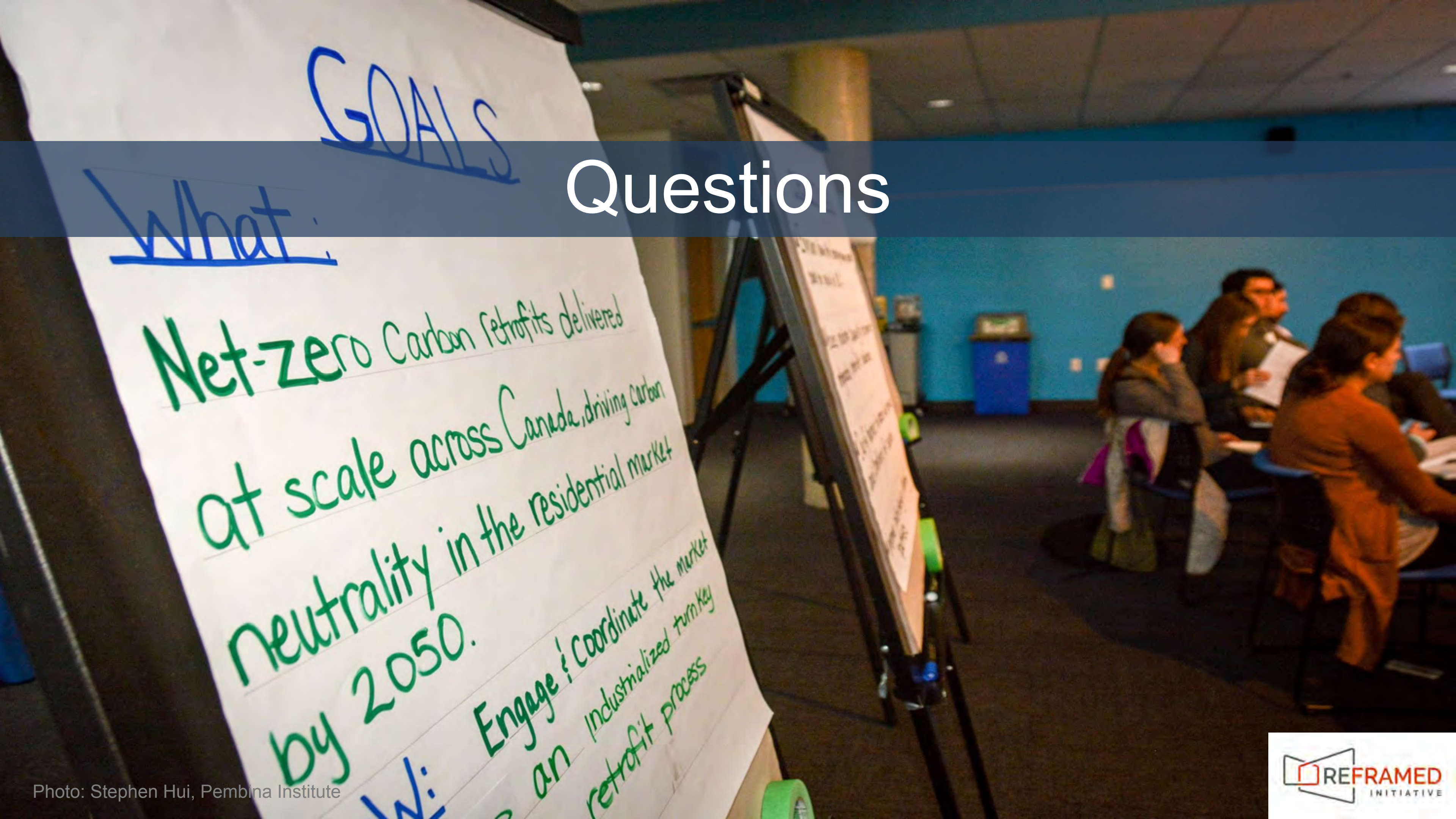


Photo: Stephen Hui, Pembina Institute

REFRAMED INITIATIVE

Introducing the Reframed Lab

- Request for proposals in summer 2020
- Multi-disciplinary teams will design solutions for low-rise residential buildings in B.C.'s Lower Mainland or Victoria area
- Six-month exploration lab with support from climate, energy, and health experts

REGISTER YOUR INTEREST: reframedinitiative.org

REFRAMED INITIATIVE

Integrated design teams

- Architects
- Building science, electrical, mechanical, and structural engineers
- Contractors, builders, and retrofitters
- Manufacturers, fabricators, and suppliers
- Modeling and data capture specialists
- Monitoring and control equipment specialists

Solutions of particular interest

- Prefabricated exterior wall and roof panels
- Low-carbon materials and building systems
- High-efficiency mechanical systems
- Roofing solutions that integrate on-site renewable electricity
- Storage and/or thermal generation
- Seismic upgrades
- Climate adaptation measures
- System controls and performance monitoring

Contact us

connect@reframedinitiative.org

reframedinitiative.org

Register as a solution provider. Sign up for updates.

#Reframed

REFRAMED INITIATIVE