REFRIGERANT EMISSIONS ELIMINATION FORUM

Designing for Decarbonization: The Role of Architects & Engineers in Supporting the Refrigerant Transition

Aleisha Khan

Executive Director
REEF

Agenda

Housekeeping Notes

GWP and Regulatory Overviews

Panel:

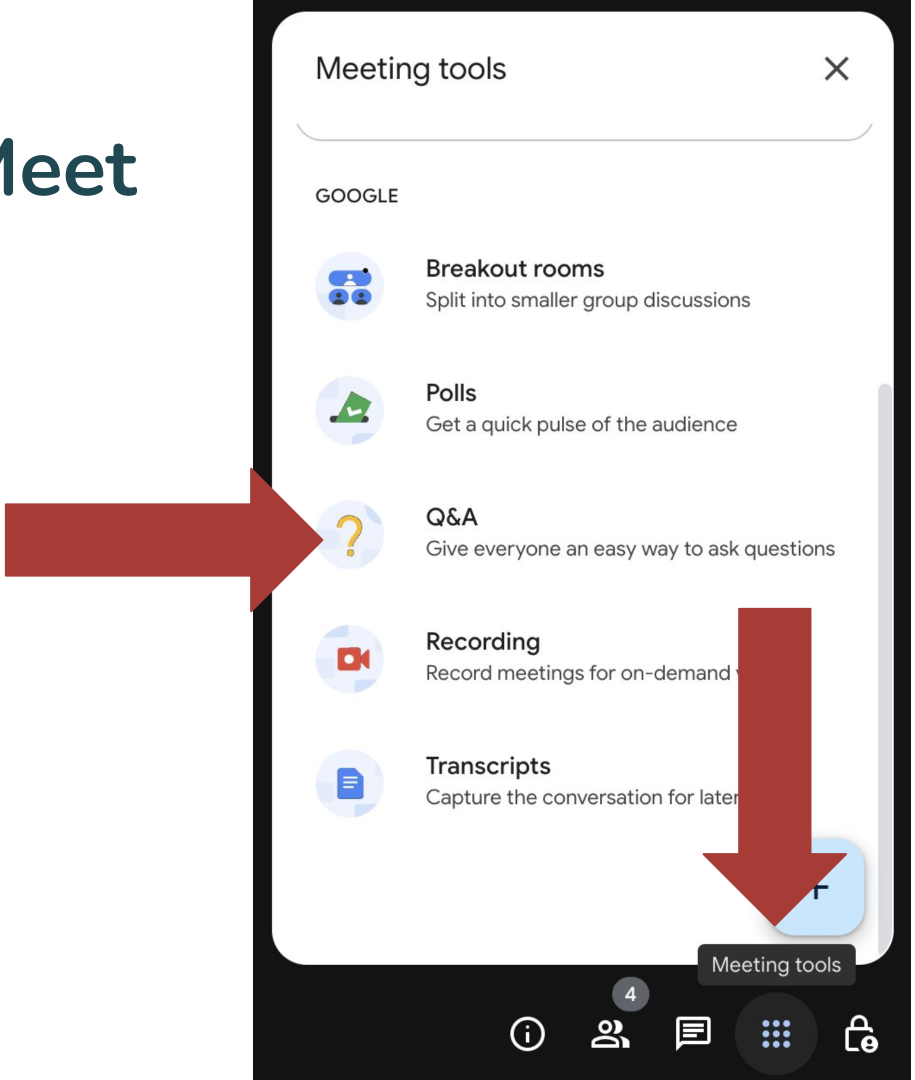
- Stet: GWP Overview and Whole Life Carbon Case Studies
- Rami: Industry Trends, Cost Risks, and Stakeholder Responsibilities
- Jamy: Code vs Rating Calculations and Specification Transition Challenges

Wrap Up and Resources

Audience Q+A for Panel

Navigating Google Meet

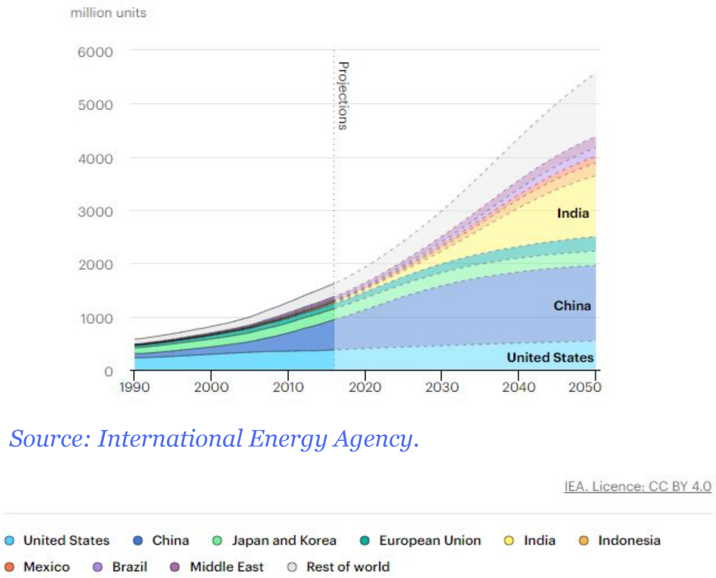
How to Submit Questions for Moderator and Speakers



Refrigerant gasses are powerful and overlooked drivers of climate change. They are EVERYWHERE. Collectively, refrigerants are also the world's fastest growing category of greenhouse gases.

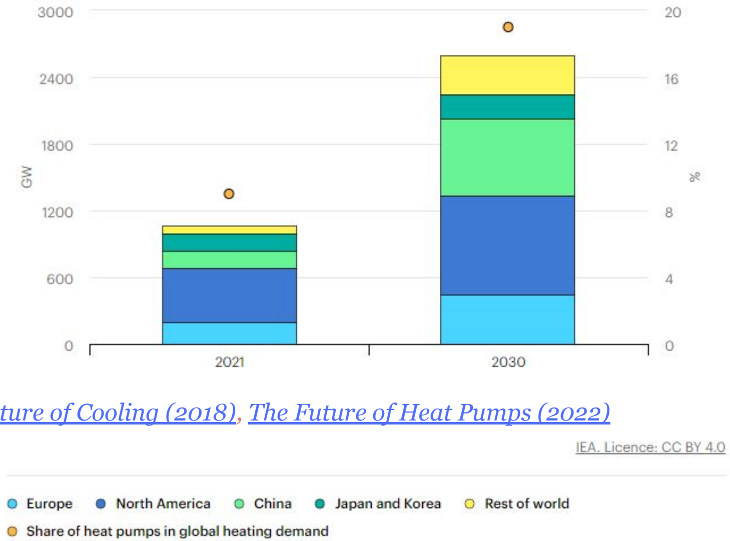
Global demand for refrigerants is increasing

Global AC stock, 1990 - 2050



Source: International Energy Agency.

Heat pump capacity in buildings, 2021 - 2030



The Future of Cooling (2018), The Future of Heat Pumps (2022)

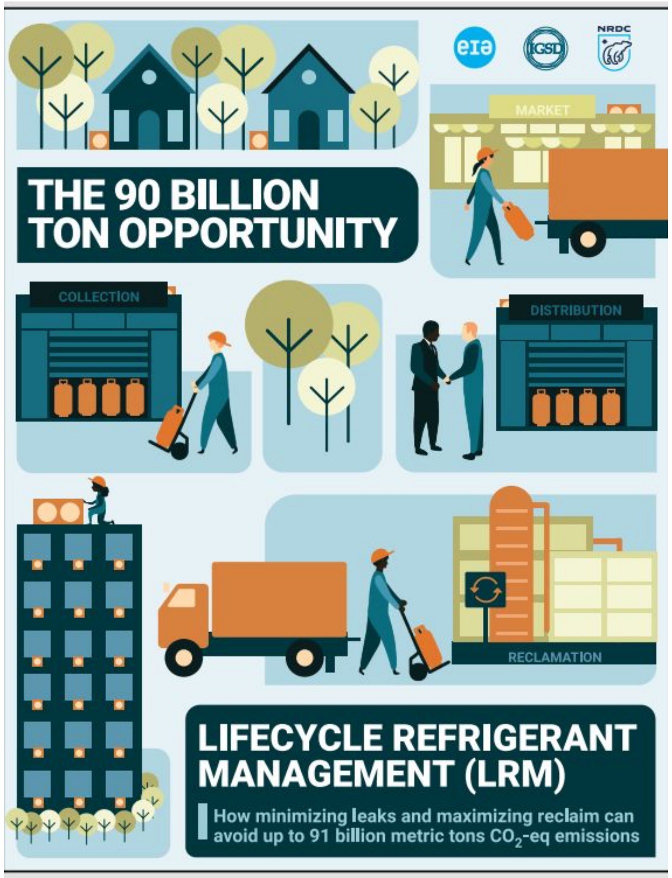
3 billion more room air conditioners are expected to be installed globally by 2050

Building electrification through heat pump adoption is growing need for refrigerants

Leaks happen

....

improper installation
insufficient maintenance
equipment degradation
venting at end of life



BUT DON'T PANIC!

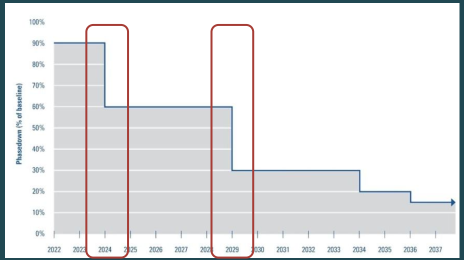
- **Product Safety Standard**
  - UL 60335-2-40 – AC
  - UL 60335-2-89 - Ref
- **Application Standard**
  - ASHRAE 15
- **Building Codes**
  - State / local level adoption
  - Typically rely on model codes

U.S. Regulations
Refrigerants & technologies are changing

Three Legs of the AIM* Act

*American Innovation and Manufacturing Act of 2020, directs EPA to phasedown the **production** & **consumption** of HFCs by **85% below baseline levels calculated from 2012-13 data by 2036 (15 yrs)**

1: HFC Production Phasedown
Began in 2022



Reduces **supply** of new HFCs
2024 40% reduction

2: Technology transition rules – subsection (i)

Requires new equipment to use lower GWP refrigerants
Began 2025

"TT" Reduces **demand** for virgin HFCs

3: Emissions Reduction and Reclamation Program – subsection (h)

Covers all RACHP equipment* >15lbs. refrigerant

"ER&R" Addresses management of **legacy** refrigerants assets

***Does not apply to residential and small commercial RACHP or GWP <53**

So why in corporate and commercial real estate are refrigerants often overlooked?

“It’s complicated”

(but we can do complicated things)

Introductions

Stet Sanborn

Vice President
Director of Climate IMPACT
SmithGroup

Reducing Risk through Reducing Charge

Right Size Equipment

Reduce Refrigerant as a Distribution Medium

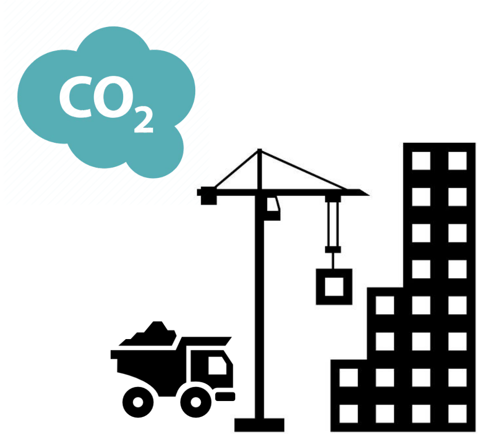
Consider Monoblock (Air to Water, Water to Water, etc)

Consider Smaller, Distributed Equipment

Spec Inverter Driven equipment

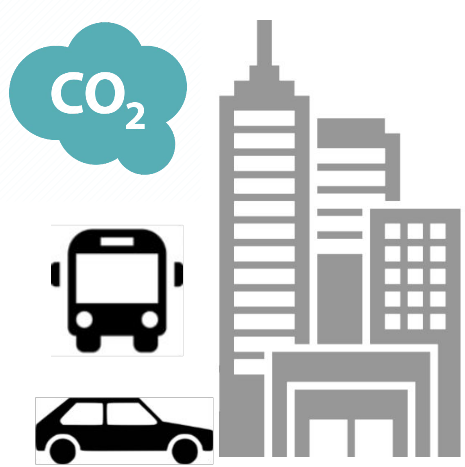
LOOK AT WHOLE LIFE CARBON

Total Carbon



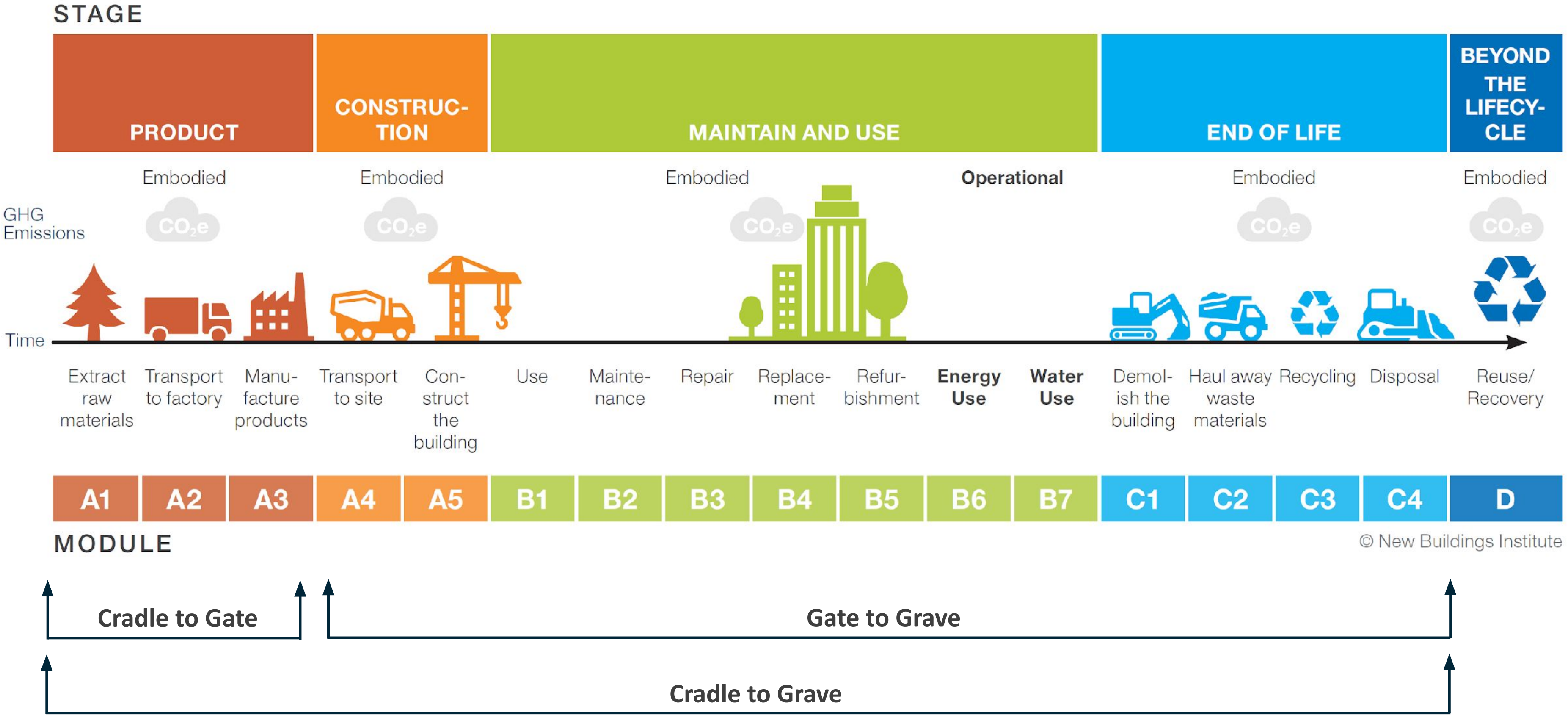
Embodied +

Operational +

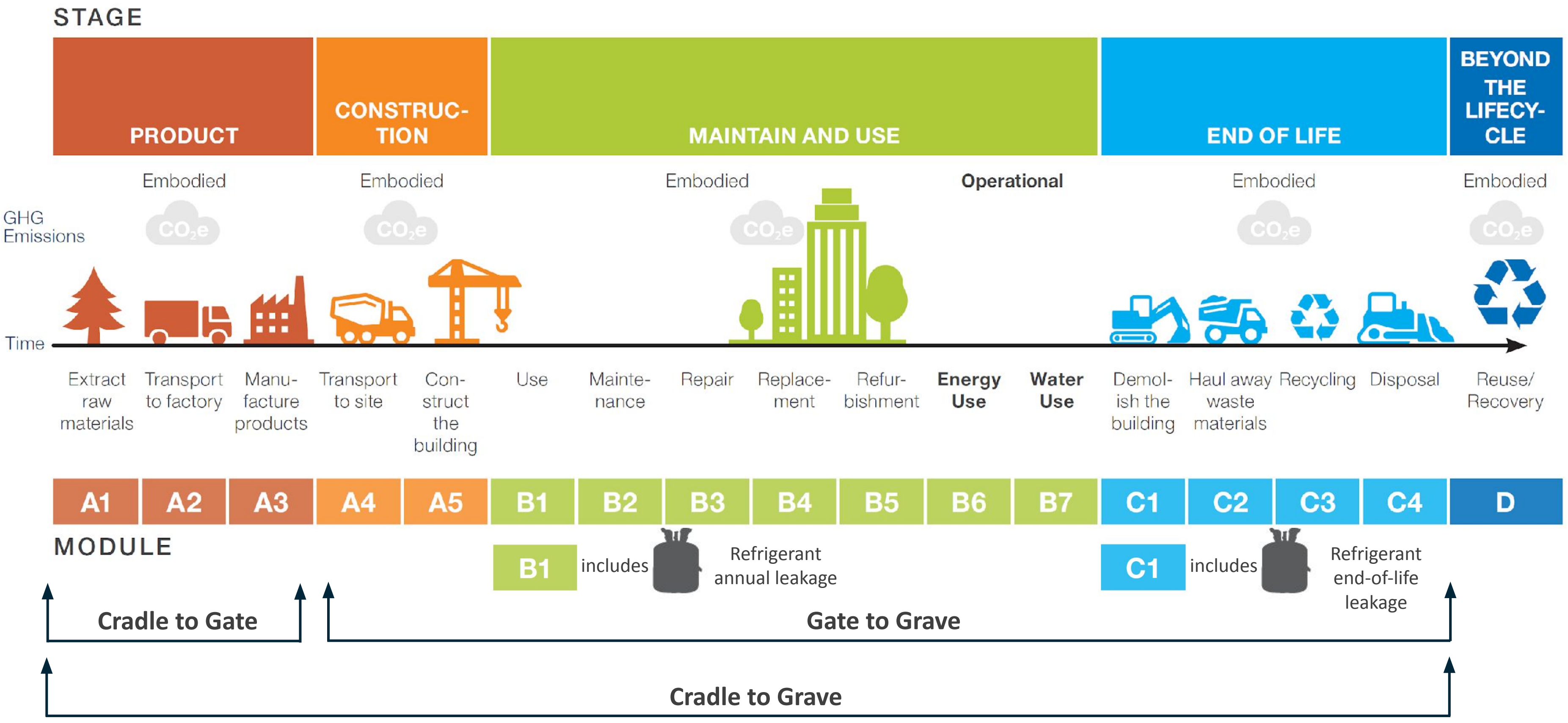


Transportation

WHOLE LIFE CARBON: BS EN 15978 – 2011



WHOLE LIFE CARBON: BS EN 15978 – 2011



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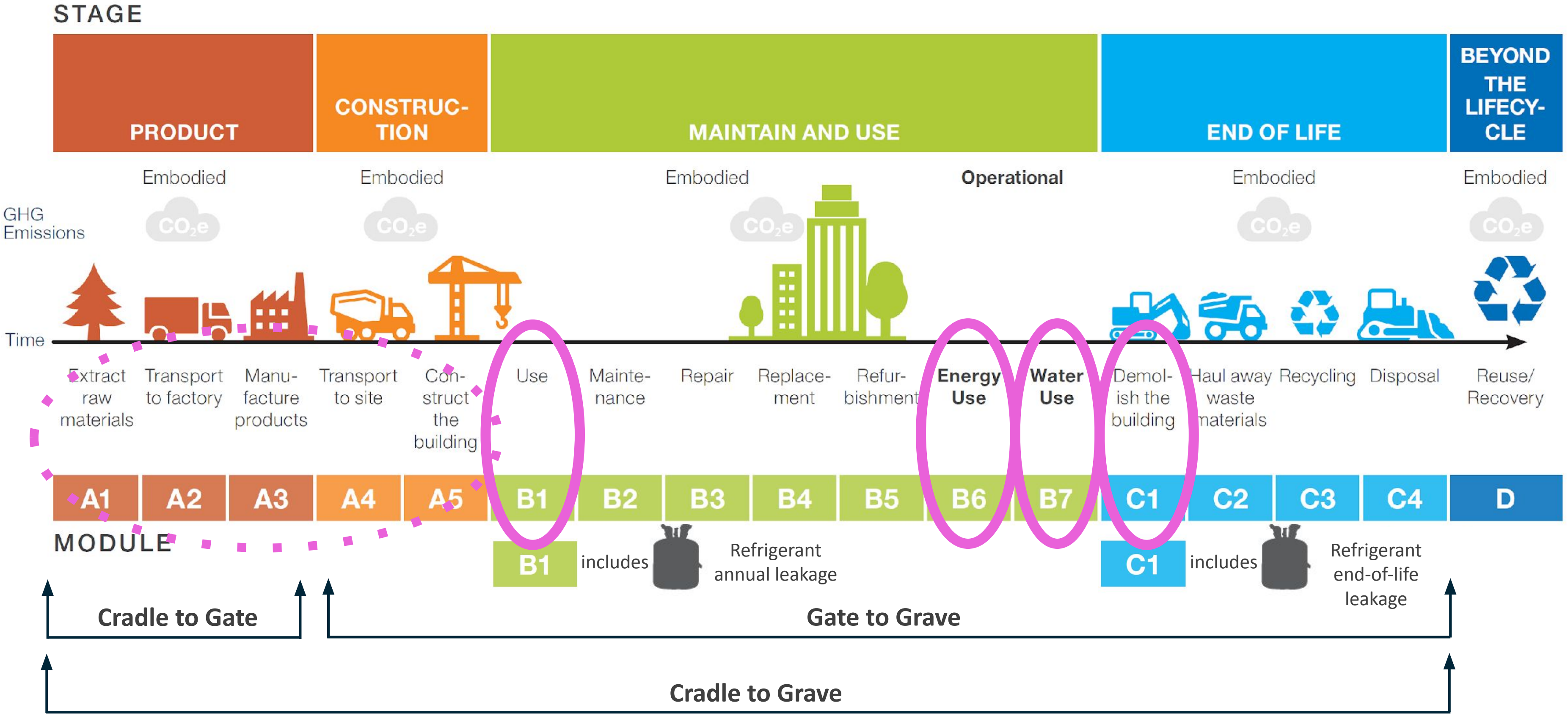
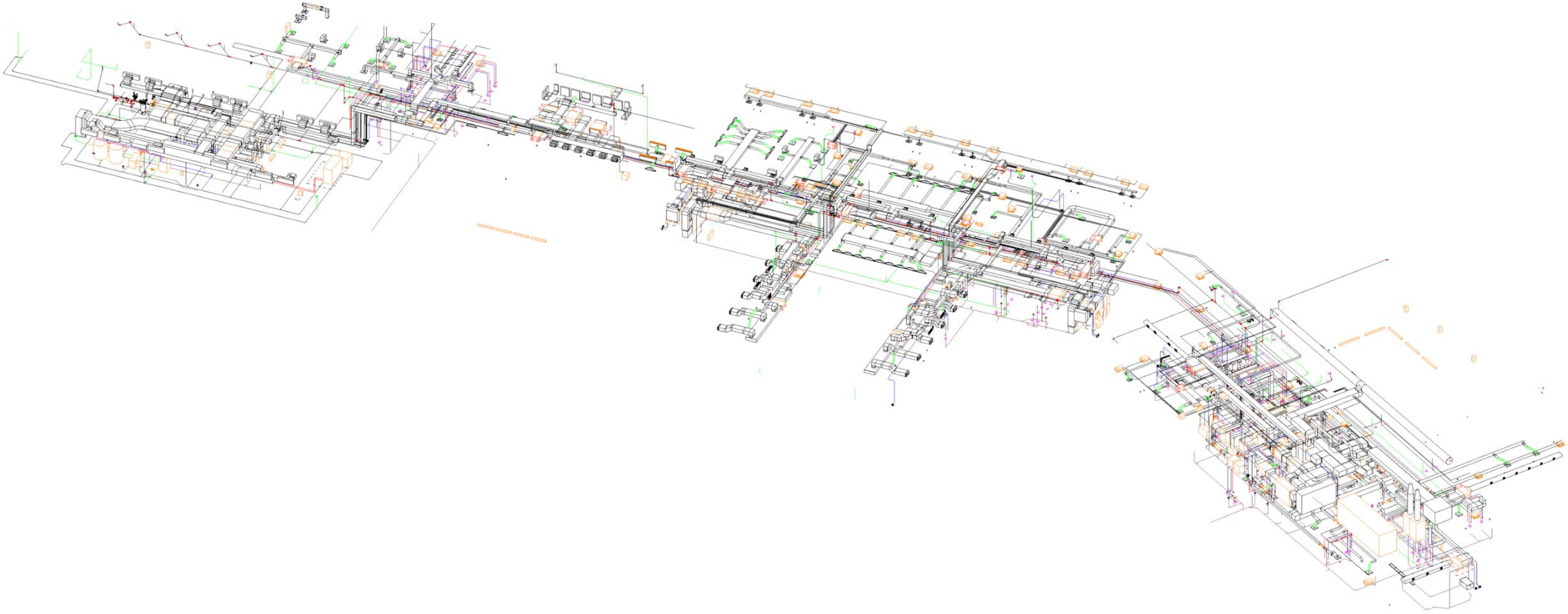
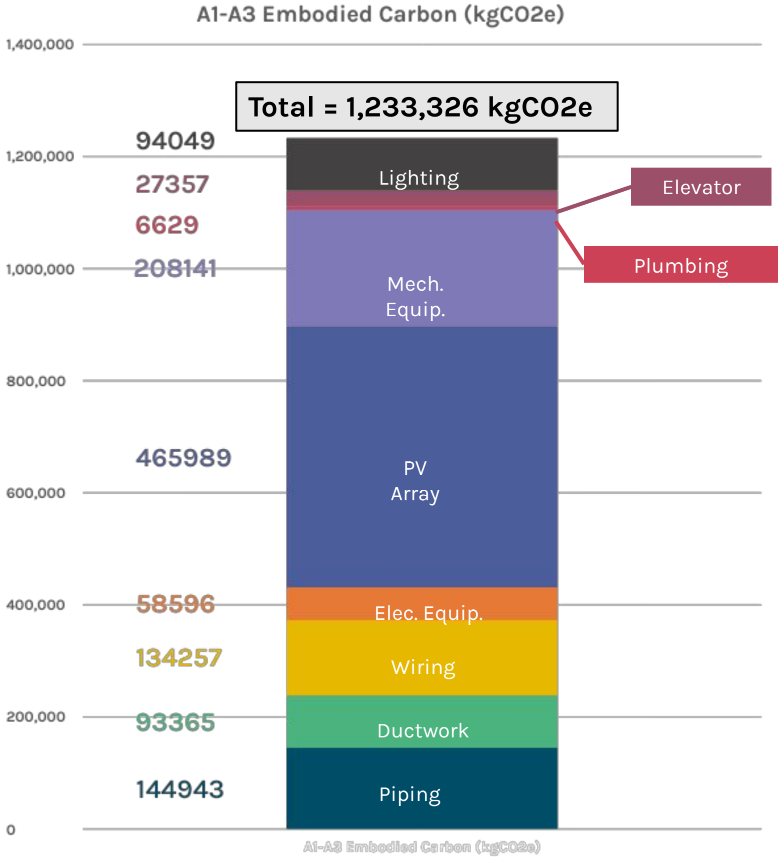


WHY DO WE CARE ABOUT REFRIGERANTS?

A WHOLE LIFE CARBON COMPARISON OF A VRF System (410A)



MEP CRADLE TO GATE (A1-A3)



EPD Source and Calculation Methodology

- Equations and EPDs sourced from MEP 2040's *Beginner's Guide to MEP Embodied Carbon*
  - Piping, Ductwork, Wiring, and PV Array
- EPDs sourced from OneClick LCA and scaled by weight (lbs) or quantity (item) to the EPD
  - Elec. Equip., Mech. Equip., Plumbing Fixtures, Elevator, and Lighting

Referenced during Calculation

- Revit model, schedules, submittals, and cut sheets
- Minor updates were made to the Revit model following discussions with MEP engineers

BEYOND THE GATE (A4-C4 RESULTS)

OUTCOMES AND INSIGHTS

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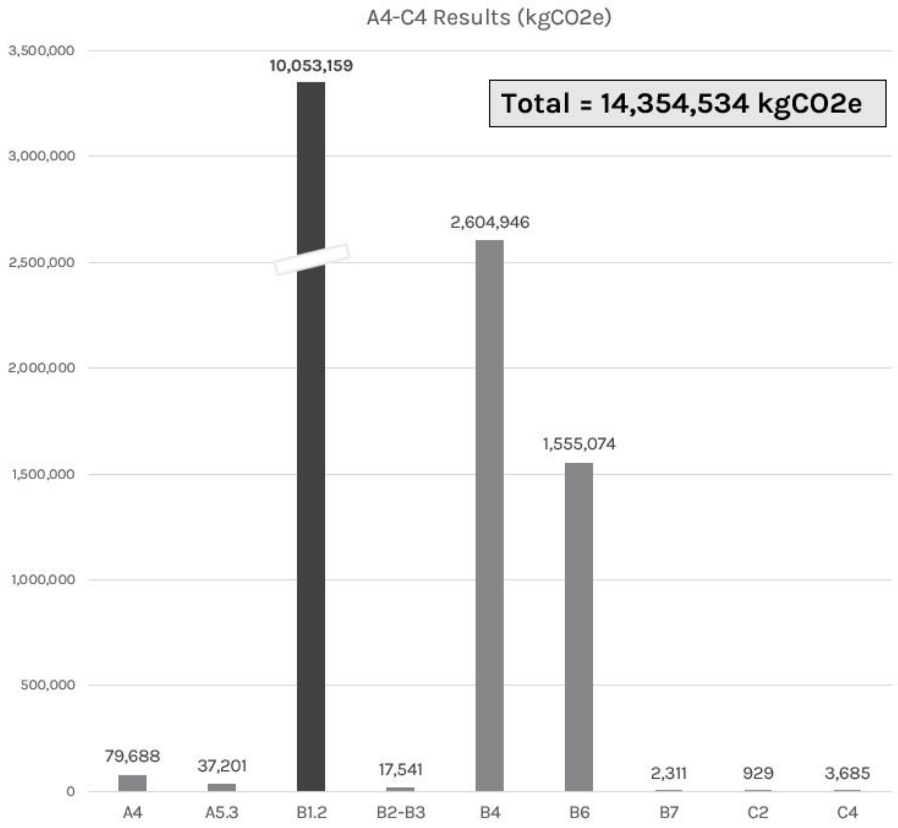
BEYOND THE GATE (A4-C4)



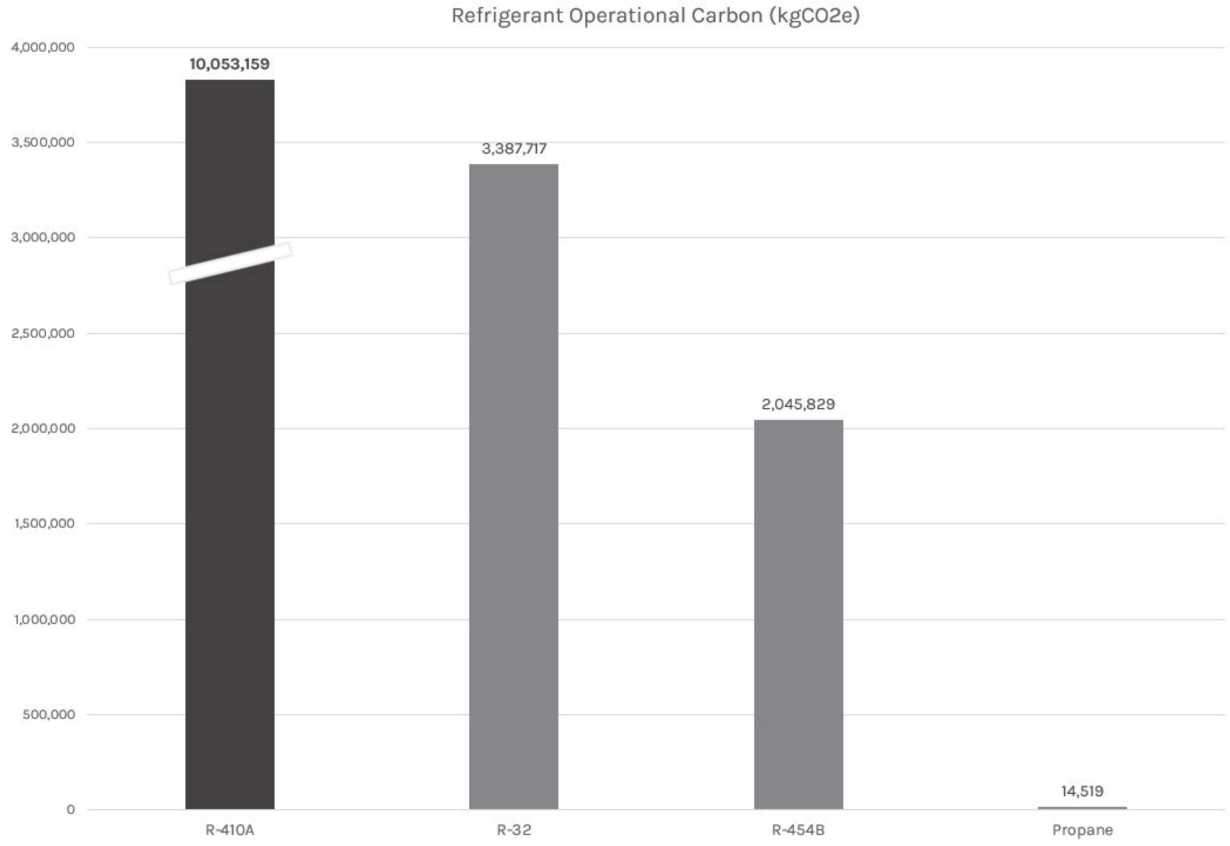
Calculation Methodology

- Equations and known values sourced directly from MEP 2040 – *Beginner's Guide to MEP Embodied Carbon*
  - A4: Transportation
  - A5.3: On-site Waste and Waste Management
  - B1.2: Fugitive Emissions (Refrigerants)
  - B2-3: Maintenance & Repair
  - B4: Service Life of Equipment (Replacement)
  - B6: Operational Energy Use
  - B7: Operational Water Use
  - C2 & C4: Recycling and Disposal

- A1-A3 results, EPDs, and the project's LEED Minimum Energy Performance Calculator were used for the calculation of A4-C4

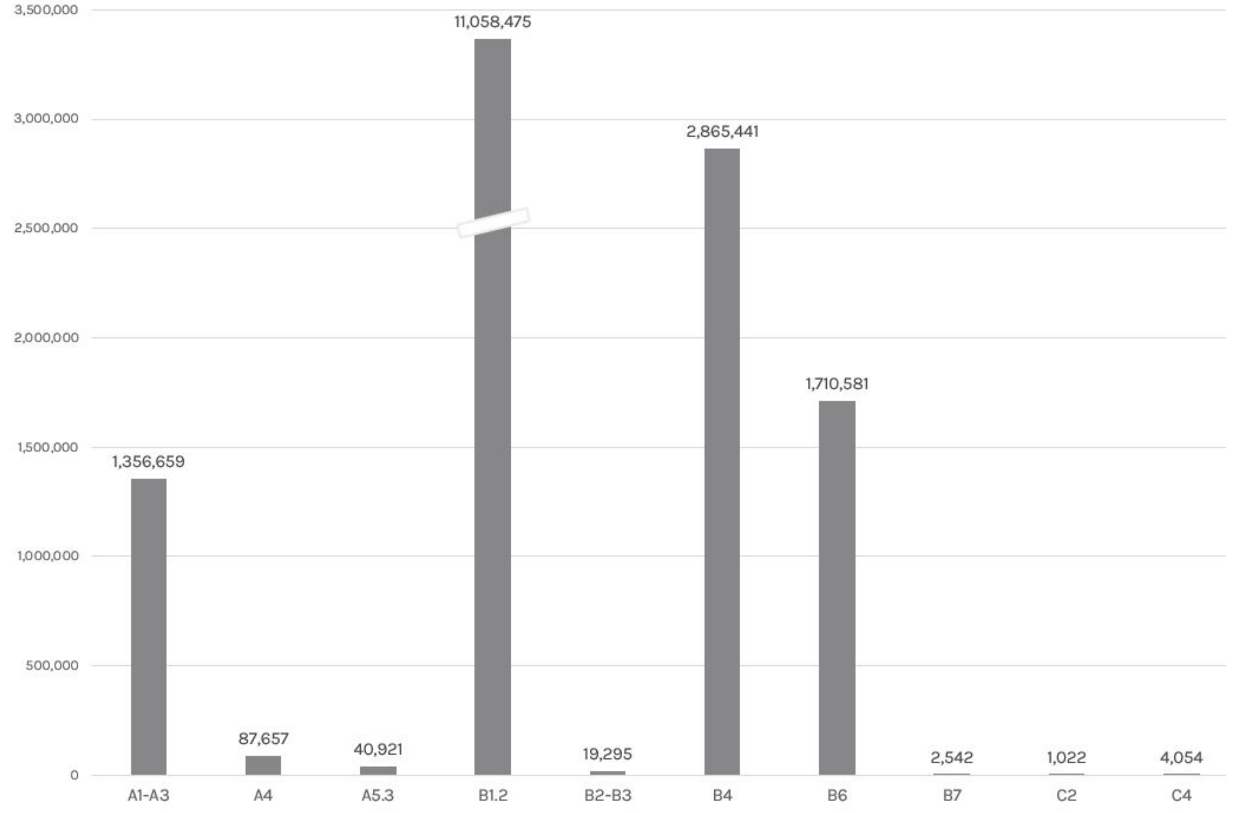
***B1.2 Refrigerants accounts for 70% of the A4-C4 Operational Carbon Emissions**

REFRIGERANT EMISSIONS COMPARISON



Comparative Impact of Refrigerant Emissions

WHOLE LIFE CARBON W/ +10% UNCERTAINTY (kg CO2e)



+10% for uncertainty

Evaluation Factors

- Contingency Factor
  - Adjusts for uncertainty inherent in the different design stages
  - LOD of the model/drawings
- Quantity Uncertainty Assessment
  - Applied quantity factors to the top 10 highest embodied carbon categories to reflect variability in material or equipment estimates
- Carbon Data Quality Review
  - Compared EPDs for the top 10 categories to assess geography, technology, product specificity, data granularity, data verification, and EPD completion data

Total Whole Life Carbon

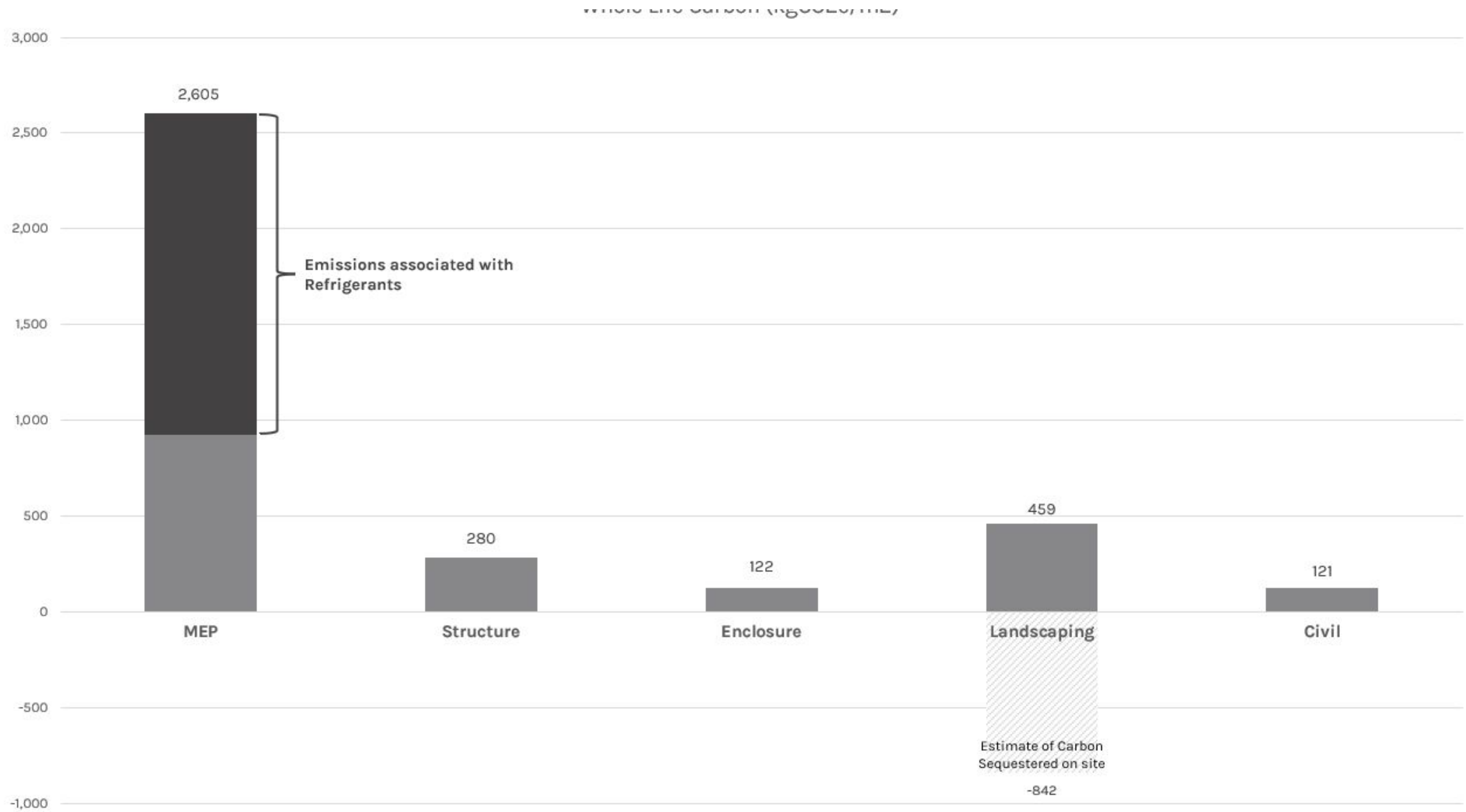
(Embodied + Operational)

17,146,645 kg CO2e

***B1.2 Refrigerants accounts for 65% of the Total Whole Life Carbon**

WHOLE LIFE CARBON STORY

*60-YEAR STUDY PERIOD



Comparative Impact of Refrigerant Emissions

CASE STUDY:

ENERGY RESEARCH AND SUSTAINABILITY CENTER – CAL POLY HUMBOLDT

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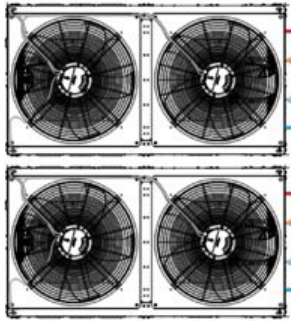
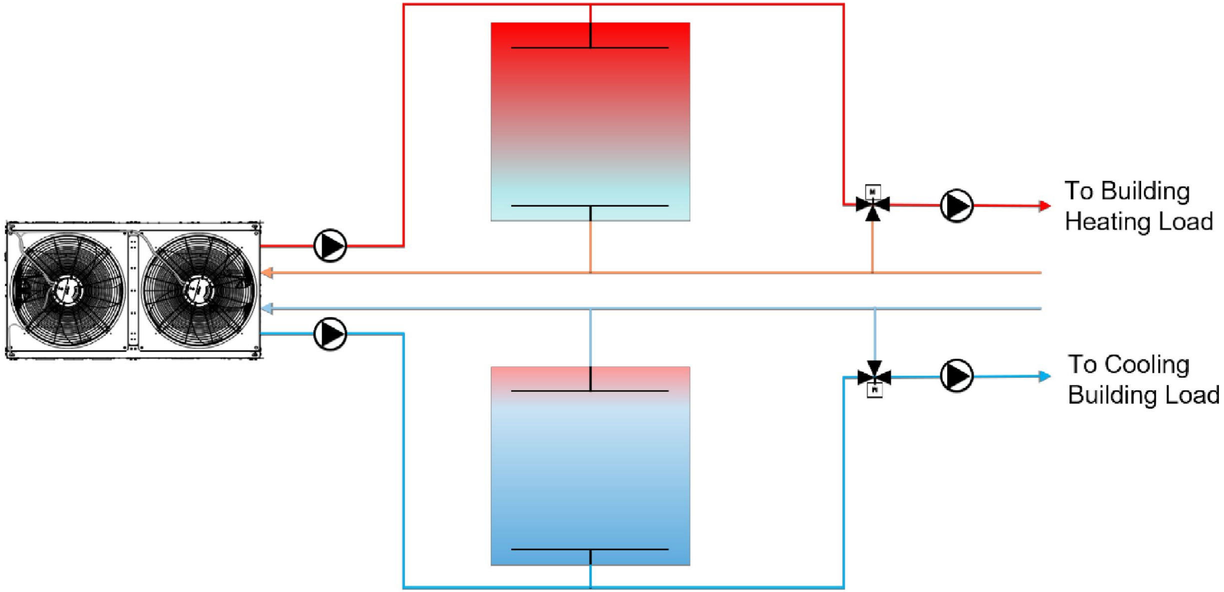
PAIR WITH TES TO DOWNSIZE EQUIPMENT

SMALLER EQUIPMENT = LESS REFRIGERANT CHARGE = LOWER FUGITIVE EMISSIONS = LOWER RISK



VS.



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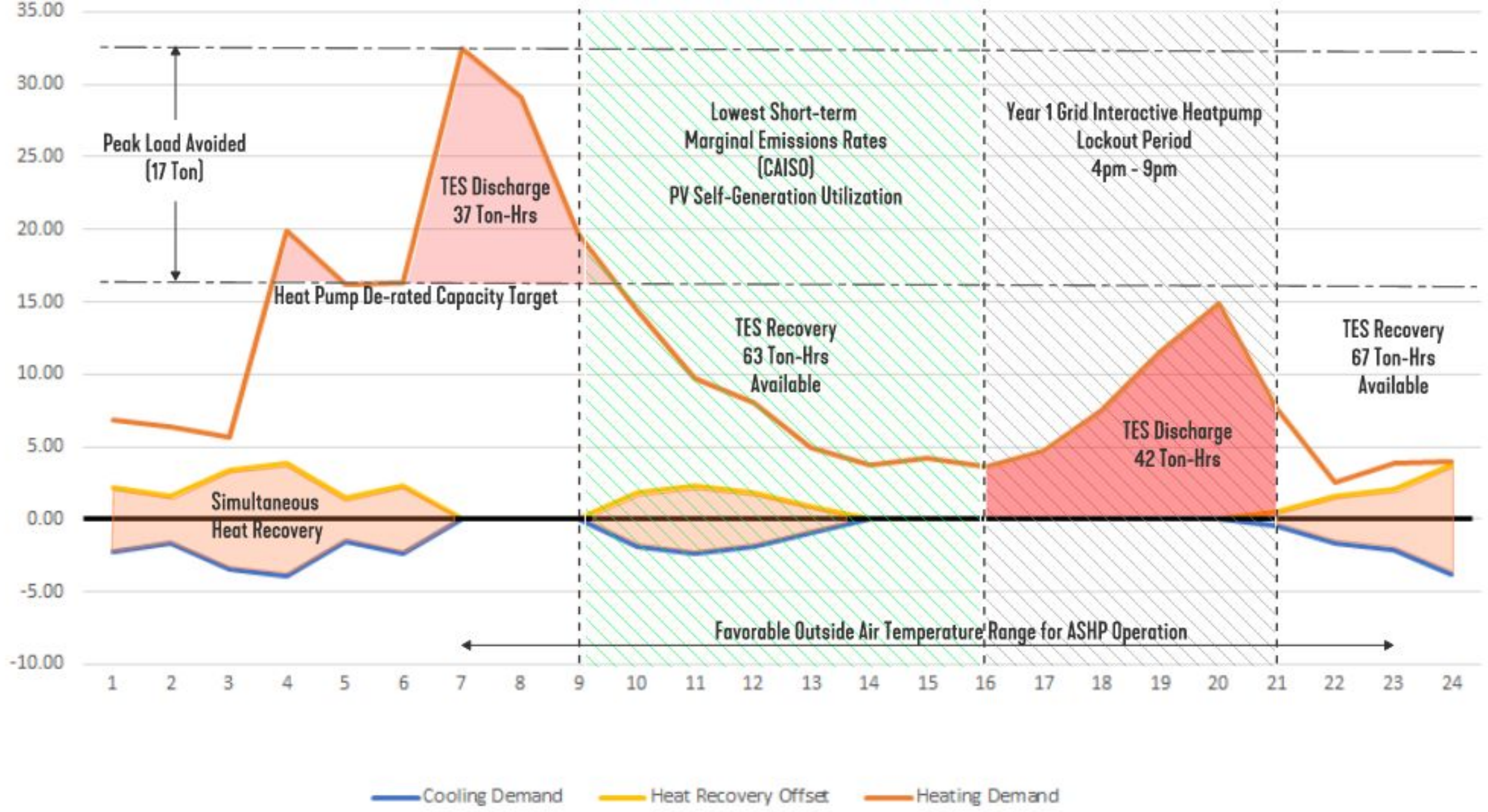
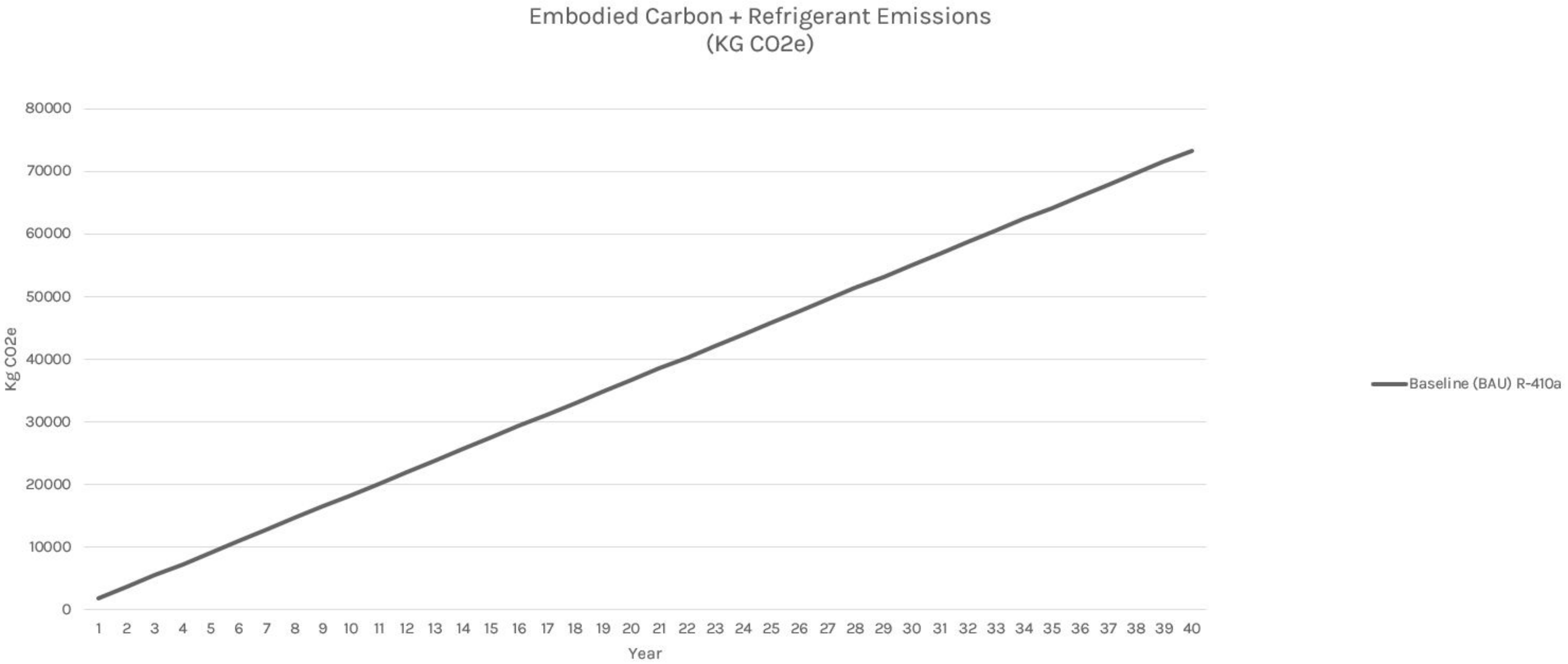


WHOLE – LIFE CARBON IMPACTS



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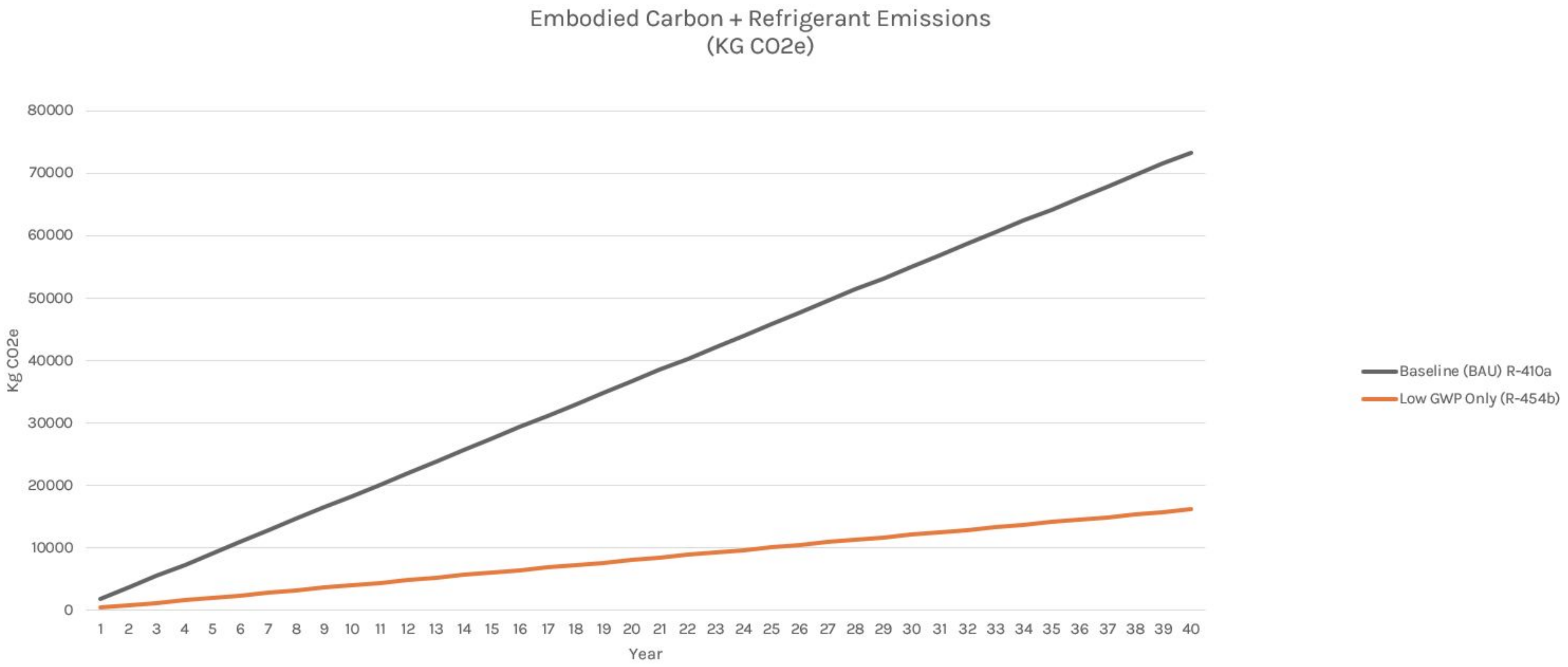

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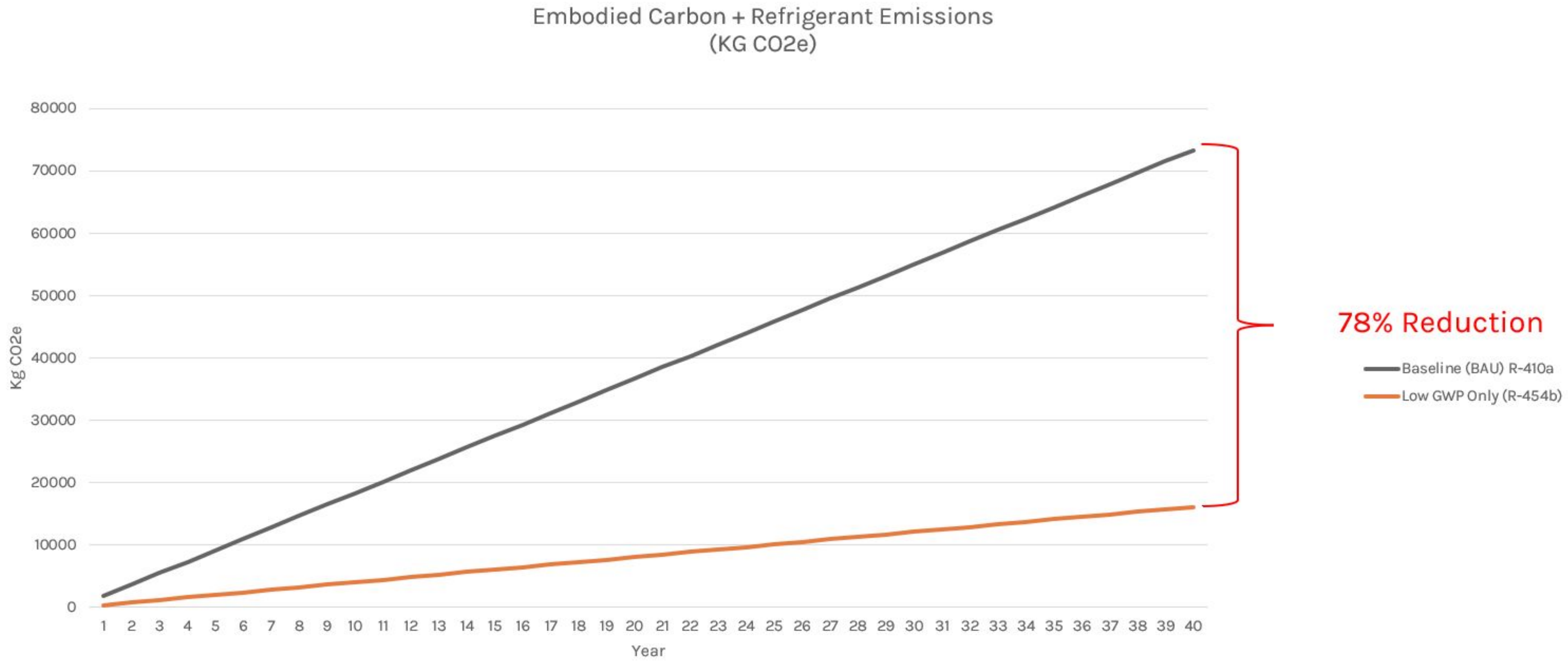
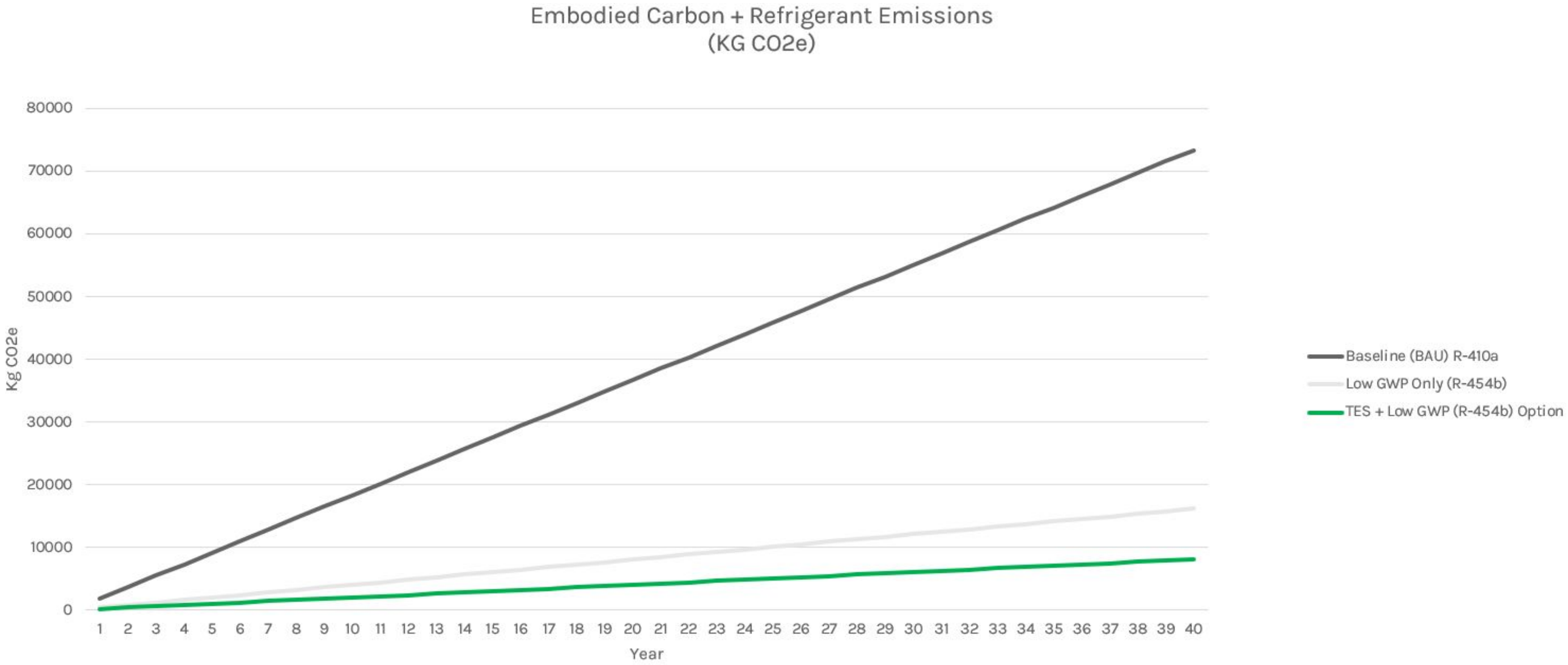
WHOLE – LIFE CARBON IMPACTS – LOW GWP



WHOLE – LIFE CARBON IMPACTS – LOW GWP + TES



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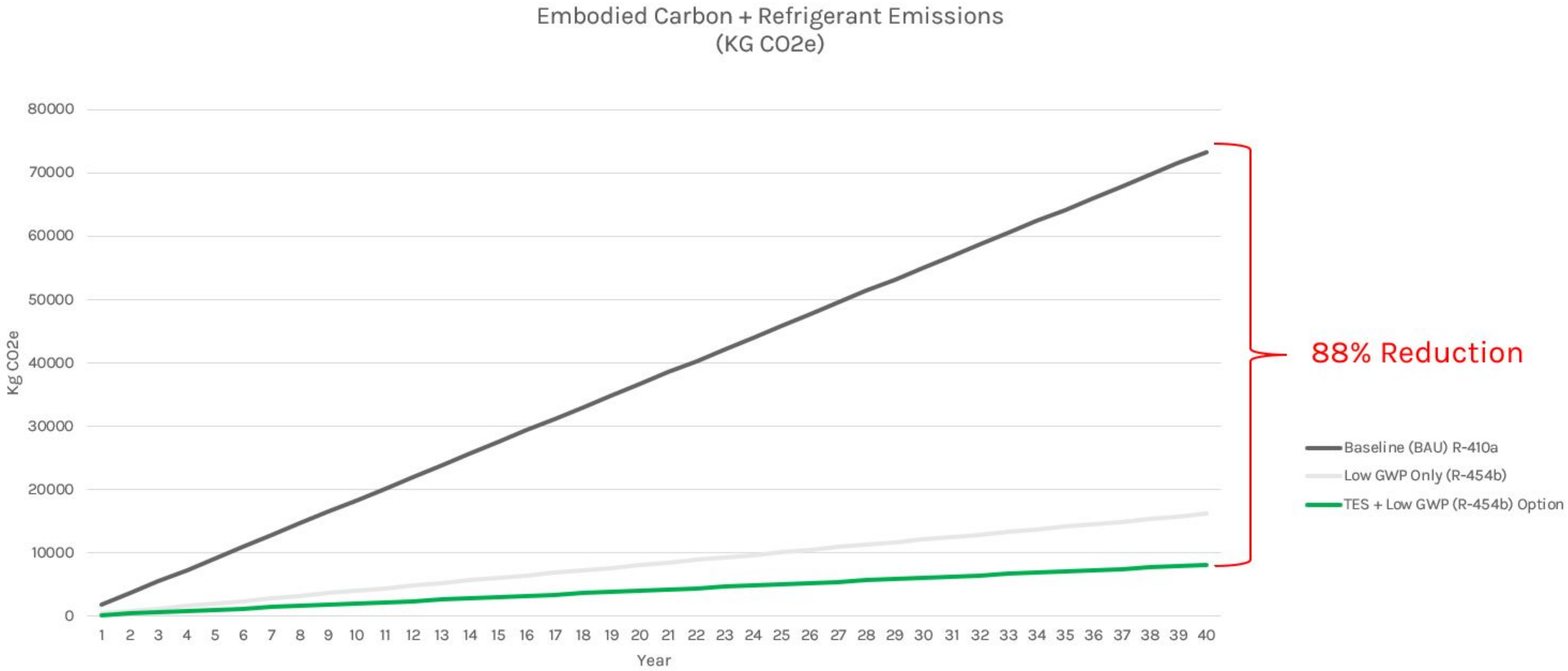
WHOLE – LIFE CARBON IMPACTS – LOW GWP + TES



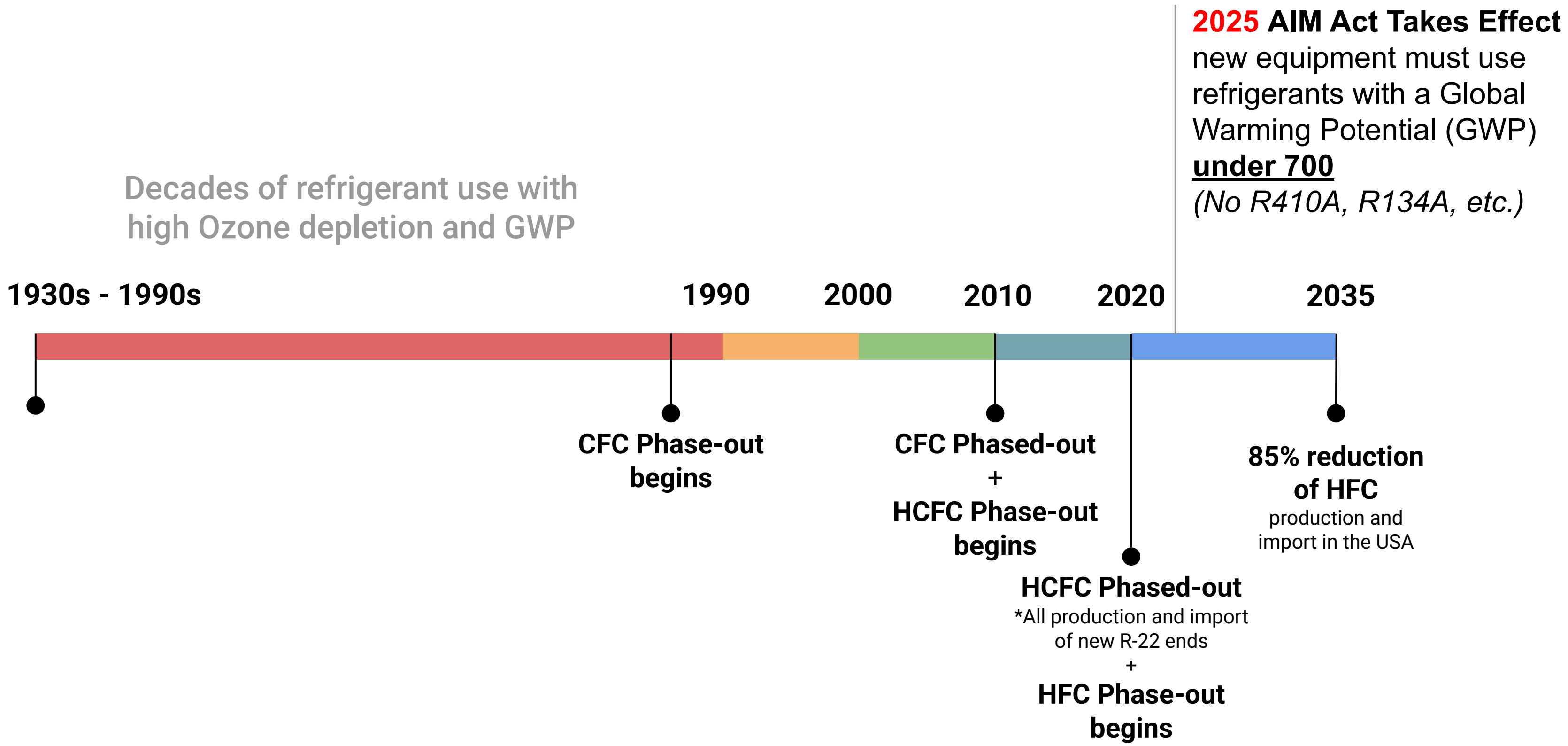
The Big Take Aways to Reduce Risk in Design

- Design to Reduce Leak Potential
  - Minimize Refrigerant Distribution
  - Ask for Monoblock Heatpump Options to Price
- Reduce Equipment Size
  - Ask team for ways to reduce peak loads
- Consider Further Reductions Using Thermal Storage
- And ASK FOR LOWER GWP REFRIGERANTS!

Rami Moussa

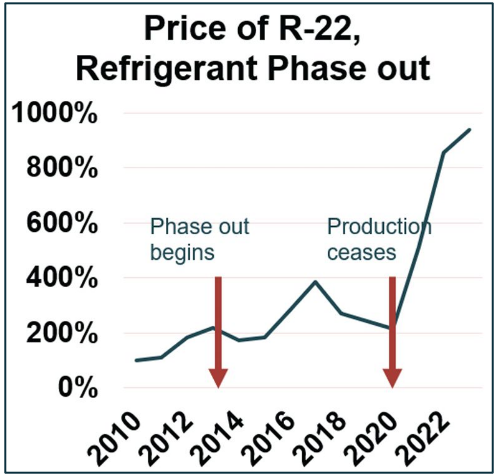
Managing Principal
Point Energy Innovations

The News



2025 AIM Act Takes Effect
new equipment must use refrigerants with a Global Warming Potential (GWP) **under 700**
(No R410A, R134A, etc.)
Decades of refrigerant use with high Ozone depletion and GWP
1930s - 1990s
1990
2000
2010
2020
2035
CFC Phase-out begins
CFC Phased-out + HCFC Phase-out begins
HCFC Phased-out
*All production and import of new R-22 ends
+
HFC Phase-out begins
85% reduction of HFC
production and import in the USA

The News



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Decades of refrigerant use with high Ozone depletion and GWP

1930s - 1990s | 1990 | 2000 | 2010 | 2020 | 2035

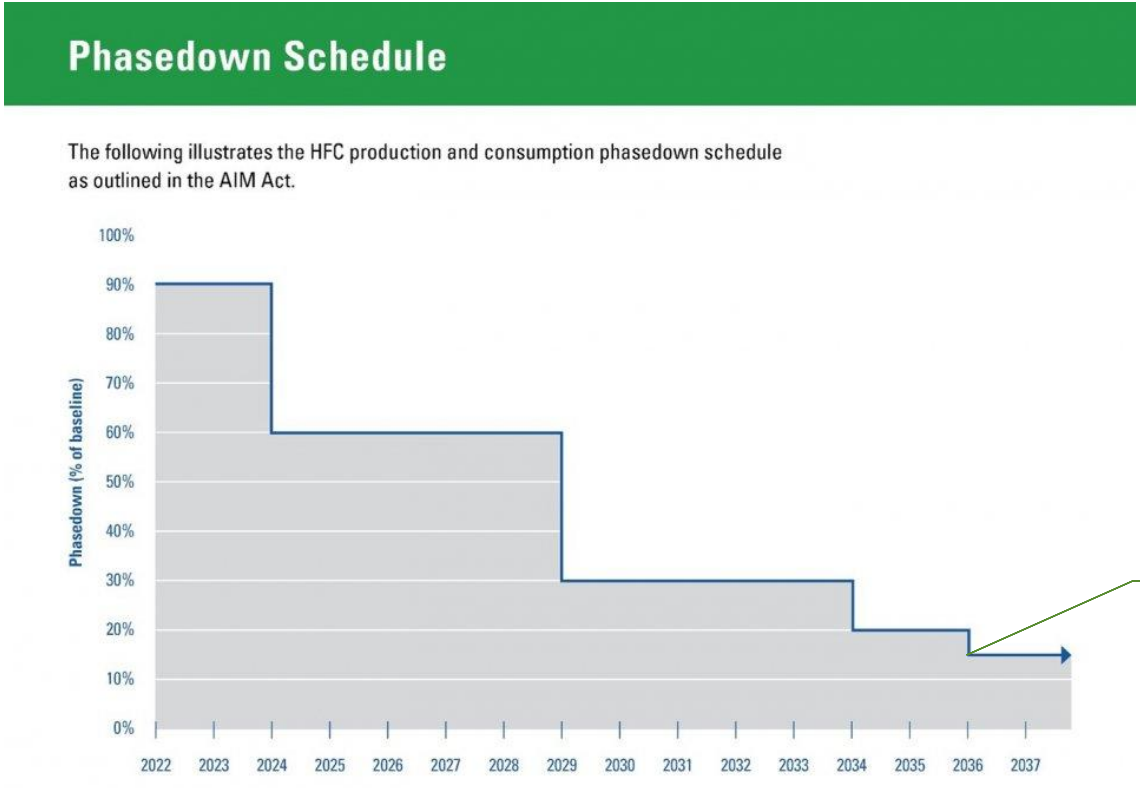
CFC Phase-out begins (1990)

HCFC Phase-out begins (2010)

HCFC Phased-out (2020)
*All production and import of new R-22 ends
+
HFC Phase-out begins

85% reduction of HFC (2035)
production and import in the USA

REFRIGERANTS – US: POST KIGALI

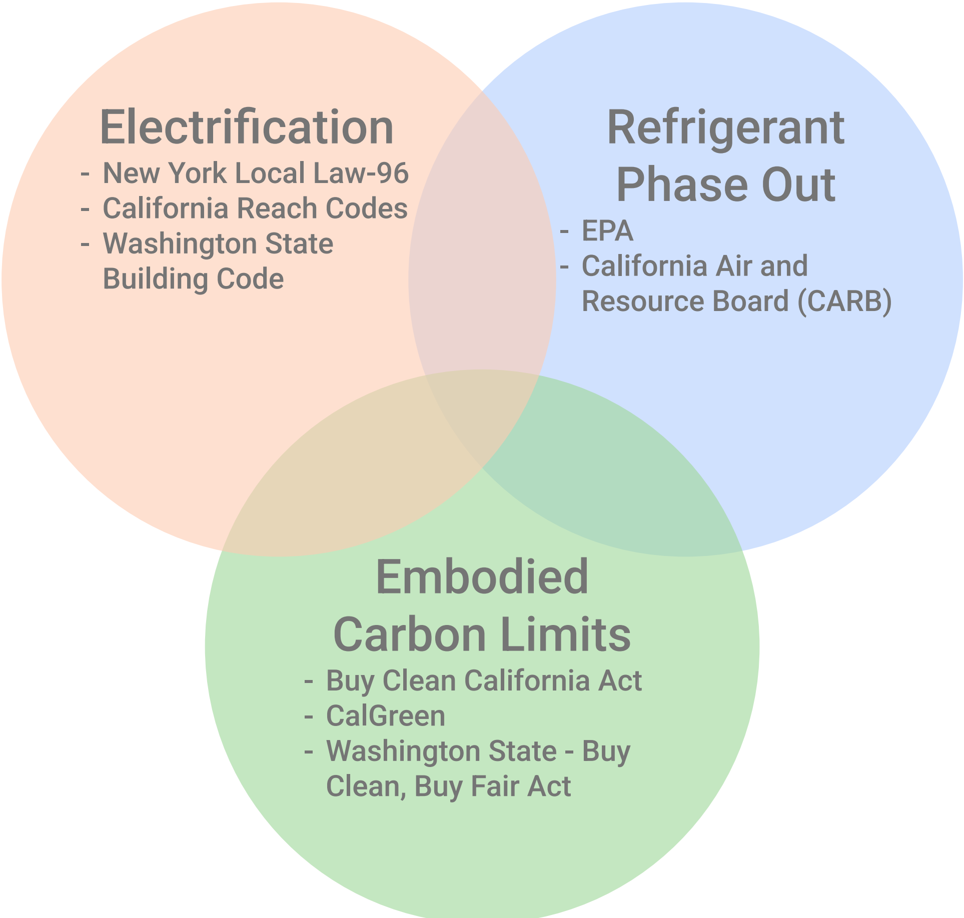


HFC PHASEDOWN
American Innovation & Manufacturing (AIM) Act
A U.S. Environmental Protection Agency Program

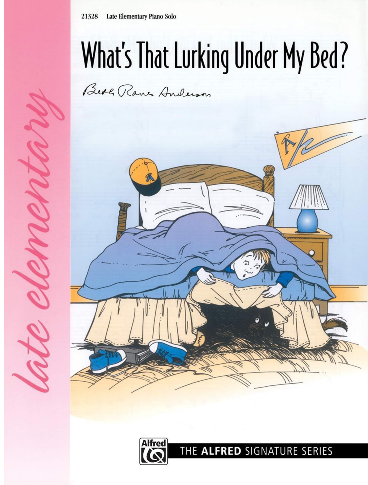
15% by 2036

SOURCE: EPA

The News


Electrification
- New York Local Law-96
- California Reach Codes
- Washington State Building Code
Refrigerant Phase Out
- EPA
- California Air and Resource Board (CARB)
Embodied Carbon Limits
- Buy Clean California Act
- CalGreen
- Washington State - Buy Clean, Buy Fair Act

Identify and Assess Risk



Develop Refrigerant Asset Register
What refrigerants do you own? How much?

Identify Equipment with Greatest Refrigerant Consumption
System refrigerant volume and leakage varies, especially between unitary and larger centralized systems. Where are the greatest offenders?

Assess Lifecycle Cost of Equipment INCLUDING Refrigerant Cost
What is the value of coping with restricted refrigerant access vs early equipment replacement? When is the right time to replace?

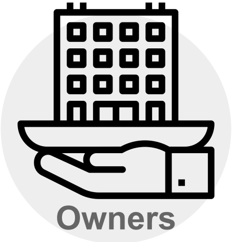
Assess Feasibility of Refrigerant Banking vs Premature Equipment Replacement
Refrigerant storage volume and space requirements?

Ensuring Forward Progress

Lessons Learned (as an industry!)

1. **Plan ahead** - Manufacturers are unlikely to have a full line of revised refrigerant equipment on Day 1 of refrigerant transition effective policy dates
2. **Ask the right questions early** - Detailed technical information on system limitations and configurations is not always published/available at time of new equipment release.
3. **Seek out education opportunities** - Technology will continue to change rapidly, systems still unfamiliar to many engineers and techs alike.
4. **Plan for longer equipment start-up than usual** - Experienced technicians and quality education and training is sorely needed
5. **Invest** - in better system instrumentation and monitoring to facilitate longer term monitoring based commissioning. This will provide the best system value!

What can YOU do?

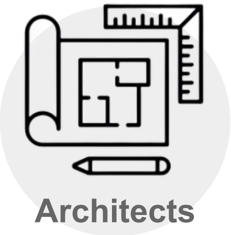


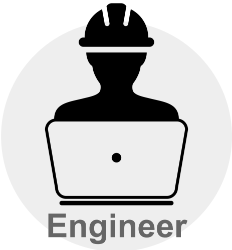
- What refrigerants do you use?
- Building Codes vs Capital plans

- Refrigerant tracking
- Refrigerant banking vs best value replacement timing

- Design for retrofit
- Design for flexibility
- High quality training
- Robust start-up

- Notify clients risks exist
- Push consultants for comprehensive life cycle assessments





- Educate clients on new risks
- Stay up-to-date on current product options
- Coordinate project guardrails for successful new equipment applications

It can be done!

Leapfrog heat pumps with CO2 refrigerant are here!

R-744 (CO2), Global Warming Potential - 1, Non-PFAS

BERKELEY LAB
Lawrence Berkeley National Laboratory

Flow Environmental Systems Inc

ProspectSV

DMG

Jamy Bacchus

Associate Principal
ME Engineers

DEFINITIONS

- **Greenhouse Gases (GHG)**: carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, refrigerants and others
- **CO_2 emissions**: the quantity of carbon dioxide emitted
- **CO_2e emissions**: equivalent emissions from all GHGs all converted to their similar radiative forcing as if they were all carbon dioxide
- **Global Warming Potential (GWP):** the heat absorbed by any greenhouse gas in the atmosphere, as a multiple of the heat that would be absorbed by the same mass of carbon dioxide (CO_2).

Note: GHGs have different lifetimes in the atmosphere

- GWP = 1 for CO_2
- **GWP 20**: GWP evaluated over a 20-year time horizon
- **GWP 100**: GWP evaluated over a 100-year time horizon

For this session we are only using 100-yr GWPs

Greenhouse Gas Lifetimes & GWP

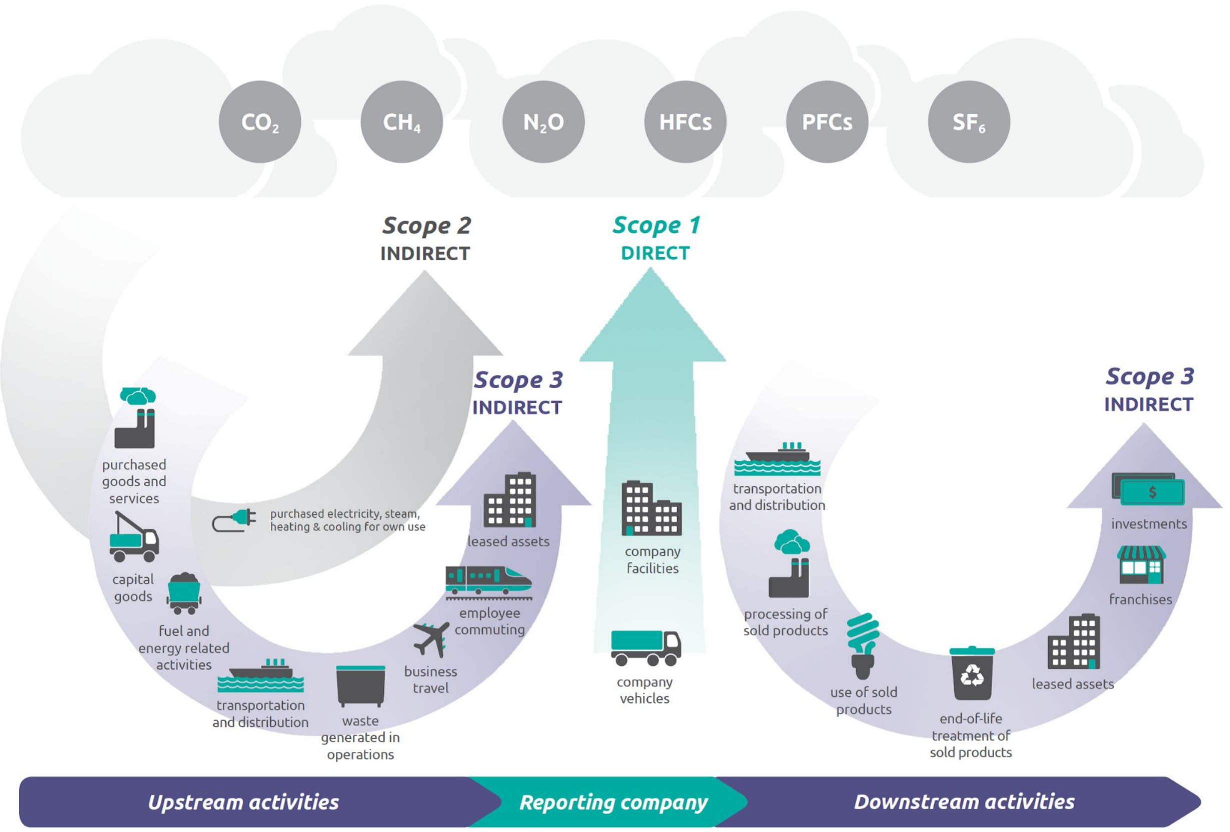
GHG	Avg. Atmospheric Lifetime	100-year GWP
Carbon Dioxide CO2	does not have a single value b/c it is moved from ocean-atmosphere-land, can remain in the atmosphere for 1,000s of years	1
Methane CH4	12	25
Nitrous Oxide N2O	114	298
Sulphur Hexafluoride SF6	3,200	22,800
Hydrofluorocarbons	up to 270	up to 14,800
Perfluorocarbons PFC	2,600-50,000	up to 12,200

SCOPE 1, SCOPE 2 & SCOPE 3 EMISSIONS

Scope 1 emissions are direct greenhouse (GHG) emissions that occur from sources that are controlled or owned by an organization such as fuel combustion in boilers, furnaces, vehicles). Refrigerant fugitive emissions included.

Scope 2 emissions are indirect GHG emissions associated with the purchase of electricity, steam, heat, or cooling.

Scope 3 are virtually everything else.



OVERLAY WRI SCOPES WITH EN 15643 & 15978

Operational Carbon

B1 – Refrigerant Leakage
- Scope 1: Fugitive emissions

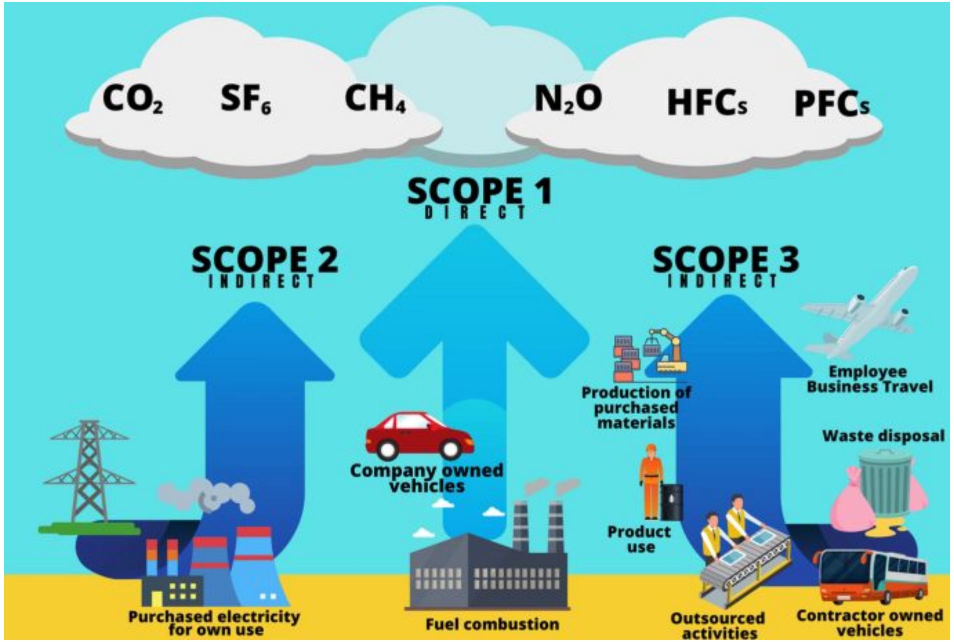
B6 – Energy Use
- Scope 1: Gas burned on site
- Scope 2: Electricity and district energy use

B7 – Water Use
- Scope 3: Municipal potable water
- Scope 3: Municipal wastewater treatment

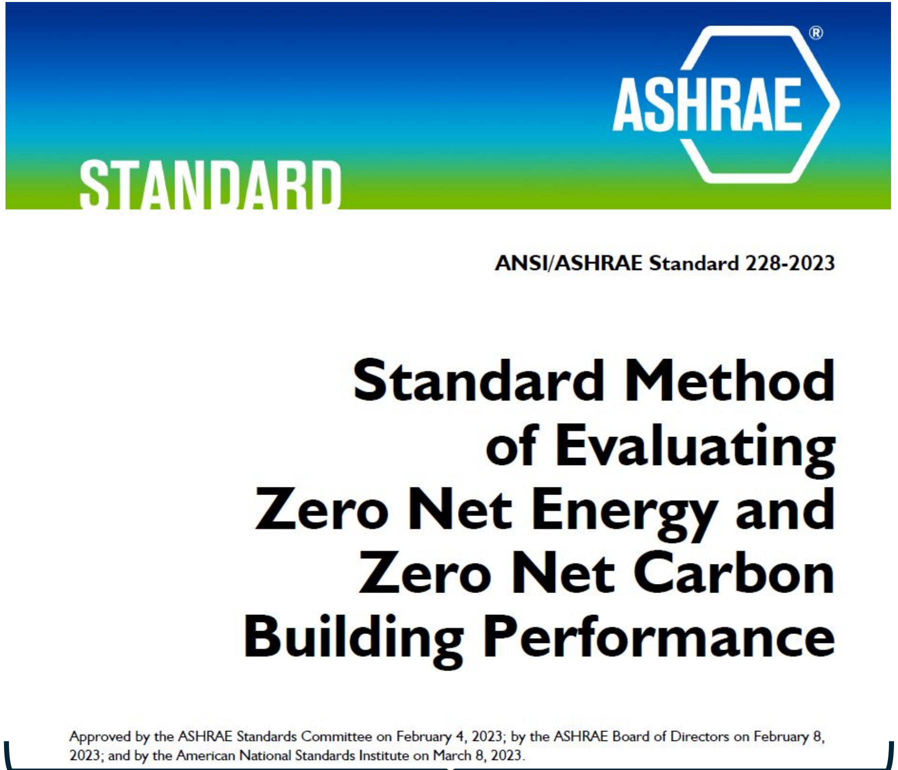
B8 –Users' Activities
- Scope 3: Transportation

End of Life

C1 – Refrigerant Recovery
- Scope 1: Fugitive emissions



NEW ASHRAE STANDARDS TO CONSIDER


STANDARD

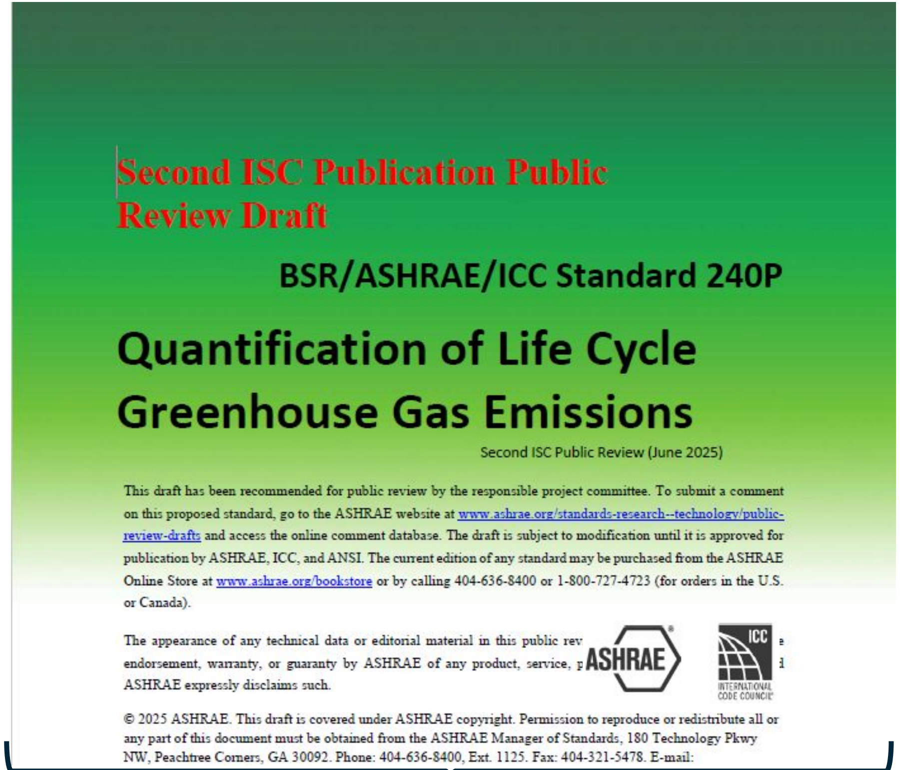
ASHRAE®

ANSI/ASHRAE Standard 228-2023

Standard Method of Evaluating Zero Net Energy and Zero Net Carbon Building Performance

Approved by the ASHRAE Standards Committee on February 4, 2023; by the ASHRAE Board of Directors on February 8, 2023; and by the American National Standards Institute on March 8, 2023.

Looks at a single year!


Second ISC Publication Public Review Draft

BSR/ASHRAE/ICC Standard 240P

Quantification of Life Cycle Greenhouse Gas Emissions

Second ISC Public Review (June 2025)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by ASHRAE, ICC, and ANSI. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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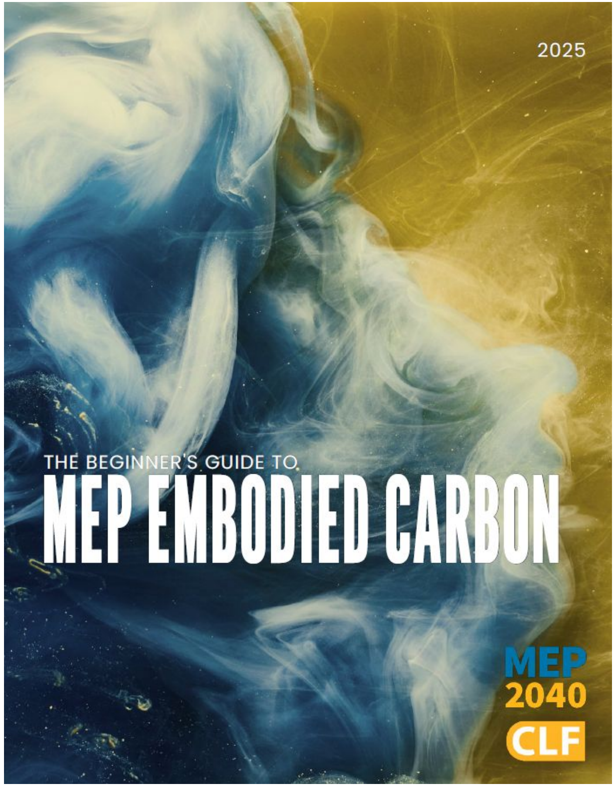
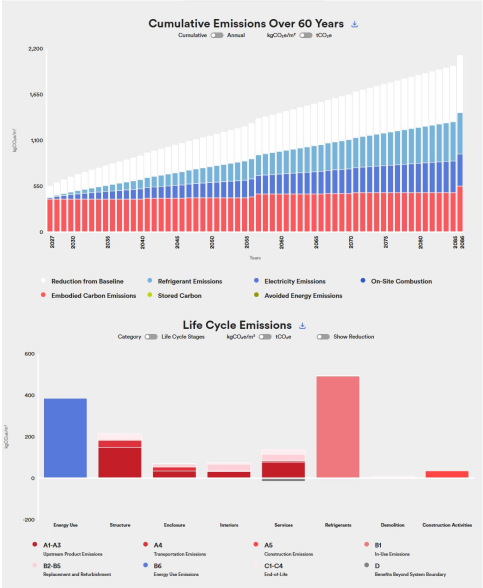
Looks at a 60 years!

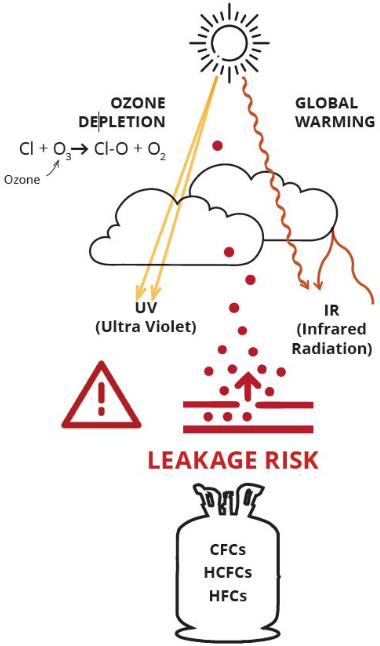
NEW RESOURCES TO CONSIDER



c.scale™



REFRIGERANTS



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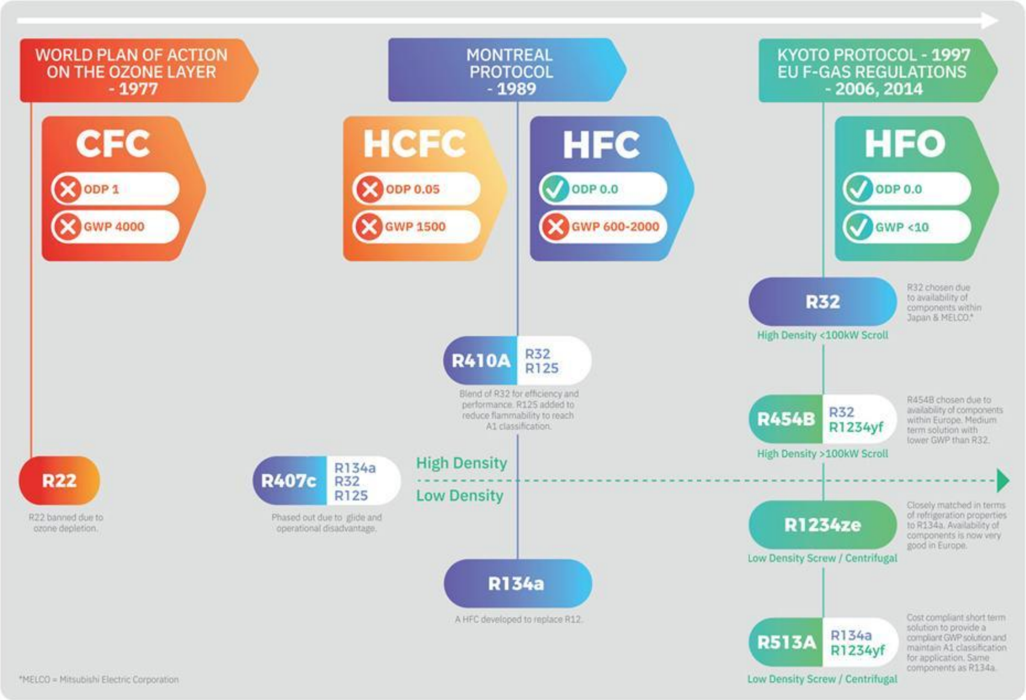


SOURCE: MITSUBISHI

REFRIGERANTS: GLOBAL WARMING POTENTIAL (GWP)

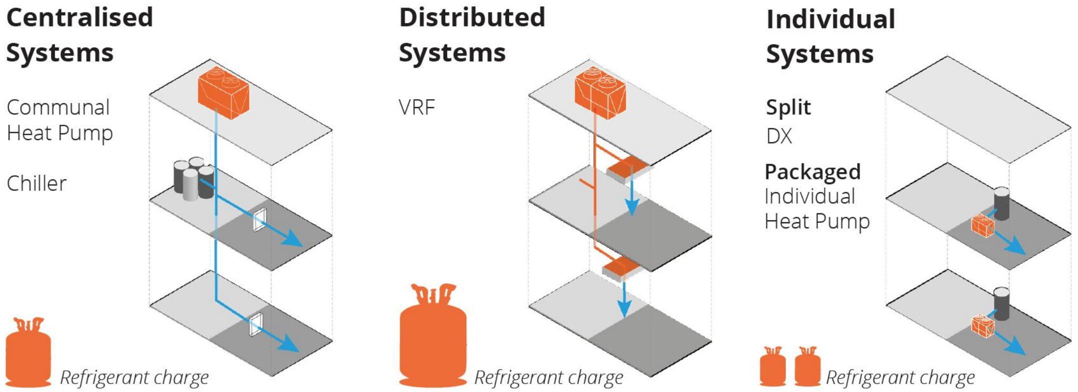
Many HFC and HCFC refrigerants are 1,000s of times more potent than CO_2 in the atmosphere if released

Refrigerant	IPCC AR4 GWP 20-yr	IPCC AR4 GWP 100-yr	IPCC AR5 GWP 20-yr	IPCC AR5 GWP 100-yr	IPCC AR6 GWP 20-yr	IPCC AR6 GWP 100-yr
R-22	5,160	1,810	5,280	1,760	5,310	1,780
R-32	2,330	675	2,430	677	2,690	771
R-123	273	79	292	79	290	80
R-125	6,350	3,500	6,090	3,170	6,740	3,740
R-134a	3,830	1,430	3,710	1,300	4,140	1,530
R-407c	4,115	1,774	4,011	1,624	4,457	1,908
R-410a	4,340	2,088	4,260	1,924	4,715	2,256
R-454B	1,606	465	1,699	467	1,881	539
R-466A	1,872	733	1,891	697	2,041	775
R-513a	1,386	630	1,633	573	1,184	340
R-514a				2	7	2
R-1233 zd	NA	5	5	1	14	4
R-1234yf				1		
R-1234ze	-	-	-	1		
R-290 (Propane)	-	-	-	3		
R-717 (NH4)	-	-	-	-		
R-718 (H2O)	-	-	-	-		
R-744 (CO2)	1	1	1	1	1	1

REFRIGERANTS: GHG IMPACTS

Installed capacities (tons) will vary based on system types

- Sum of zone peaks, Sum of building peak, Sum of floor peak
- Any oversizing, redundancy or other criteria
- Generally rounding up to the next nominal equipment size



SOURCE: INTROBA née ELEMENTA

B1 & C1: REFRIGERANT GHG EMISSIONS

Service Life	System Life LEED refrig calc	System Life ASHRAE	System Life CARB	**System Life Place-holders**
Air-cooled DX	15	15	15	15
Air-Cooled VRF	15	15	15	15
PTACs	15	15	12	14
Packaged RTUs	15	15	20	17
Flr-by-Flr Water-Cooled DX AHUs	24	24	20	23
WSHPs	24	15	15	18
Air-Cooled Chiller	23	23	20	22
Water-Cooled Chiller	25	25	20	24

Who has data?
When was it done and what regions?
What type of equipment did they study?
What refrigerants were in use at that time?
Are the results still valid for newer equipment and practices?
Are they transferable across regions?

Leakage Rates	LEED v4 & v4.1		ASHRAE Std 240P				ASHRAE Std 228-2023		CARB		CIBSE TM65 UK		CIBSE TM65 for North America		AIRAH TEWI		IIR 2015		IFC EDGE		**Placeholder**	
	Annual Leakage	EoL Leakage	Installation Leakage	Annual Leakage	Recovery rate (zd)	EoL Leakage	Annual Leakage	EoL Leakage	Annual Leakage	EoL Leakage	Annual Leakage	EoL Leakage	Annual Leakage	EoL Leakage	Annual Leakage	EoL Leakage	Annual Leakage	EoL Leakage	Annual Leakage	EoL Leakage	**Annual Leakage**	**EoL Leakage**
Air-cooled DX	2%	10%	1%	5.0%	80%	20%	2%	NA	5.3%	80.0%	6%	3%	5%	80%	4%	30%	4%	15%	2.5%	NA	4.0%	34.0%
Air-Cooled VRF	2%	10%	1%	3.0%	80%	20%	10%	NA	5.3%	80.0%	6%	3%	3%	80%	4%	30%	4%	15%	3.0%	NA	4.5%	34.0%
PTACs	2%	10%	0%	1.0%	80%	20%	2%	NA	2.0%	98.5%	2%	1%	1%	80%	2%	30%	2.5%	15%	?	NA	1.8%	36.4%
Packaged RTUs	2%	10%	1%	7.0%	80%	20%	6%	NA	7.0%	20.0%	2%	1%	7%	80%	5%	30%	5%	15%	?	NA	5.1%	25.1%
Flr-by-Flr Water-Cooled DX AHU	2%	10%	0%	3.3%	80%	20%	1%	NA	7.0%	20.0%	2%	1%	3.3%	80%	2%	30%	5%	15%	?	NA	3.2%	25.1%
WSHPs	2%	10%	0%	3.3%	80%	20%	1%	NA	4.7%	56.0%	2%	1%	3.3%	80%	2%	30%	5%	15%	?	NA	2.9%	30.3%
Air-Cooled Chiller	2%	10%	1%	6.0%	80%	20%	5%	NA	7.0%	20.0%	4%	2%	6%	80%	7%	10%	5%	15%	3.0%	NA	5.0%	22.4%
Water-Cooled Chiller	2%	10%	1%	3.0%	80%	20%	5%	NA	3.0%	20.0%	4%	2%	3%	80%	7%	10%	5%	15%	3.0%	NA	3.9%	22.4%

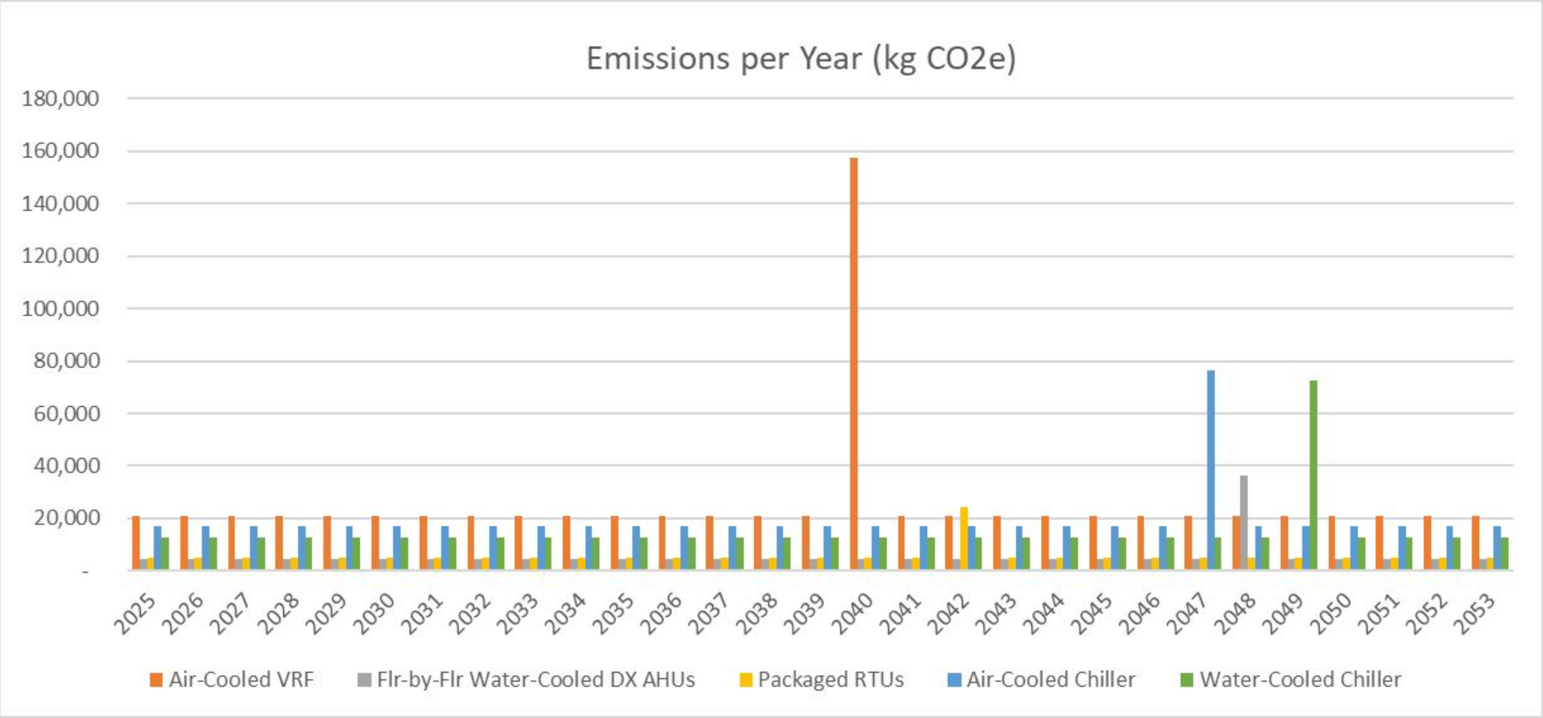
F-GASES AND SCOPE 1 REFRIGERANT LEAKAGE

(Initial Leakage Rate x charge + Annual Leakage Rate x charge x Service Life + End of Life Leakage x charge) x GWP = ???? of CO_2e

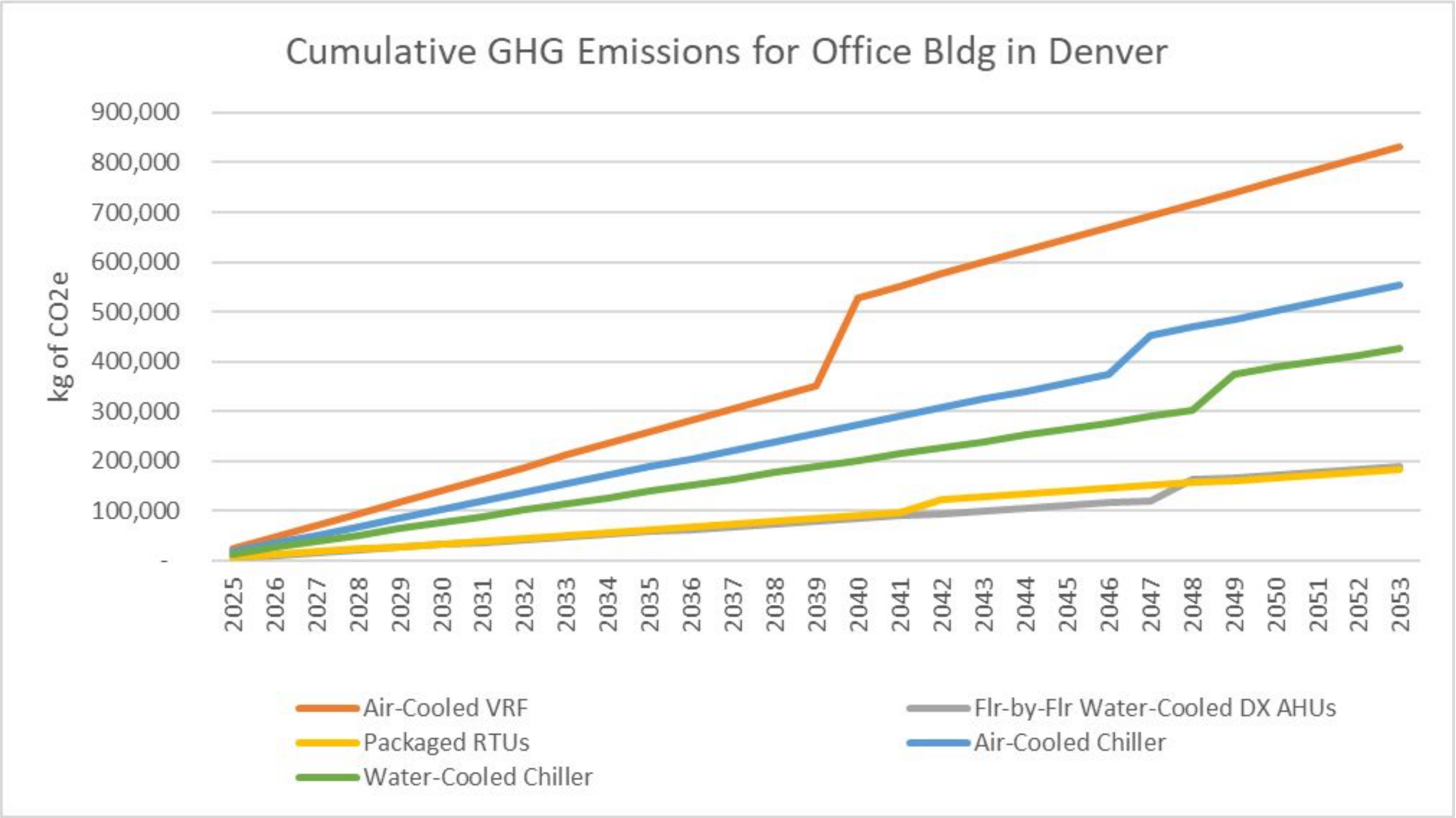
System	Refrigerant	Annual Leakage Rate	End of Life Leakage Rate	GWP years	GWP	Service Life (yrs)	Refrigerant Charge (kg)	2025	2026	2027	2028	2029	2030	2031
Air-Cooled VRF	R-410a	4.5%	34.0%	100	2087.5	15	276.2	25,822	25,822	25,822	25,822	25,822	25,822	25,822
Flr-by-Flr Water-Cooled DX AHUs	R-410a	3.2%	25.1%	100	2087.5	23	86.3	5,773	5,773	5,773	5,773	5,773	5,773	5,773
Packaged RTUs	R-410a	5.1%	25.1%	100	2087.5	17	57.6	6,157	6,157	6,157	6,157	6,157	6,157	6,157
Air-Cooled Chiller	R-410a	5.0%	22.4%	100	2087.5	22	181.4	18,934	18,934	18,934	18,934	18,934	18,934	18,934
Water-Cooled Chiller	R-410a	3.9%	22.4%	100	2087.5	24	172.3	13,990	13,990	13,990	13,990	13,990	13,990	13,990

2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049
25,822	25,822	25,822	25,822	25,822	25,822	25,822	25,822	196,065	25,822	25,822	25,822	25,822	25,822	25,822	25,822	25,822	25,822
5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	5,773	45,309	5,773
6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	6,157	30,206	6,157	6,157	6,157	6,157	6,157	6,157	6,157
18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	18,934	84,934	18,934	18,934
13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	13,990	80,687

F-GASES AND SCOPE 1 REFRIGERANT LEAKAGE



F-GASES AND SCOPE 1 REFRIGERANT LEAKAGE



SIMBUILD 2022 & 2024: REFRIGERANTS – GHG IMPACTS

If you assume a split system has the highest charge (lbs/ton) *and* the highest installation leakage *and* the highest annual leakage, then *yes* it's likely going to look the worst.
If you add 100% redundant chillers, then that too will greatly increase the charge size.

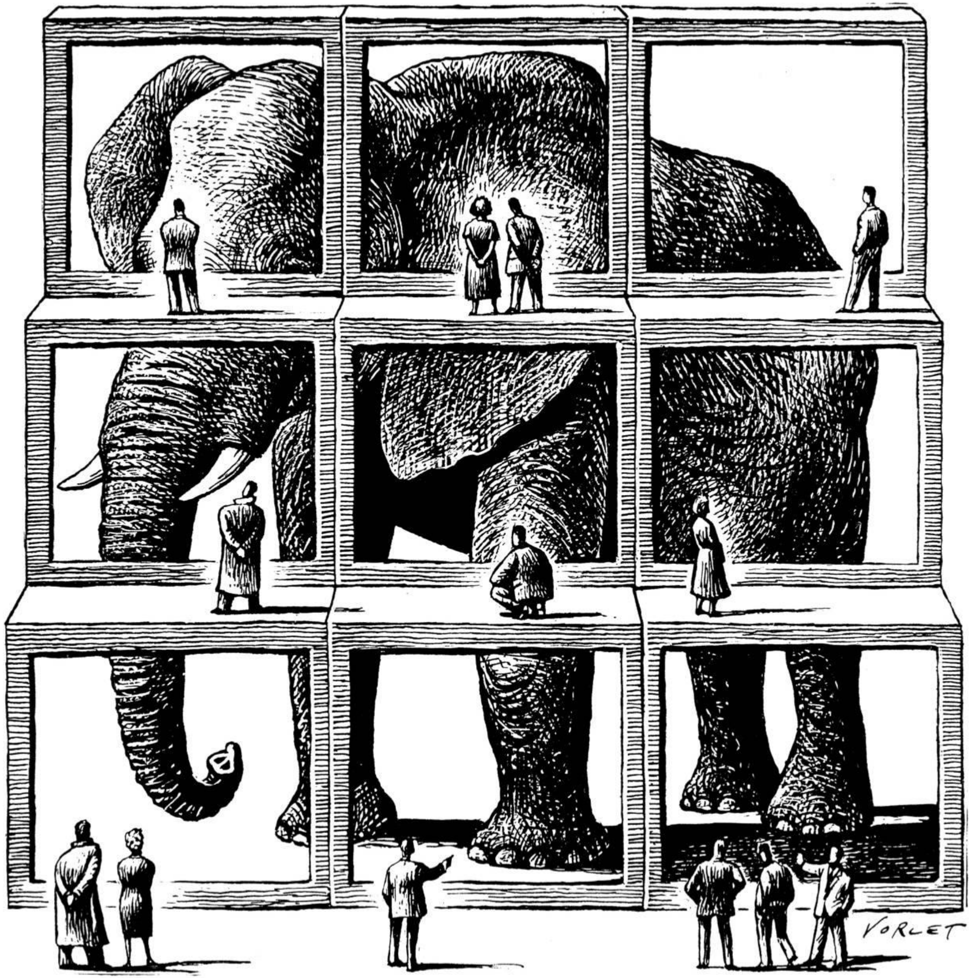
Lifetime Leakage in kg of CO_2e per Year using 100-yr GWPs

Medium-Sized Office Building	Refrigerant	NYC	Atlanta	Chicago	Houston	Denver	Seattle	SF
Air-Cooled VRF	R-410a	37,497	37,822	35,163	37,941	33,981	29,844	30,140
Flr-by-Flr Water-Cooled DX AHUs	R-410a	7,112	7,174	6,669	7,196	6,445	5,660	5,717
Packaged RTUs	R-410a	6,223	6,277	5,836	6,296	5,639	4,953	5,002
Air-Cooled Chiller	R-410a	19,003	20,903	19,003	22,804	17,103	15,202	17,103
Water-Cooled Chiller	R-410a	16,099	17,709	16,099	19,319	14,489	12,879	14,489

Mid-Rise Multi-Family Residential	Refrigerant	NYC	Atlanta	Chicago	Houston	Denver	Seattle	SF
Air-Cooled DX	R-410a	6,766	7,148	6,460	7,514	6,827	6,384	7,209
PTACs	R-410a	4,163	4,398	3,975	4,623	4,200	3,928	4,435
Air-Cooled VRF	R-410a	10,908	11,524	10,416	12,115	11,007	10,293	11,623
WSHPs	R-410a	2,374	2,508	2,266	2,636	2,395	2,240	2,529
Air-Cooled Chiller	R-410a	7,601	7,601	7,601	7,601	5,701	5,701	5,701
Water-Cooled Chiller	R-410a	6,440	6,440	6,440	6,440	4,830	4,830	4,830

WHOLE LIFE CARBON IS THE BIG PICTURE OF GHGS

There are still the other LCA environmental impacts like eutrophication of water bodies, acidification of land and water, ozone depletion, water use, waste generation and energy use.



	Performance or Design	Metric	Boundary	Combustion Allowed?	Efficiency Required?	Off-site RE Allowed?	Other Reqs.
LIVING BUILDING CHALLENGE					NC: 70% EBB* EB: 50% EBB (both w/ PV)	Yes. Using the off-site RE exception.	Must include on-site storage; 20% embodied carbon reduction.
ZERO ENERGY CERTIFICATION					Highest efficiency	Yes, must be local. 75% of roof for solar.	
ZERO CARBON CERTIFICATION					NC: 25% < 90.1-2010 EB: 30% < CBECS	Yes. Must be *additional*.	10% Embodied Carbon Reduction + Carbon offsets for the remainder
LEED Zero ENERGY / LEED Zero CARBON					No, but LEED Certified	Yes. See tiered structure for on- and off-site RE	Must be LEED-NC or EBOM certified. Performance in Arc. TOU option for LZC.
ZERO CODE					Must meet ASHRAE 90.1-2019	Yes. After on-site. Tiered structure applies discount factor to various	Off-site renewables are discounted
WORLD GREEN BUILDING COUNCIL					Highly energy efficient building	Yes	Embodied carbon may be included later
AIA 2030 Commitment				Not allowed in 2030	70% better than CBECS 2003	Yes, but not counted	Seeking to incorporate refined carbon specific metrics
ZERO CARBON BUILDING STANDARDS™ Canada Green Building Council					Must meet TEDI	Yes	Also includes refrigerant leakage
ASHRAE Standard 228-2023					Must meet ASHRAE 90.1-2019	Yes, but capped	Also includes refrigerant leakage
Zero Emissions Building					EnergyStar or ASHRAE Std 100	Yes	

= Transportation = Embodied Carbon = Site Energy Use = CO2e = Source Energy Use

Credit: WSP, NBI and ME Engineers

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Few definitions ban combustion

= Transportation = Embodied Carbon = Site Energy Use = CO2e = Source Energy Use

Credit: WSP, NBI and ME Engineers

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Credit: WSP, NBI and ME Engineers

Few definitions ban combustion

Few definitions include materials

	Performance or Design	Metric	Boundary	Combustion Allowed?	Efficiency Required?	Off-site RE Allowed?	Other Reqs.
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Credit: WSP, NBI and ME Engineers

Few definitions ban combustion

Few definitions include materials

Few definitions include transit

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= Transportation = Embodied Carbon = Site Energy Use = CO2e = Source Energy Use

Credit: WSP, NBI and ME Engineers

Few definitions ban combustion

Few definitions include materials

Few definitions include transit

Few definitions include refrigerants

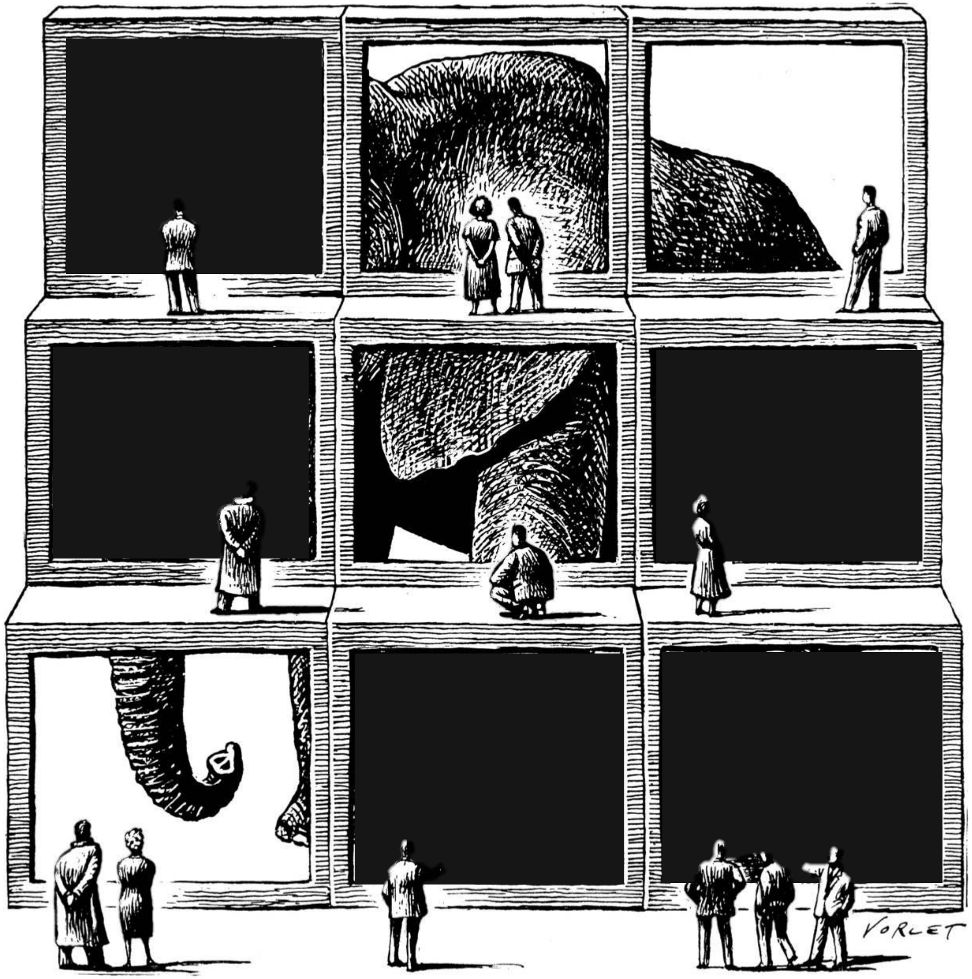
WHICH PORTIONS ARE UNIMPORTANT?

Can we ignore some components as negligible?

Can we table some as having no relation to design decisions?

Do local policies direct all our attention towards one metric?

Do rating systems force us to consider the whole?



REFRIGERANT CLASSIFICATIONS

Higher Flammability ↑

Higher Flammability	A3	B3
Flammable	A2	B2
Lower Flammability	A2L	B2L
No Flame Propagation	A1	B1

Higher Toxicity →

Class 3 Requirements

1. Exhibit flame propagation @ 60ºC & 101.3 kPa
2. LFL ≤ 0.10 kg/m³ or HOC ≥ 19,000 kJ/kg

Class 2 Requirements

1. Exhibit flame propagation @ 60ºC & 101.3 kPa
2. LFL > 0.10 kg/m³
3. HOC < 19,000 kJ/kg

Class 2L Requirements

1. Exhibit flame propagation @ 60ºC & 101.3 kPa
2. LFL > 0.10 kg/m³
3. HOC < 19,000 kJ/kg
4. S_u ≤ - 10 cm/s

Class 1 Requirements

1. No flame propagation @ 60ºC & 101.3 kPa

kPa = pressure in kilopascals
kJ/kg = energy in kilojoules per kilogram
S_u = burning velocity in centimeters per second

2024 I-CODES

Prior versions of the I-Codes don't properly address what designers need to do to accommodate next gen A2L refrigerants.

The 2024 suite of I-Codes attempt to bridge that with updates to the IBC, IFC and IMC.

…but don't be surprised if you want to borrow or need items from *ASHRAE Standard 15 – 2022 or 2024* to actually design your spaces, systems and shafts.

ICC INTERNATIONAL CODE COUNCIL®

2024 I-Code A2L Refrigerant Related Changes

Based on the

2021 International Fire Code®

2021 International Building Code® and

2021 International Mechanical Code®

ASHRAE STANDARD 15-2024

ASHRAE Std 15 2024 or at least 2022 deal with A2L refrigerants

ASHRAE Standard 15 gives a method for determining the maximum amount of refrigerant that can safely be used in a given space, occupied or unoccupied. That maximum amount may differ depending on the type of refrigeration system and mitigation actions.

STANDARD

ASHRAE®

ANSI/ASHRAE Standard 15-2024
(Supersedes ANSI/ASHRAE Standard 15-2022)
Includes ANSI/ASHRAE addenda listed in Appendix G

Safety Standard for Refrigeration Systems

See Informative Appendix G for approval dates by ASHRAE and the American National Standards Institute.

This Standard is under continuous maintenance by a Standing Standard Project Committee (SSPC) for which the Standards Committee has established a documented program for regular publication of addenda or revisions, including procedures for timely, documented, consensus action on requests for change to any part of the Standard. Instructions for how to submit a change can be found on the ASHRAE® website (www.ashrae.org/continuous-maintenance).

The latest edition of an ASHRAE Standard may be purchased from the ASHRAE website (www.ashrae.org) or from ASHRAE Customer Service, 180 Technology Parkway, Peachtree Corners, GA 30092. E-mail: orders@ashrae.org. Fax: 678-539-2129. Telephone: 404-636-8400 (worldwide), or toll free 1-800-527-4723 (for orders in US and Canada). For reprint permission, go to www.ashrae.org/permissions.

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DEFINITIONS IN ASHRAE STANDARDS 15 & 34

effective dispersal volume charge (EDVC): the maximum *refrigerant* charge permitted for an *effective dispersal volume*.

immediately dangerous to life or health (IDLH): the maximum concentration from which unprotected persons are able to escape within 30 minutes without escape-impairing symptoms or irreversible health effects.

lower flammability limit (LFL): see ASHRAE Standard 34.

occupational exposure limit (OEL): see ASHRAE Standard 34.

refrigerant concentration limit (RCL): see ASHRAE Standard 34.

High-Probability System: is any *refrigeration system* in which the basic design or the location of components is such that a leakage of *refrigerant* from a failed connection, seal, or component will enter the *occupied space.*

Low-Probability System: is any *refrigeration system* in which the basic design or the location of components is such that a leakage of *refrigerant* from a failed connection, seal, or component cannot enter the *occupied space*.

7.2.3.2.2 Natural Ventilation Opening for Group A2L, A2, or A3 Refrigerants. The minimum size of the opening for a Group A2L, A2, or A3 *refrigerant* (A_{vent}) *shall* be calculated using Equation 7-2a or 7-2b:

$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 0.417} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M_r}{M_r - M_a}} \qquad \text{(7-2a [I-P])}$$

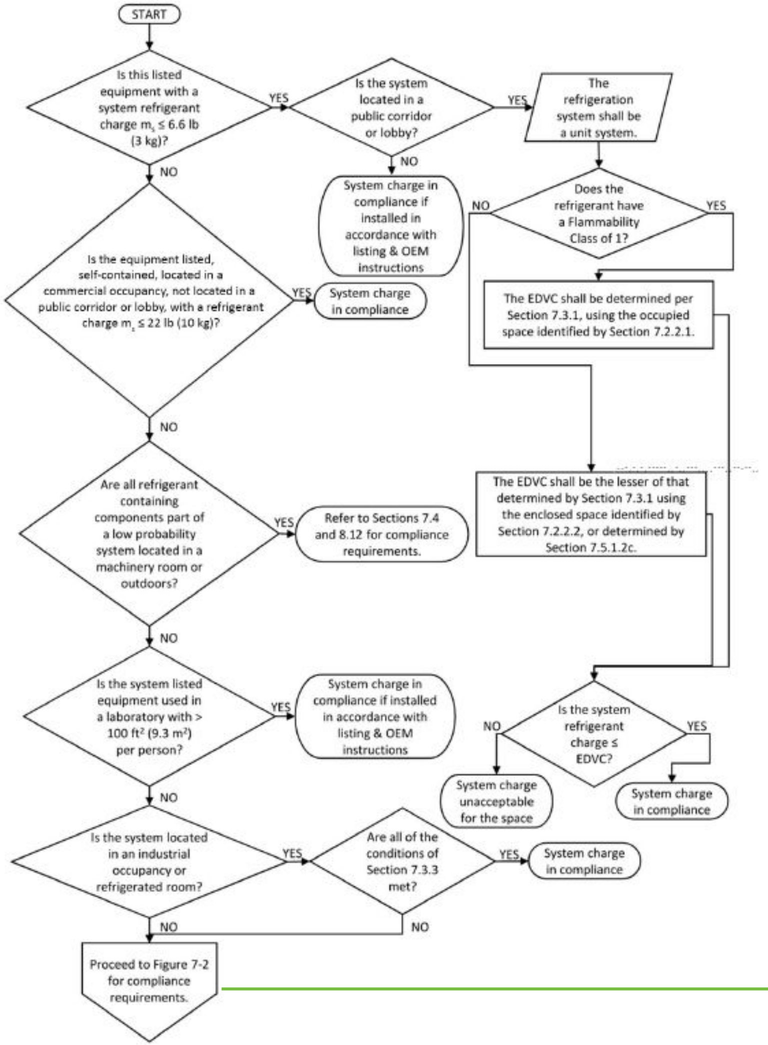
$$A_{vent} = \frac{m_{rel} - m_{room}}{LFL \times 104} \times \sqrt{\frac{A}{g \times m_{room}} \times \frac{M_r}{M_r - M_a}} \qquad \text{(7-2b [SI])}$$

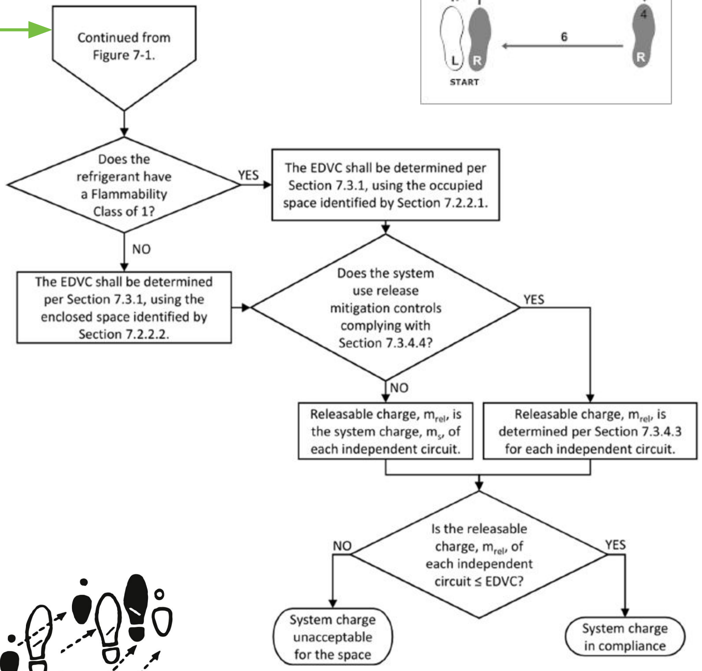
where

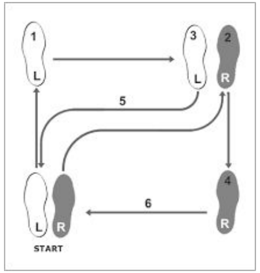
A_{vent} = minimum area of a permanent opening, ft^2 (m^2)
m_{rel} = *releasable refrigerant charge*, lb (kg)
m_{room} = allowable *refrigerant* charge of an individual room, lb (kg); (V_{eff}, used to calculate *EDVC*, is the volume of an individual room.)
LFL = *lower flammability limit*, lb/1000 ft^3 (kg/m^3)
A = actual area of the individual room, ft^2 (m^2)
M_a = *relative molar mass* of air, 29.0, dimensionless
M_r = *relative molar mass* of the *refrigerant*, dimensionless
g = acceleration due to gravity, 32.2 ft/s^2 (9.81 m/s^2)
0.417 = I-P conversion factor
104 = SI conversion factor

7.3.1 EDVC Calculation. The maximum charge permitted for an *effective dispersal volume shall* be calculated using Equation 7-3a or 7-3b, except for *refrigeration systems* covered by Section 7.3.1.1:

$$EDVC = RCL \times V_{eff} \times F_{occ} \qquad \text{(7-3a [I-P])}$$


START
Is this listed equipment with a system refrigerant charge m_s ≤ 6.6 lb (3 kg)?
YES
Is the system located in a public corridor or lobby?
YES
The refrigeration system shall be a unit system.
NO
System charge in compliance if installed in accordance with listing & OEM instructions
NO
Does the refrigerant have a Flammability Class of 1?
NO
YES
The EDVC shall be determined per Section 7.3.1, using the occupied space identified by Section 7.2.2.1.
Is the equipment listed, self-contained, located in a commercial occupancy, not located in a public corridor or lobby, with a refrigerant charge m_s ≤ 22 lb (10 kg)?
YES
System charge in compliance
NO
The EDVC shall be the lesser of that determined by Section 7.3.1 using the enclosed space identified by Section 7.2.2.2, or determined by Section 7.5.1.2c.
Are all refrigerant containing components part of a low probability system located in a machinery room or outdoors?
YES
Refer to Sections 7.4 and 8.12 for compliance requirements.
NO
Is the system listed equipment used in a laboratory with > 100 ft² (9.3 m²) per person?
YES
System charge in compliance if installed in accordance with listing & OEM instructions
Is the system refrigerant charge ≤ EDVC?
NO
YES
System charge unacceptable for the space
System charge in compliance
NO
Is the system located in an industrial occupancy or refrigerated room?
YES
Are all of the conditions of Section 7.3.3 met?
YES
System charge in compliance
NO
NO
Proceed to Figure 7-2 for compliance requirements.


Continued from Figure 7-1.
Does the refrigerant have a Flammability Class of 1?
YES
The EDVC shall be determined per Section 7.3.1, using the occupied space identified by Section 7.2.2.1.
NO
The EDVC shall be determined per Section 7.3.1, using the enclosed space identified by Section 7.2.2.2.
Does the system use release mitigation controls complying with Section 7.3.4.4?
YES
NO
Releasable charge, m_{rel}, is the system charge, m_s, of each independent circuit.
Releasable charge, m_{rel}, is determined per Section 7.3.4.3 for each independent circuit.
Is the releasable charge, m_{rel}, of each independent circuit ≤ EDVC?
NO
YES
System charge unacceptable for the space
System charge in compliance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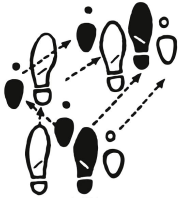

Stet Sanborn

Q+A Moderator

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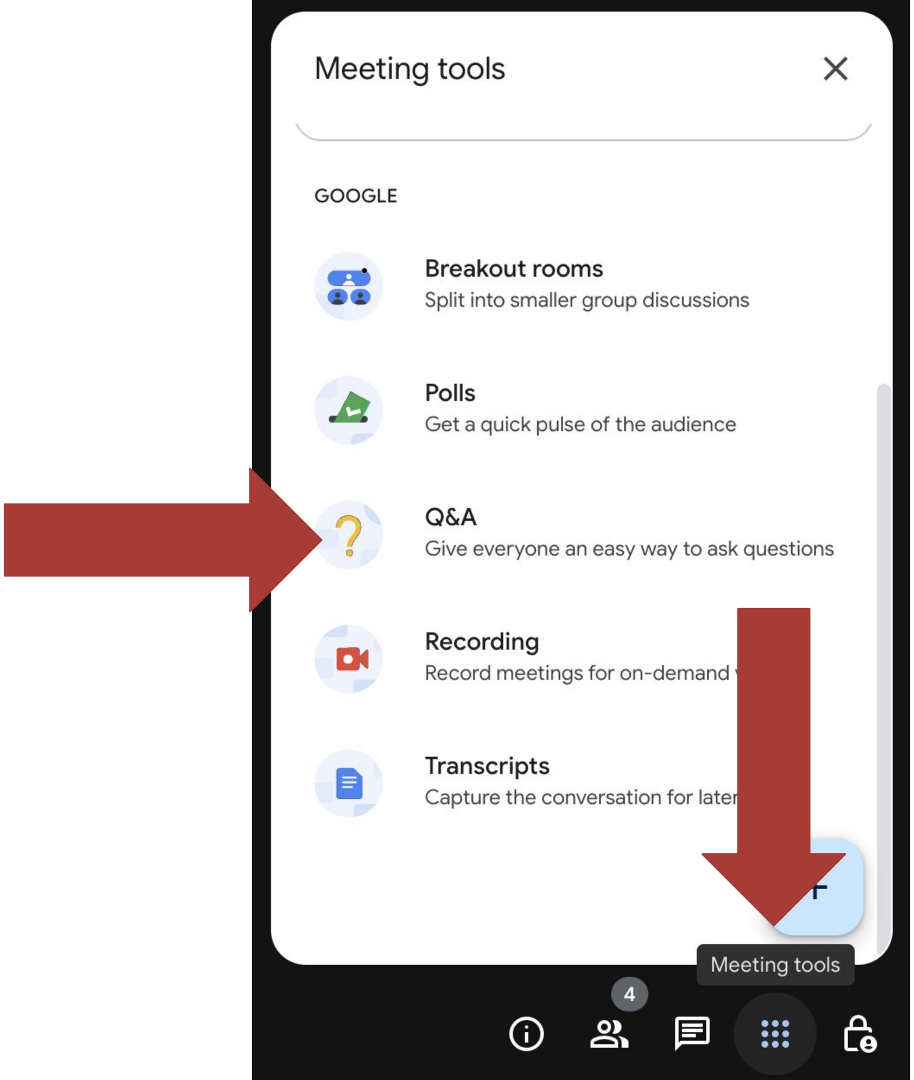

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