


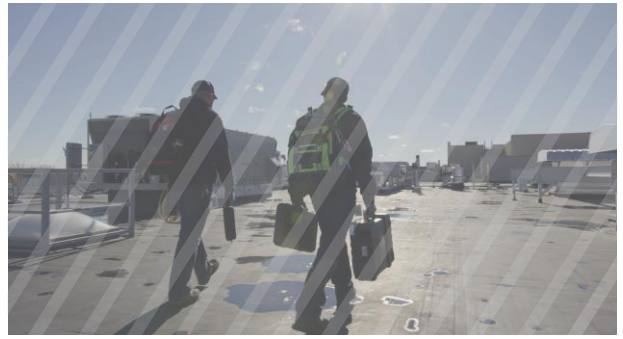

Preparing Buildings for A2L Refrigerants

Sharon Haeg

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- Always consult your state & local codes, which may take precedence over standards like ASHRAE Standards 15, 34, or other standards which vary in adoption, complete or partial, by state. Also note that a state may adopt a different year of the standard than the latest version.
- The local Authority Having Jurisdiction (AHJ) has the final authority in interpreting code requirements. When in doubt, contact the AHJ.

Agenda

How do refrigerants align with the goal of decarbonization?

Regulations and standards driving changes for applied equipment

Can I use A2L refrigerants in applied products in my jurisdiction?

Are A2Ls safe?

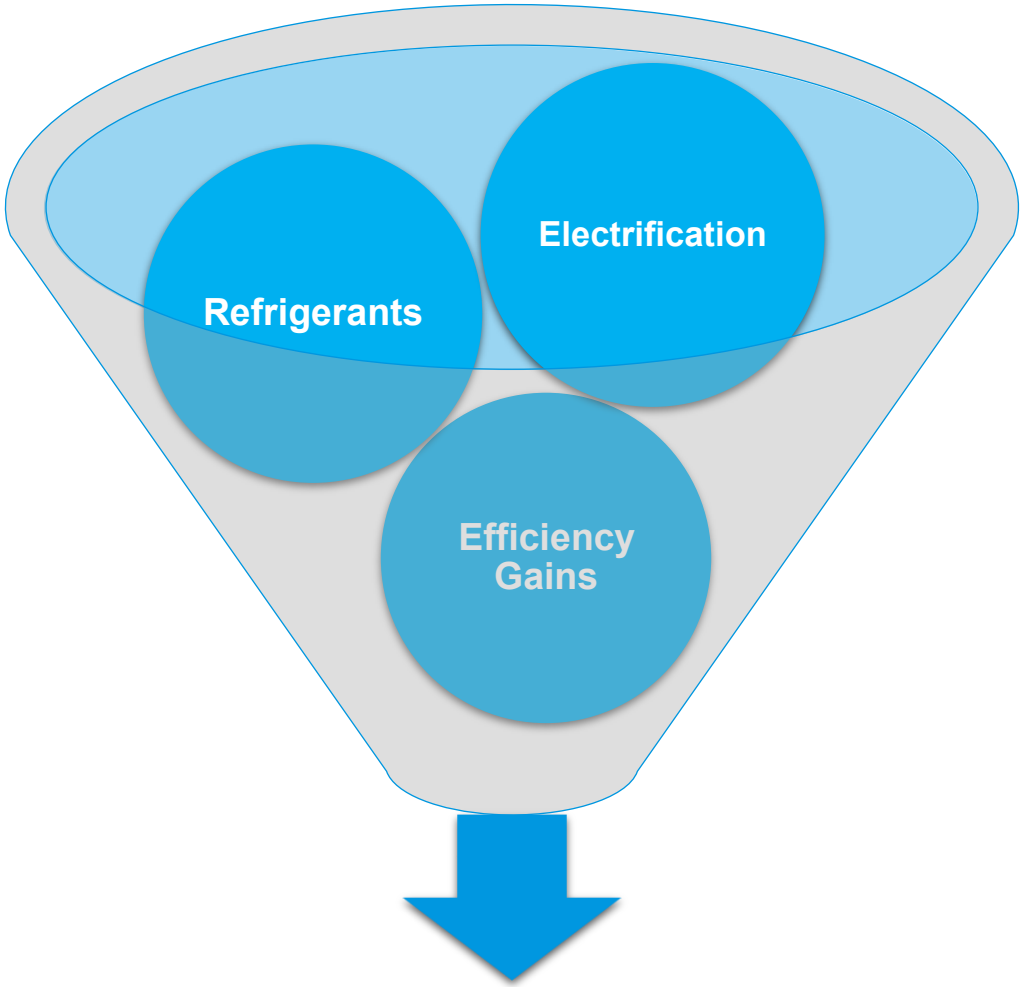
R-410A alternatives and common misconceptions

What do I need to do to prepare?

- Design requirements
- Refrigerants detection/control signals
- Ventilation
- Refrigerant piping

Why are Refrigerants Important for Decarbonization?

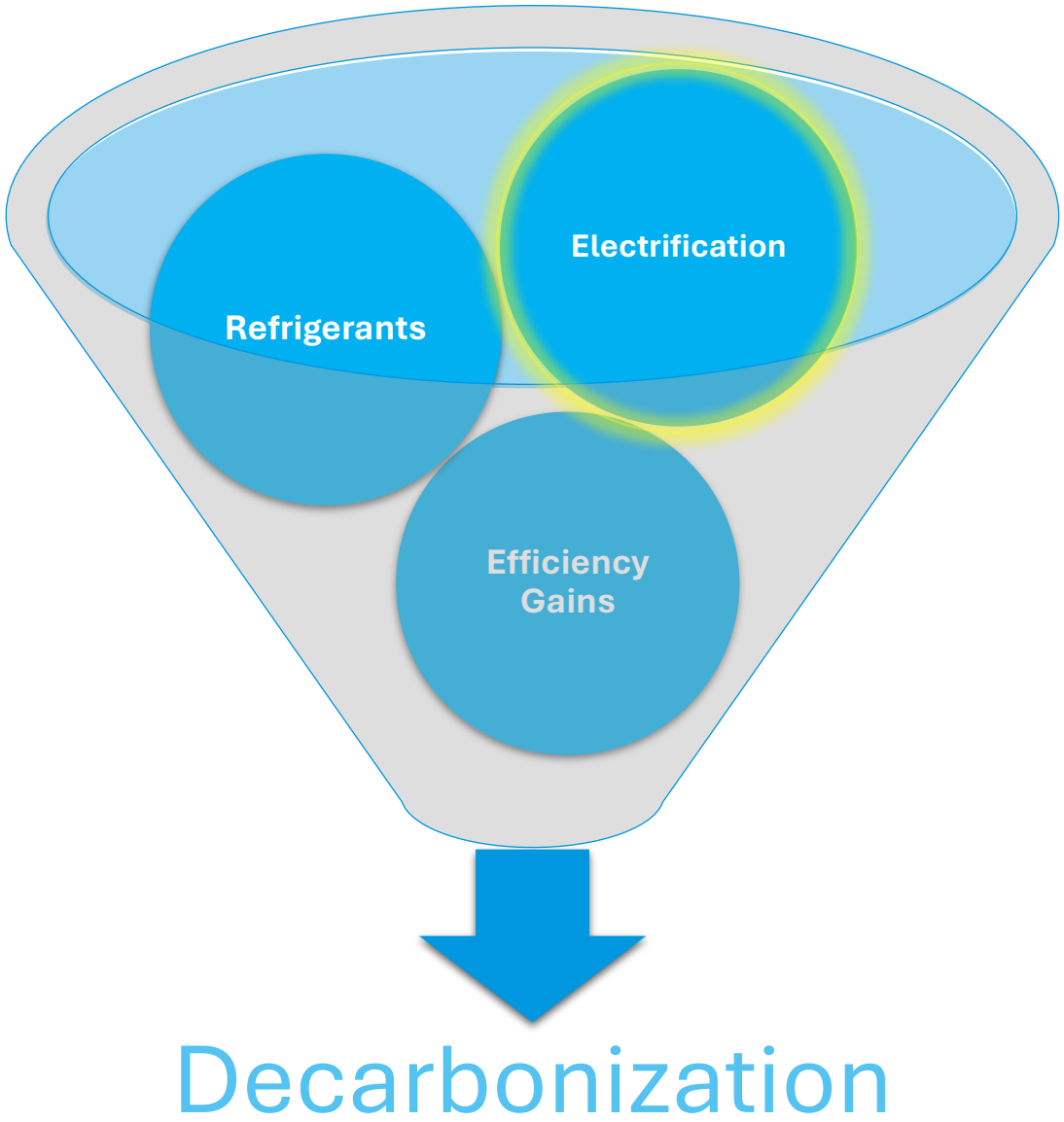
Decarbonization in HVAC



Decarbonization in HVAC

Electrification

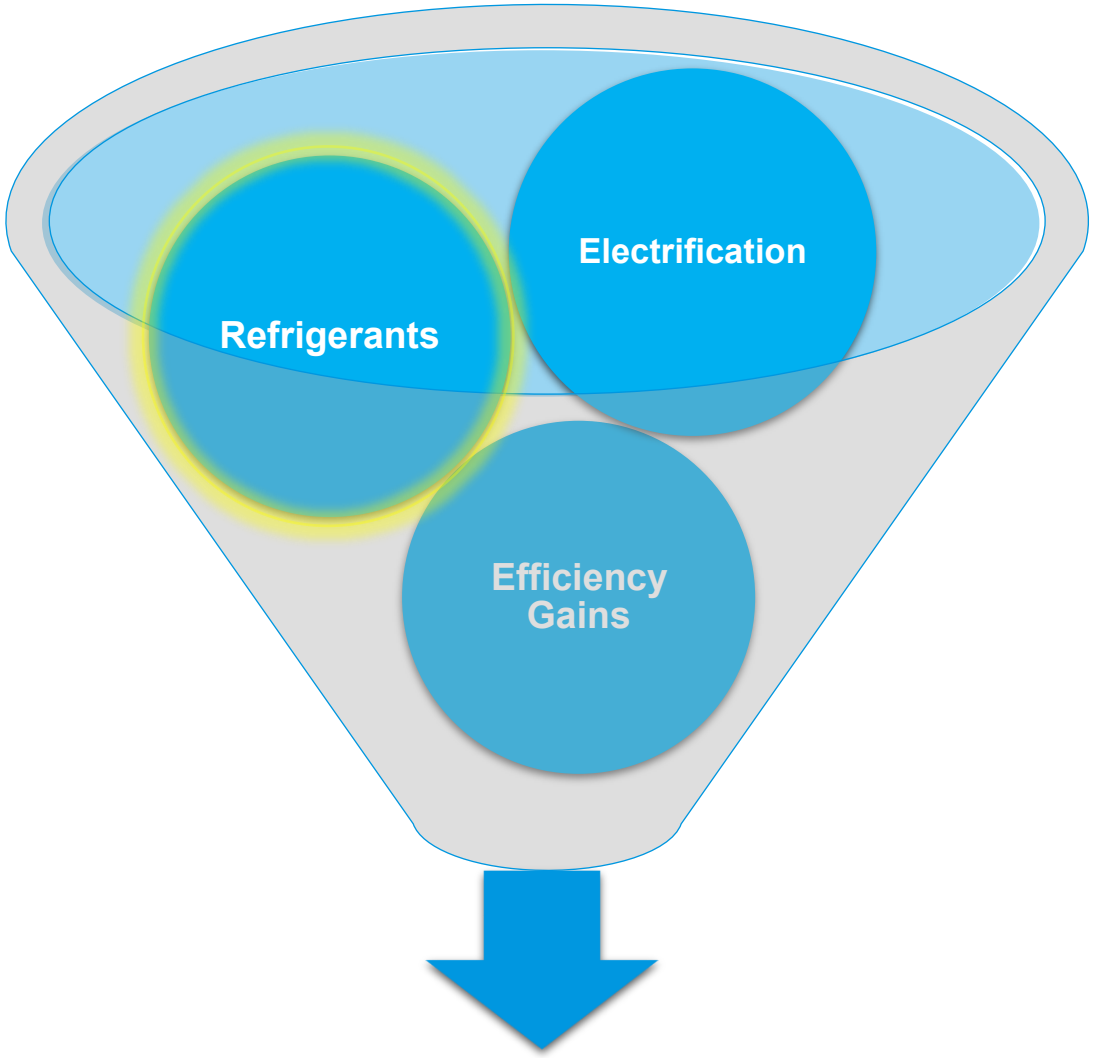
- Convert fossil fuel equipment/ processes to electric
- Most benefit with highly-renewable power grid



Decarbonization in HVAC

Refrigerants

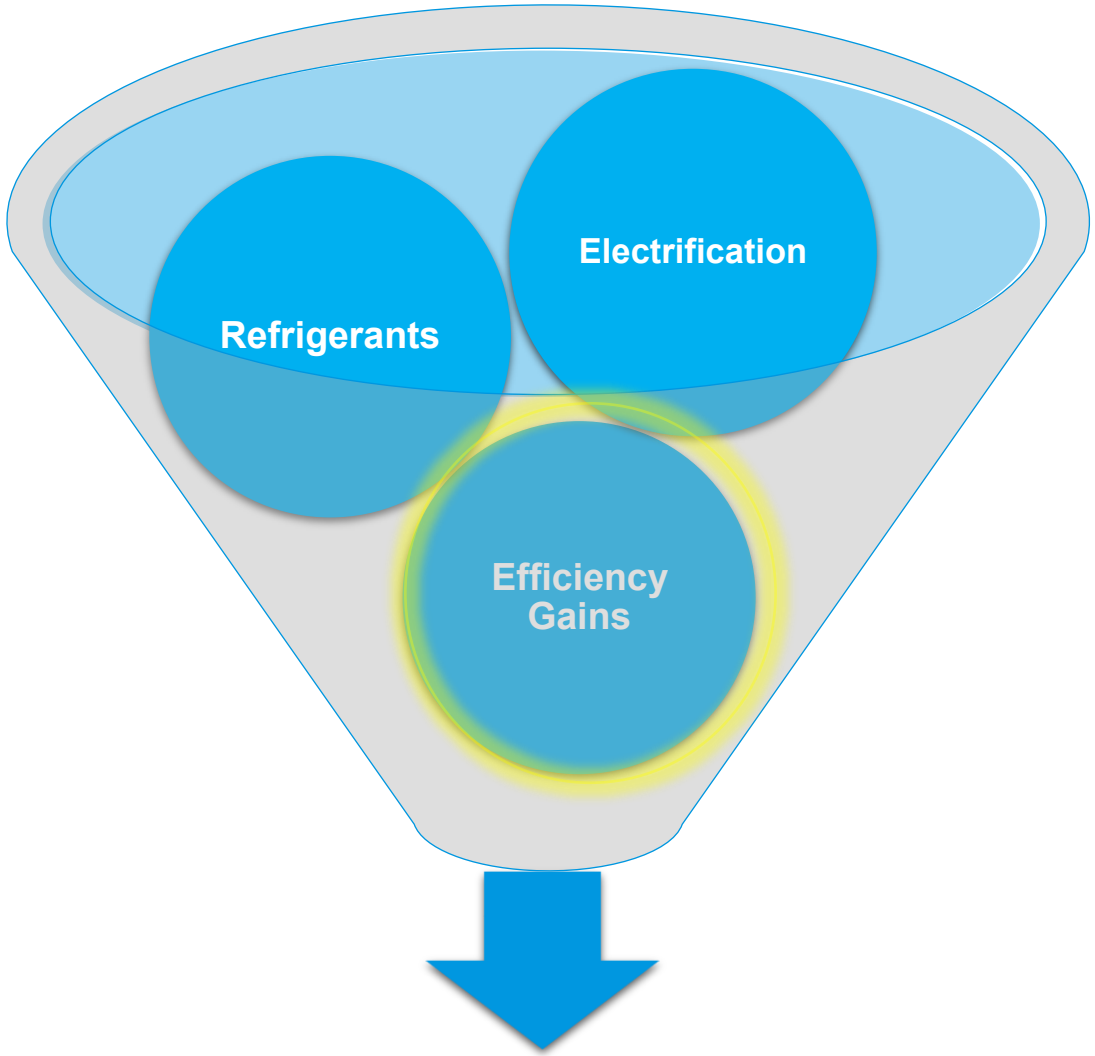
- Direct effect: greenhouse effect of the gas
- Indirect effect: change in efficiency changes power usage over equipment lifecycle



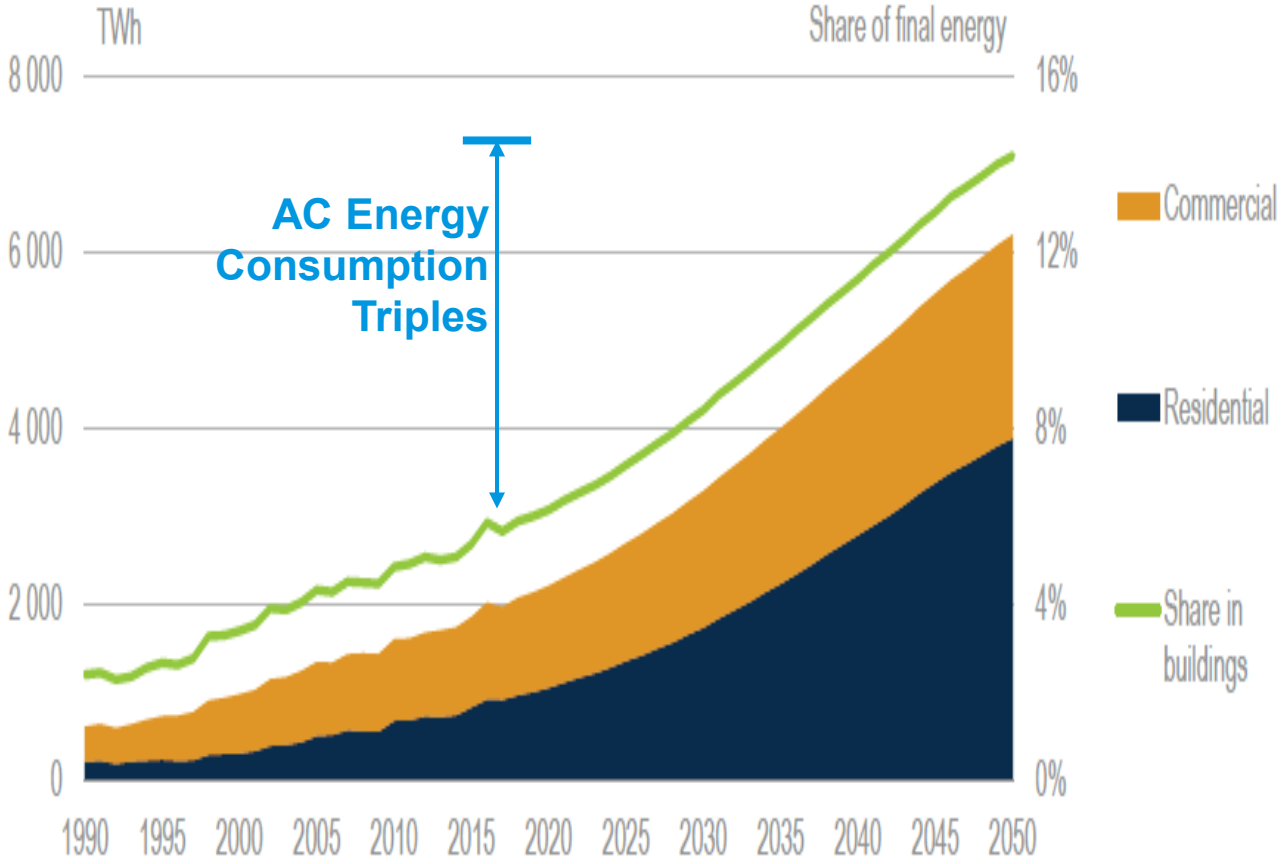
Decarbonization in HVAC

Efficiency

- Greatest impact with grids using higher percentage of fossil fuels
- Reduced (but not zero) impact as grid converts to renewable (e.g. embedded carbon in power gen equipment)

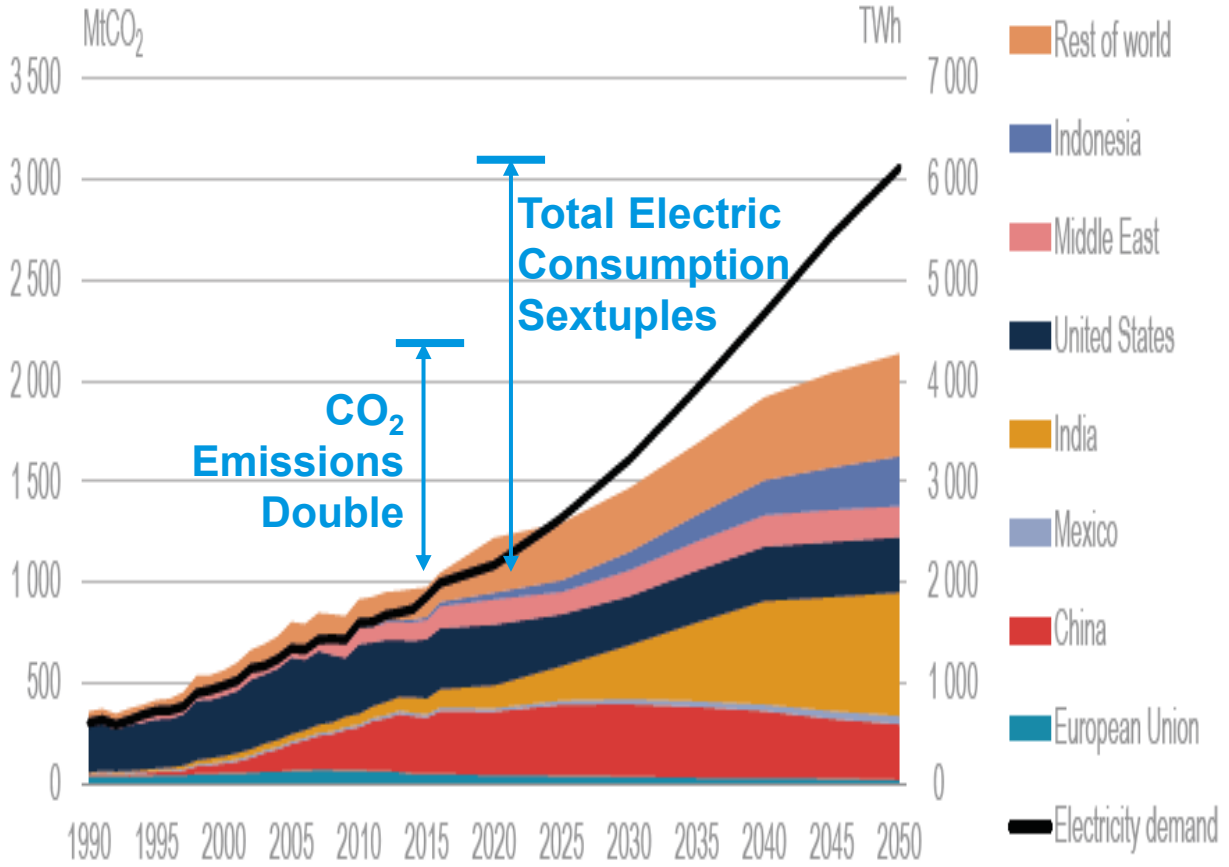


Growth of AC Through 2050: Impact to Energy Use and CO2 Emissions



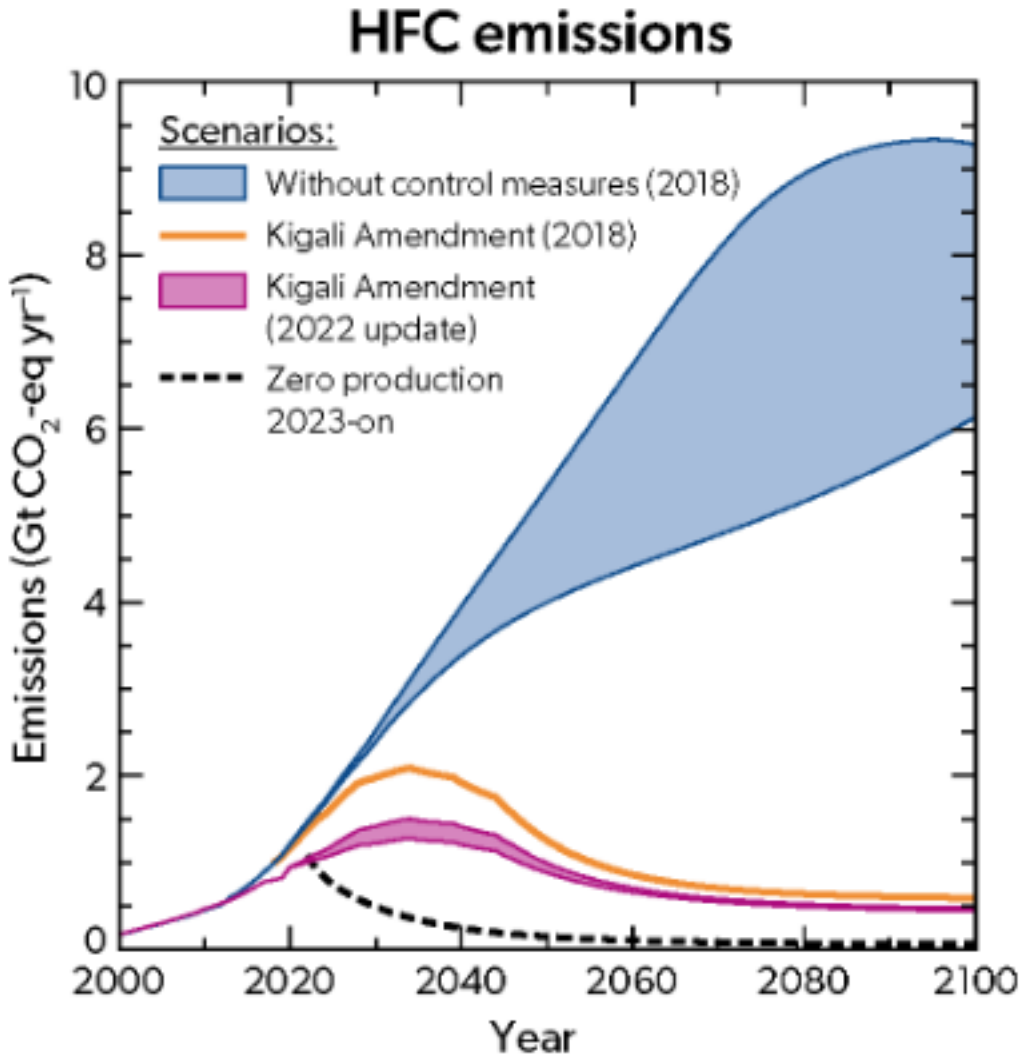
1.6B → 5.6B

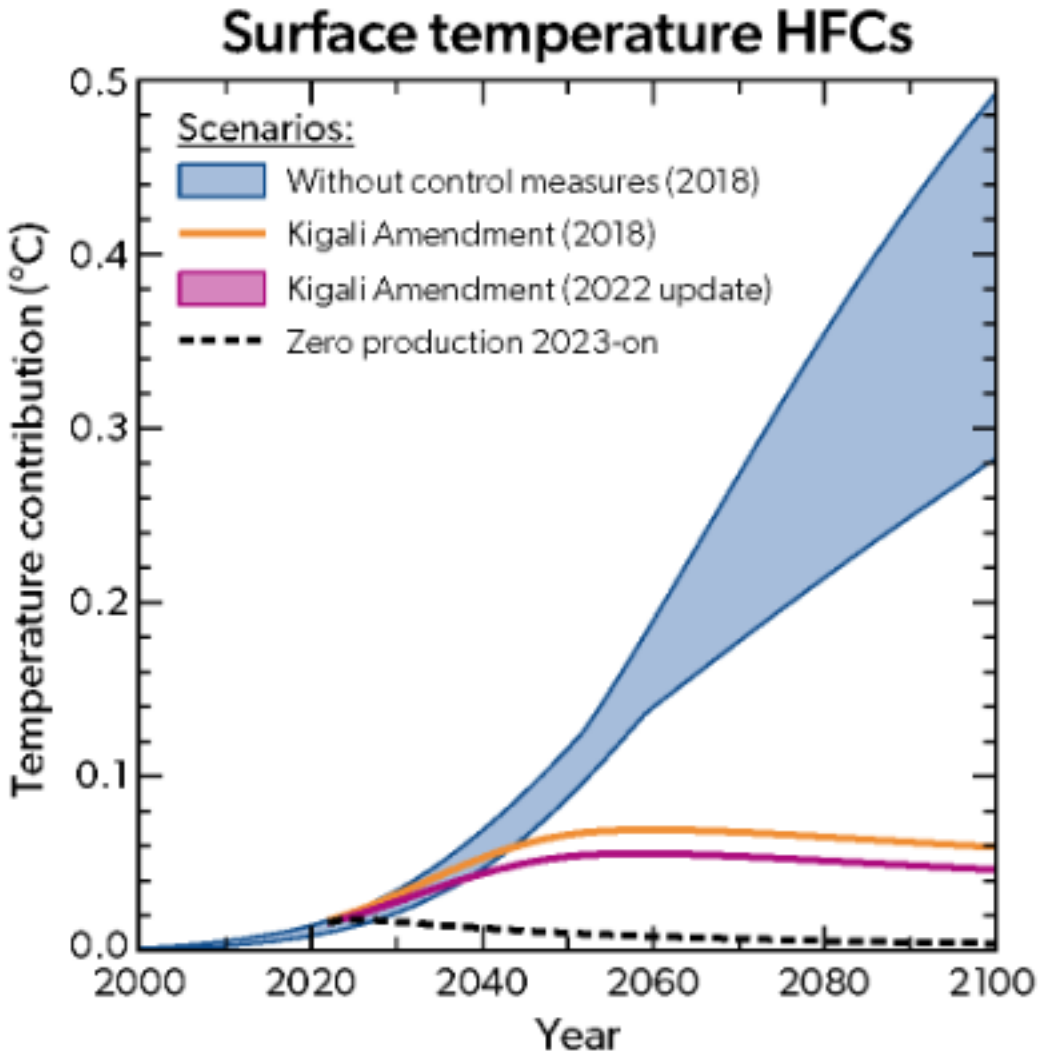
People using AC



Source: IEA “The Future of Cooling”

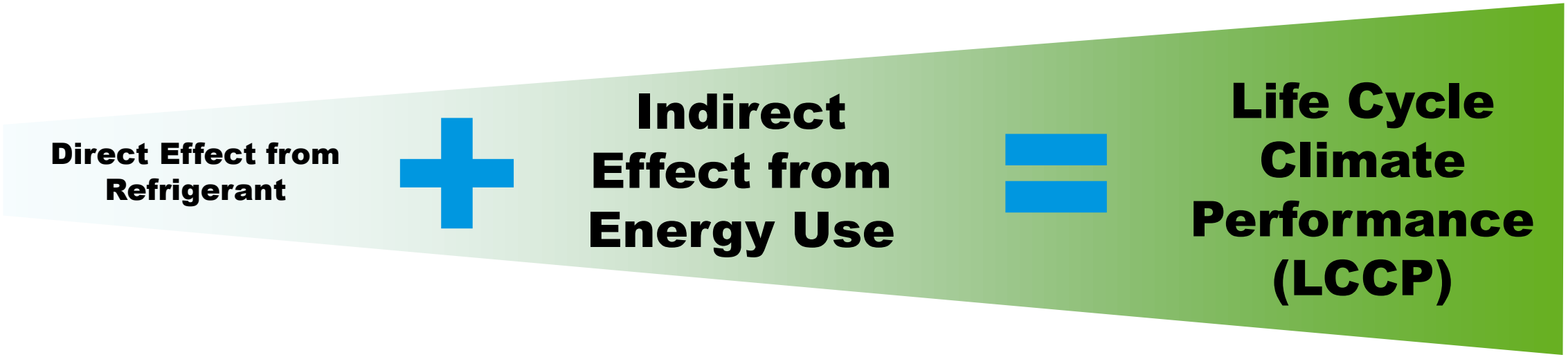
Kigali Amendment to Montreal Protocol





Scientific Assessment of Ozone Depletion: 2022, Executive Summary

GWP is Not the Full Measure of Emissions

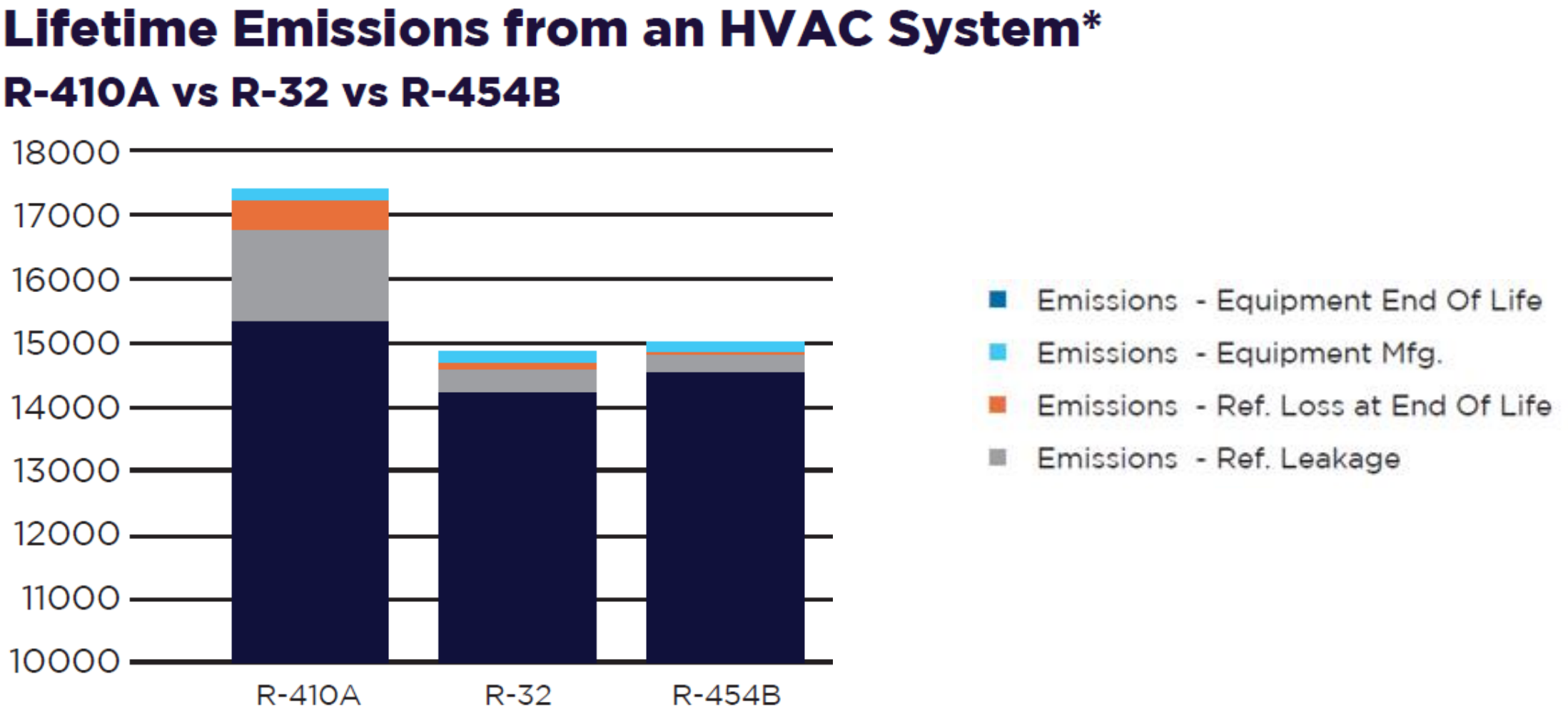


- Majority of climate impact from HVAC is electrical power generation over equipment lifetime

- A lower GWP refrigerant with lower efficiency could actually create more global warming!

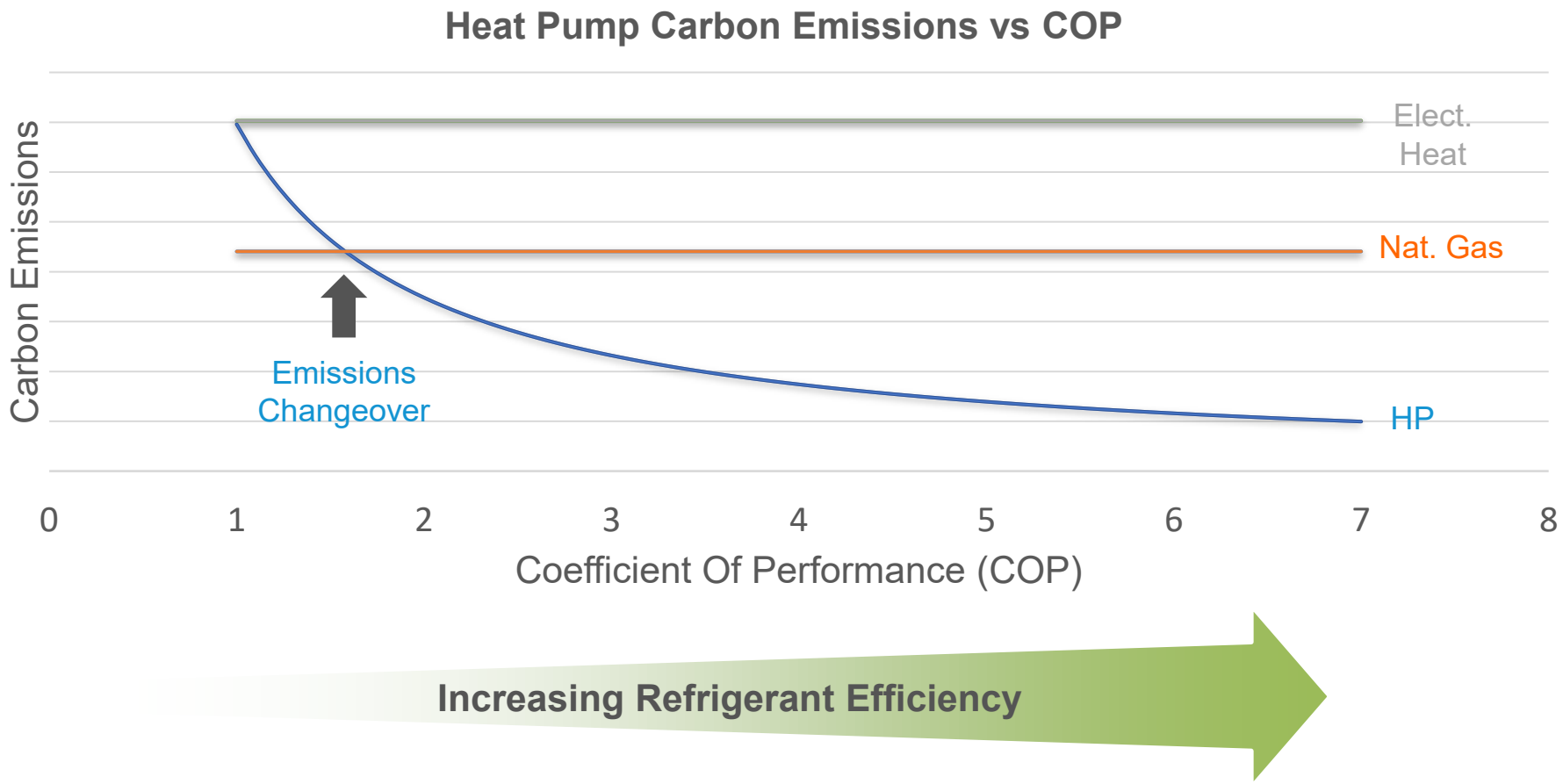
Source: Zhang M., et al. 2011. “Life Cycle Climate Performance Model for Residential Heat Pump Systems.” AHRTI Report 09003-01

Lifetime Emissions



*Comparison is made using the Life Cycle Climate Performance (LCCP) metric, measured in kg-CO2.eq. LCCP analysis was performed using a high efficiency HP (24+ SEER), using performance gains claimed by respective refrigerant manufacturer, for a residential sized (9000 Btu/h cooling capacity), installed in Houston, TX climate zone, with an assumed annual leakage rate of 4% and end of life refrigerant leakage of 15% with a 15 year lifetime. The heating COP and SEER were adjusted based on refrigerant characteristics and performance. The physical system size, trim charge requirements and capacity were kept consistent to ensure a like-to-like comparison.

HP Emissions vs Gas – National Average

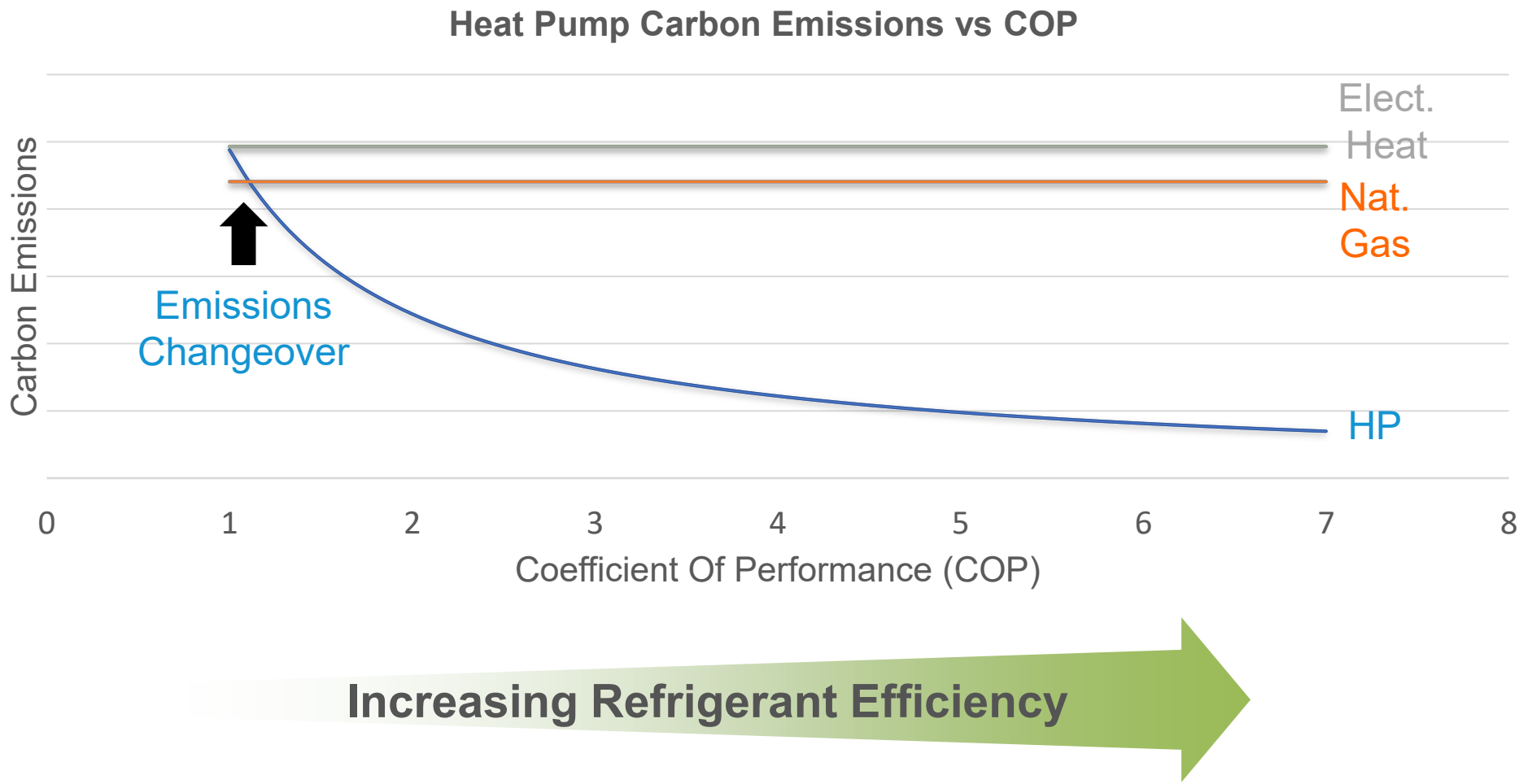


Assumptions

Natural Gas Efficiency:	85%
Electric Resistance Efficiency:	99%
Grid Emissions Factor: (gram/kWh)	348
Natural Gas Emissions (lbs/therm)	12.1

Note: This is highly dependent on electric grid emissions factors – Based on US EPA eGRID data

HP Emissions vs Gas – Massachusetts

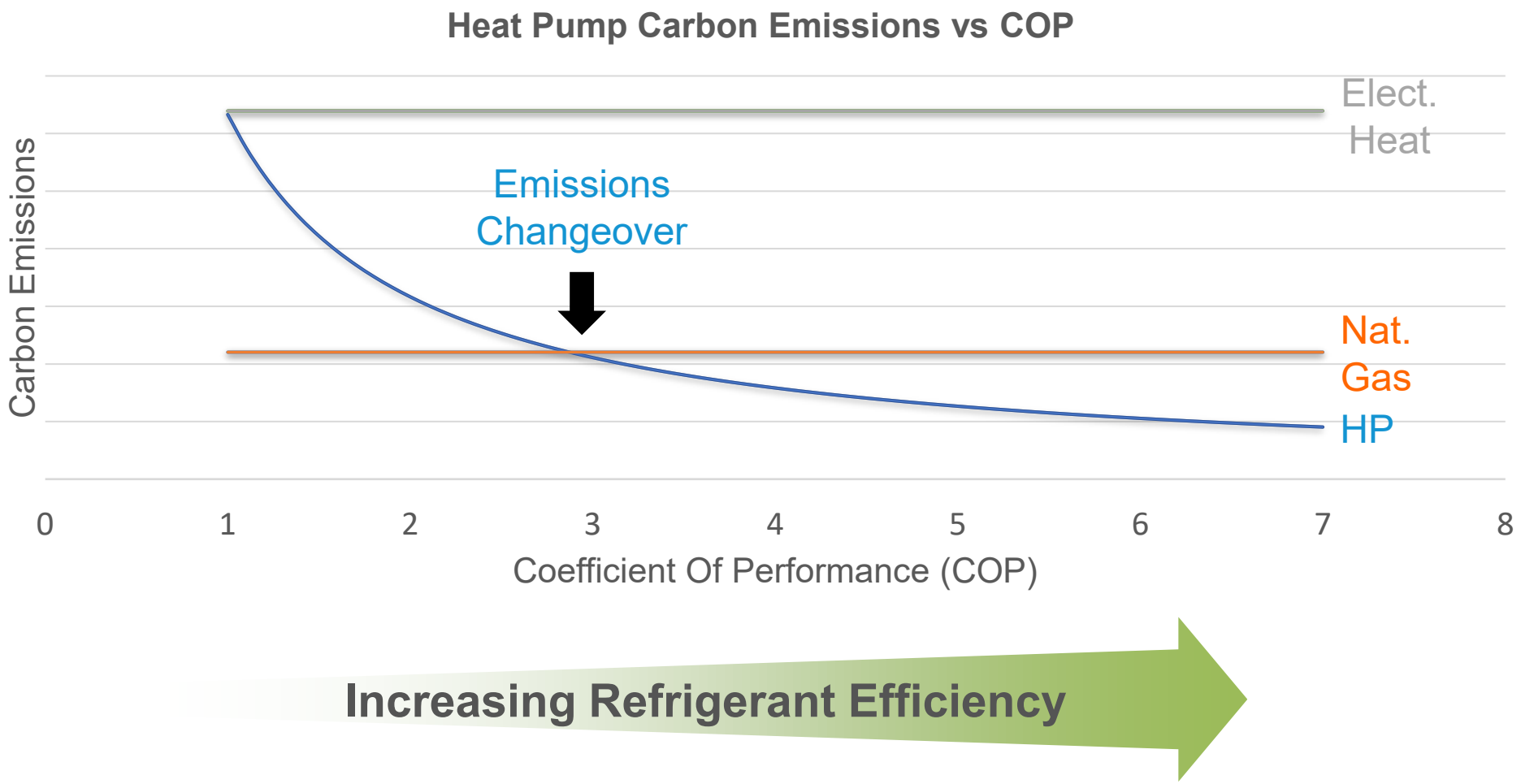


Assumptions

Natural Gas Efficiency:	85%
Electric Resistance Efficiency:	99%
Grid Emissions Factor: (gram/kWh)	245
Natural Gas Emissions (lbs/therm)	12.1

Note: This is highly dependent on electric grid emissions factors – Based on US EPA eGRID data

HP Emissions vs Gas – Kentucky

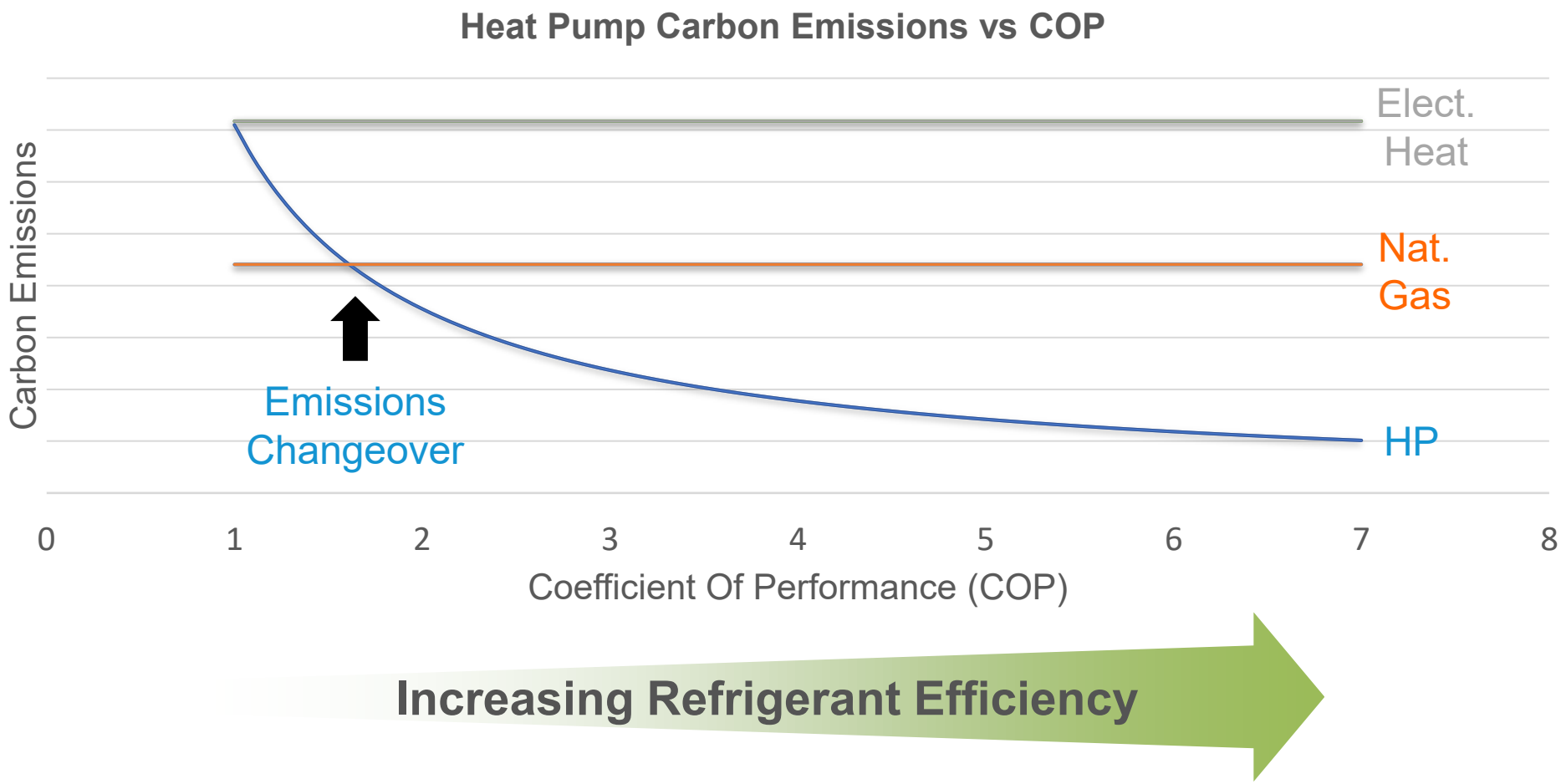


Assumptions

Natural Gas Efficiency:	85%
Electric Resistance Efficiency:	99%
Grid Emissions Factor: (gram/kWh)	633
Natural Gas Emissions (lbs/therm)	12.1

Note: This is highly dependent on electric grid emissions factors – Based on US EPA eGRID data

HP Emissions vs Gas – Florida



Assumptions

Natural Gas Efficiency:	85%
Electric Resistance Efficiency:	99%
Grid Emissions Factor: (gram/kWh)	355
Natural Gas Emissions (lbs/therm)	12.1

Note: This is highly dependent on electric grid emissions factors – Based on US EPA eGRID data

How will the AIM Act Affect Applied HVAC Systems?

AIM Act: Law Passed Dec. 2020 | EPA Rulemaking Status

The AIM Act gives authority to the EPA to phase down HFC refrigerants in the US

Old news: EPA must write rules to *phase down* production and consumption of bulk HFCs to 15% of baseline, maximize reclamation, minimize releases from equipment and facilitate transition through sector-based restrictions

PHASEDOWN

via CO2eq Allocations of Bulk HFCs

(Supply Side constraints)

TECHNOLOGY TRANSITIONS

Sector based controls

SNAP restrictions

REFRIGERANT MANAGEMENT

Minimizing leaks

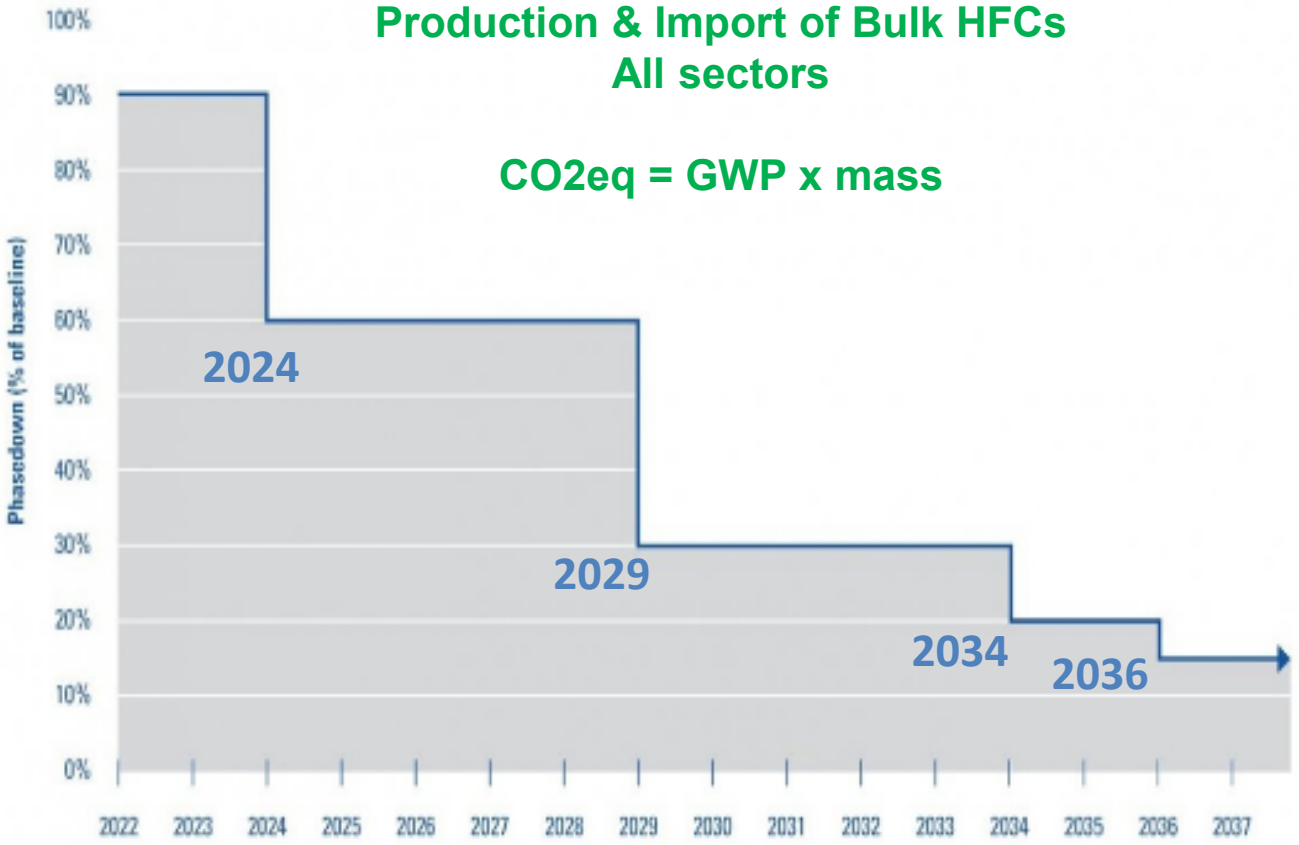
Maximizing recovery & reclamation

AIM Act: EPA Phasedown and Allocations

Phasedown Schedule

Production & Import of Bulk HFCs
All sectors

CO2eq = GWP x mass



CO2eq Phasedown

- Baseline over 300 million metric tonnes CO2 equivalency
- Phases down creating supply shortage of HFCs

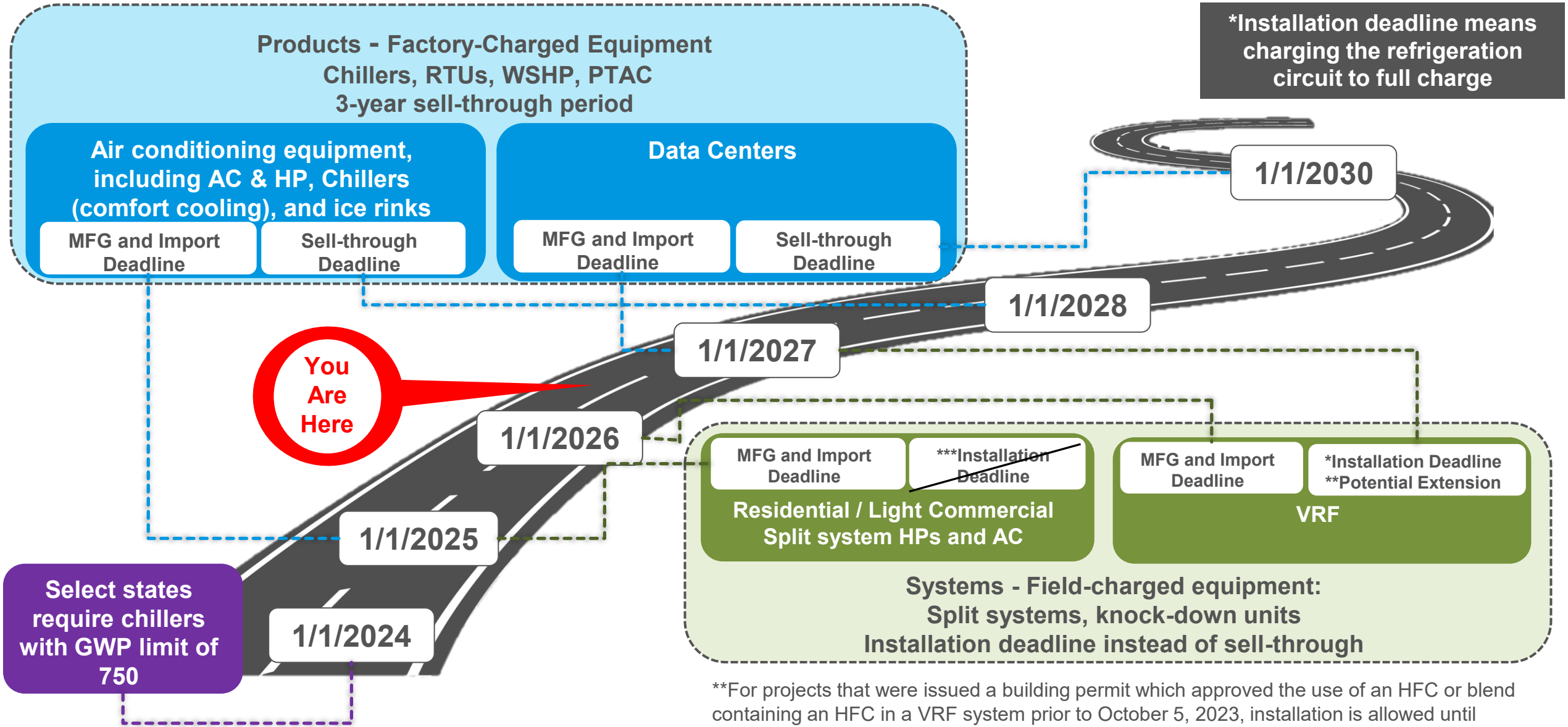
Not refrigerant specific – not a phaseout

- All bulk virgin HFCs in all sectors
- Produced in USA and imported

Existing equipment may be serviced

- Installed base can be serviced
- Will need to transition to lower GWP refrigerants

AIM Act: EPA Technology Transition



**For projects that were issued a building permit which approved the use of an HFC or blend containing an HFC in a VRF system prior to October 5, 2023, installation is allowed until January 1, 2028.

***Installation deadline for Residential / Light Commercial removed per Final Rule May 2026.

Can I Repair My Existing System?

EPA Technology Transition provides regulation on what is considered service on an existing system vs a new installation subject to GWP restrictions

Components (condensing units, condensers, compressors, evaporator units, & evaporators) needed to repair existing RACHP equipment can be serviced as long as the repair doesn't consist of a new system installation and the service parts that are specified components are labeled appropriately.

To distinguish between routine maintenance and what qualifies as a new system installation, the EPA has issued specific criteria in its October 2023 Final Rule – Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons under Subsection (i) of the American Innovation and Manufacturing Act of 2020 Facts Sheet.
"Specifically, the following actions, upon charging the system to full charge, are considered a new installation of a RACHP system and thus subject to the relevant HFC use restrictions:

- ***Assembling a system for the first time from used or new components;***
- ***Increasing the cooling capacity, in BTU per hour, of an existing system; or***
- ***Replacing 75 percent or more of evaporators (by number) and 100 percent of the compressor racks, condensers, and connected evaporator loads of an existing system."***

Any system modifications meeting these criteria are treated as new installations rather than maintenance and must comply with refrigerant GWP restrictions.

Evaluating existing High GWP Refrigerant DX Systems (Figure 1)

Simplifying assumptions:

- Equipment is not a Variable Refrigerant Flow or commercial refrigerating system.
- The application is a high probability system

Figure 1: EPA defines the distinction between maintenance of a system and installation of a new system in the October 2023 Final Rule – Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons under Subsection (i) of the American Innovation and Manufacturing Act of 2020 facts sheet. "Specifically, the following actions, upon charging the system to full charge, are considered a new installation of a RACHP system and thus subject to the relevant HFC use restrictions:

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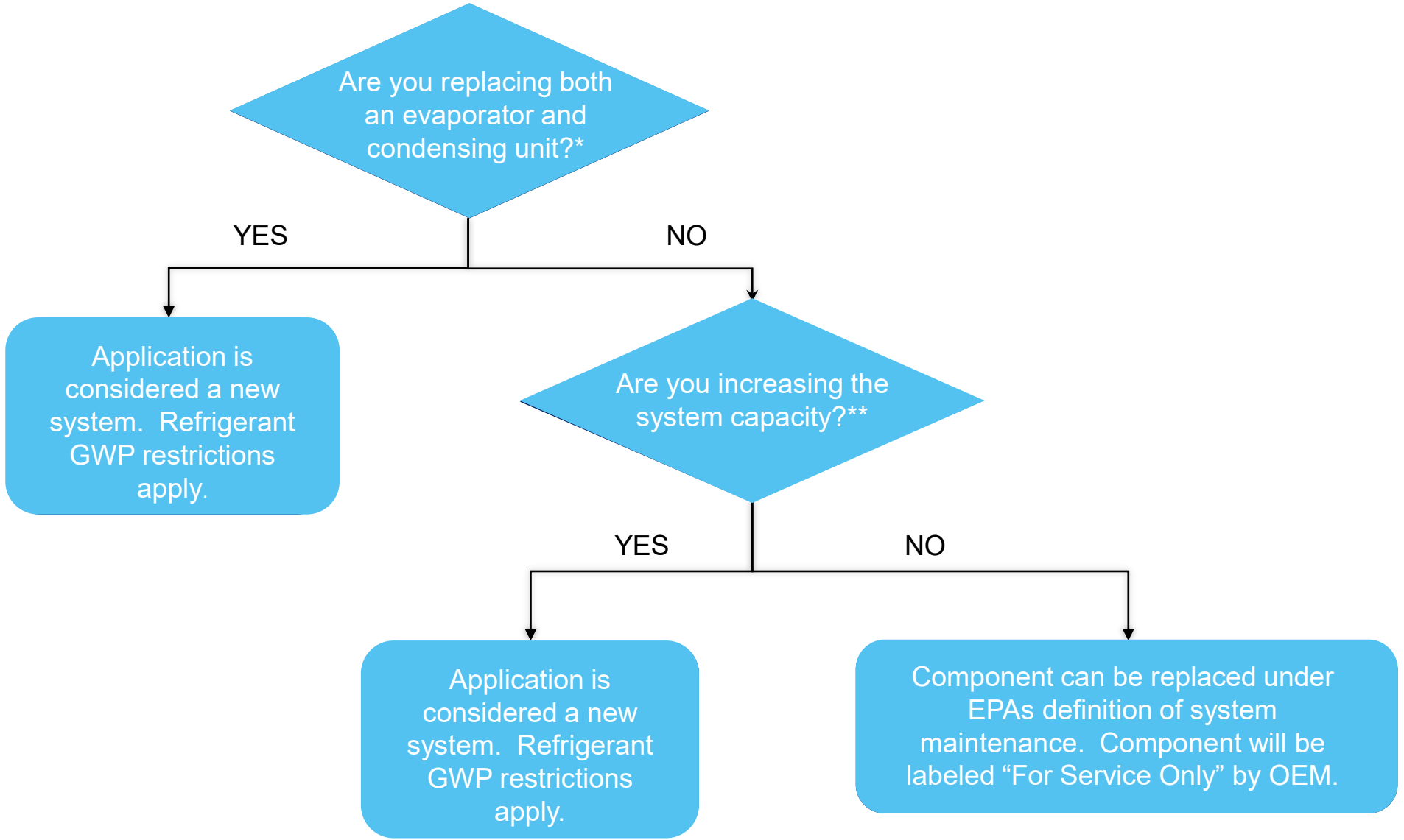
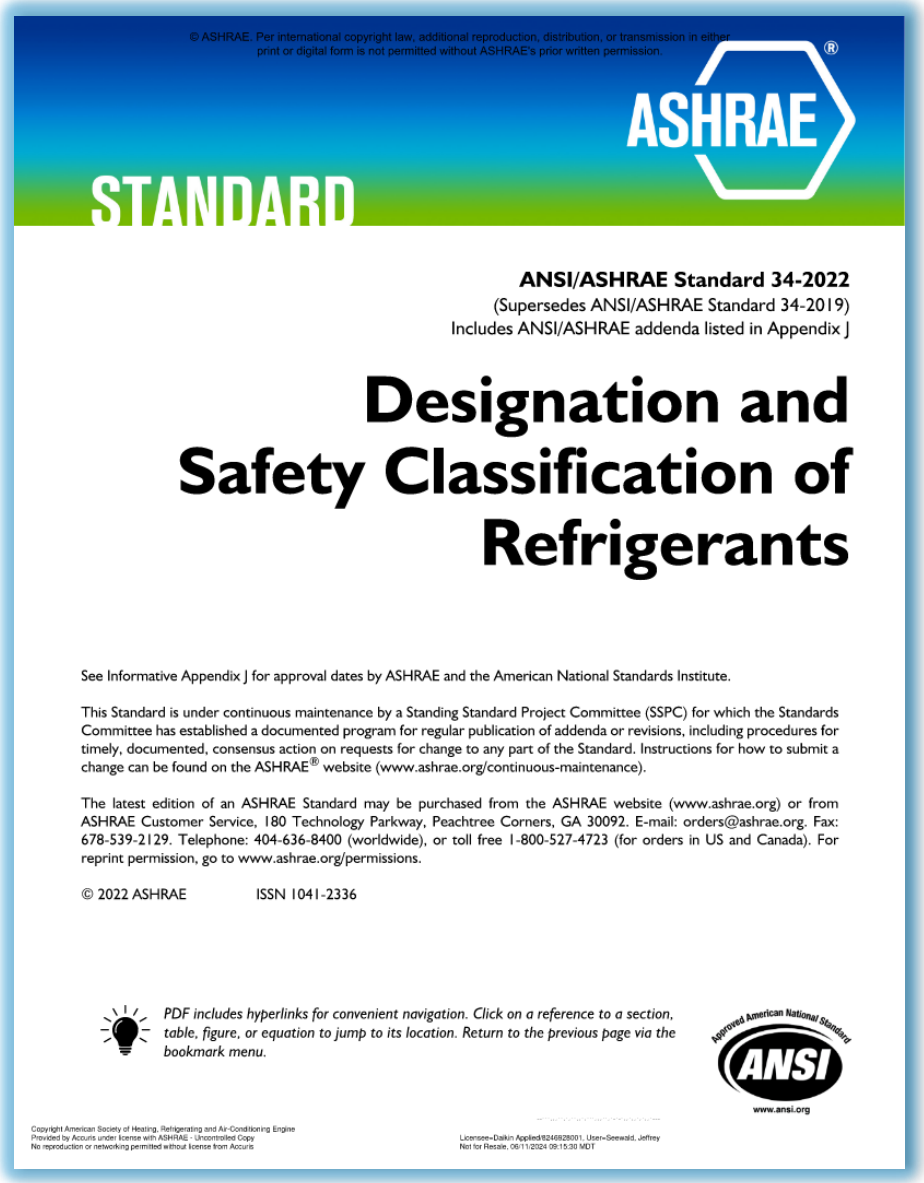


ASHRAE Standard 34-2022

Designation and Safety Classification of Refrigerants

ASHRAE Standard 34

- Naming of refrigerants
- Safety classifications
- Refrigerant concentration limits



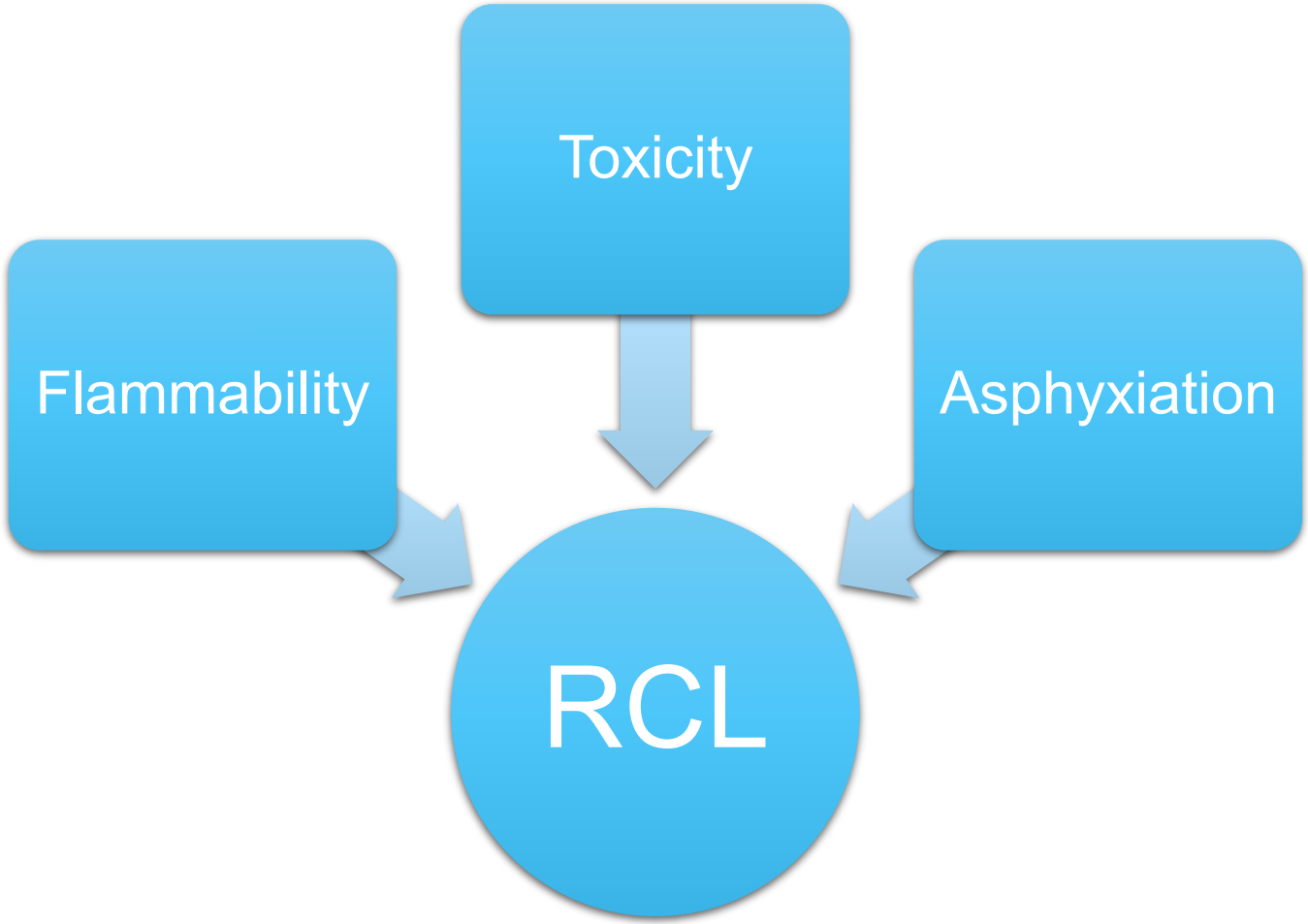
ASHRAE Standard 34 – Safety Groups

Flammability	Lower Toxicity	Higher Toxicity
Class 3 Higher flammability	A3	B3
Class 2 Flammable	A2	B2
Class 2L Lower flammability	A2L	B2L
Class 1 No flame propagation	A1	B1

Toxicity

ASHRAE Standard 34 Basics: RCL

Refrigerant Concentration Limit
Maximum allowable concentration of refrigerant based on worst case of:



A2L Refrigerants – How Flammable Are They?

A2Ls have 'lower flammability'

Burning Velocity (S_u)

- How fast does a flame propagate (<0.1 m/s)

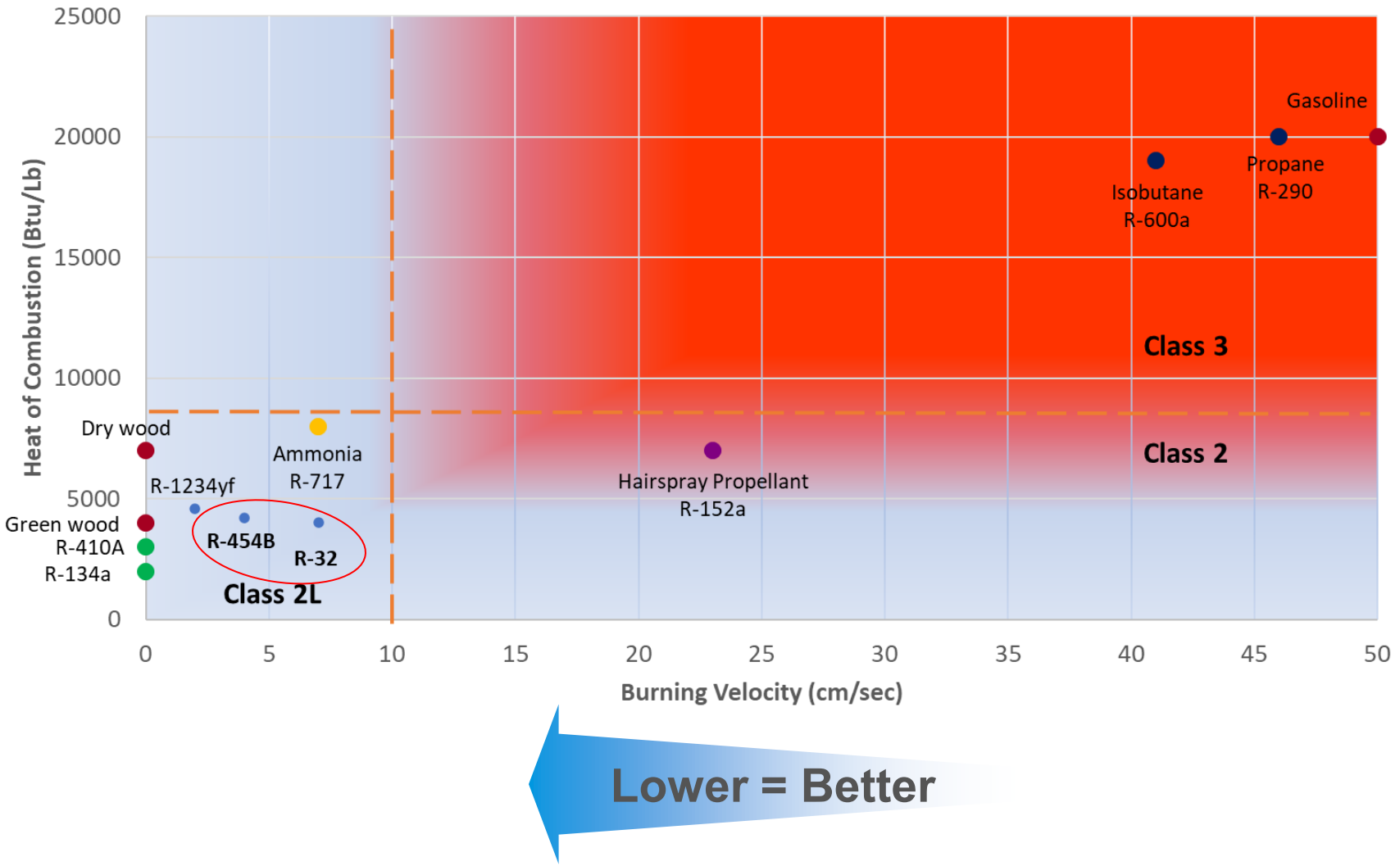
Heat of combustion (HOC)

- How much energy is released by burning (< 1900 kJ/kg)

Lower Flammability Limit (LFL)

- What is the concentration required to burn (> 0.1 kg/m^3)

Relatively lower burning velocity & heat generation



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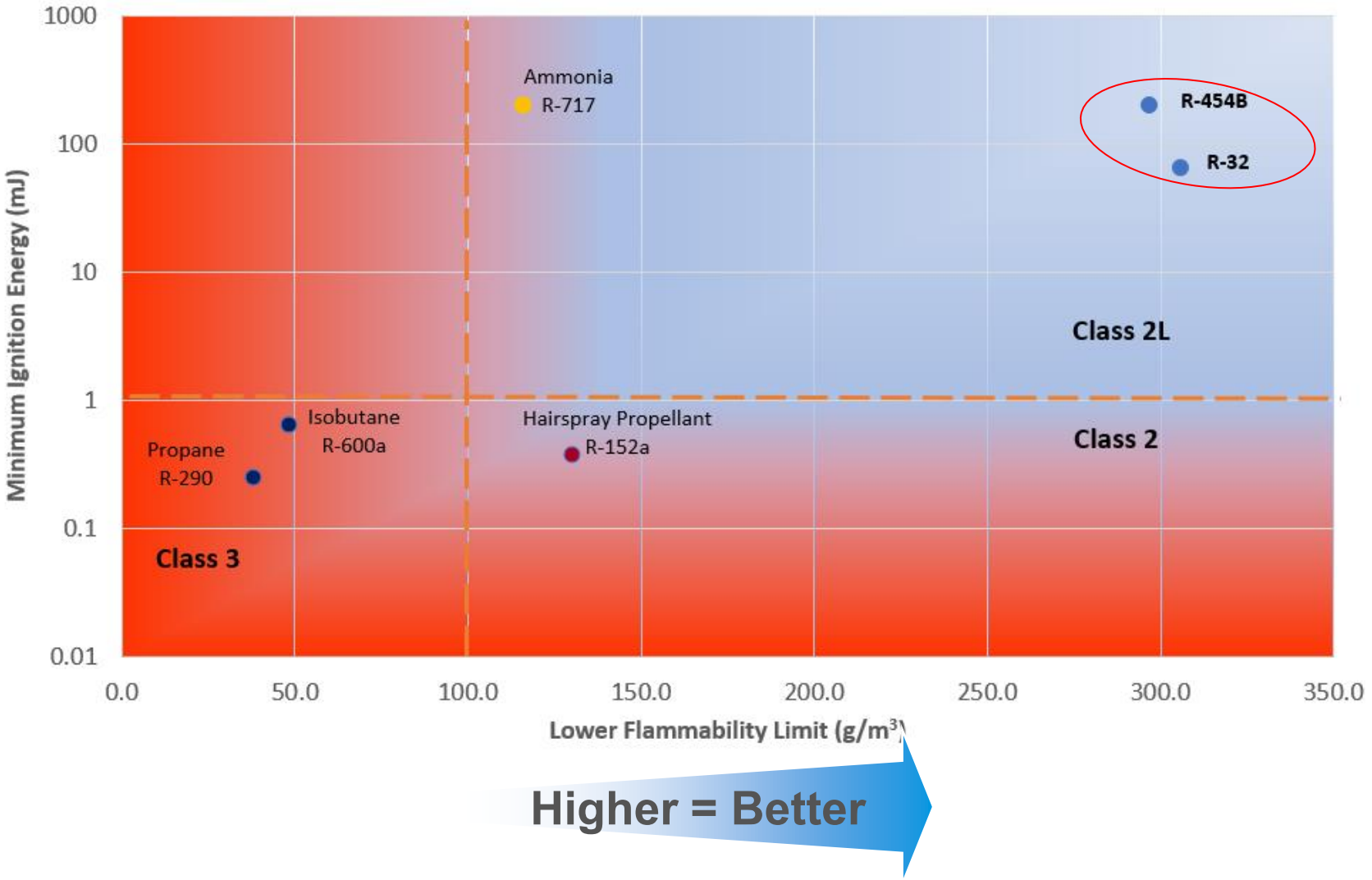
Heat of combustion (HOC)

- How much energy is released by burning (< 1900 kJ/kg)

Lower Flammability Limit (LFL)

- What is the concentration required to burn (> 0.1 kg/m^3)

Most difficult to ignite/higher concentration required



‘New’ and Legacy Refrigerant Properties

‘New’ and Legacy Refrigerant Properties

Refrigerant	ASHRAE 34 Classification	GWP_{100} (AR4)	RCL (g/m^3)	Composition	Efficiency	Capacity	Toxicity
R-410A Substitutes							
R-410A	A1	2088	420	50% R-32 / 50% R-125			
R-32	A2L	675	77	PURE 100% R-32			
R-454B	A2L	466	74**	68.9% R-32 / 31.1% R-1234yf			
R-134a Substitutes							
R-134a	A1	1430	210				
R-513A	A1	630*	320	44% R-134a / 56% R-1234yf			
R-515B	A1	292*	290	91.1% R-1234ze(E) / 8.90% R-227ea			
R-1234ze(E)	A2L	1	76				
R-123 Substitutes							
R-123	B1	77	57				
R-1233zd(E)	A1	2*	85				
R-514A	B1	2*	14	74.7% R-1336mzz(E) / 25.3% R-1130(E)			

*Refrigerant was not included in AR4, AR5 values are utilized in lieu of AR4

**ASHRAE 34 previously listed an RCL of 49, but that value was later updated in Addendum "a" of Standard 34-2022

What Refrigerant to Use When

Common HVAC Refrigerants

Compressor	Previous Refrigerant	Low GWP Alternative	
 Higher Pressure *Scroll*	**R410A** GWP = 2088	**R32** GWP = 675	**R454B** GWP = 466
 Medium Pressure Screw or Centrifugal	**R134a** GWP = 1430	**R513A** GWP = 631	**R1234ze** GWP ~ 1
 Low Pressure Centrifugal	**R123** GWP = 77 (but has ODP)	**R514A** GWP ~ 2	**R1233zd** GWP ~ 1

Pressure

What will Replace R-410A?

What is Replacing R-410A?

Examples of announced products using R-32

DAIKIN Amana Heating & Air Conditioning Goodman

All products previously using R-410A

Carrier

Air-cooled scroll chillers

LENNOX

Mini-split products

SAMSUNG

Most products except ‘Hylex

LG

All split-system products

Examples of announced products using R-454B

Johnson Controls

Residential, light commercial and commercial ducted HVAC applications

Carrier

Ducted and ductless residential and light commercial applications

LENNOX

Residential HPs and AC; commercial rooftop units and ducted split systems

MITSUBISHI ELECTRIC TRANE

MITSUBISHI ELECTRIC TRANE HVAC US

Light commercial and residential heating and AC products

Why is R-32 the Right Choice to Replace R-410A?

PROVEN

- In over 280 million units installed around the world

EASY

- Top off and recharge R-32 in the field

EFFICIENT

- Up to 12% more efficient than comparable R-410A systems

AVAILABLE

- A commodity with no active patents on the refrigerant

R-32 is Proven

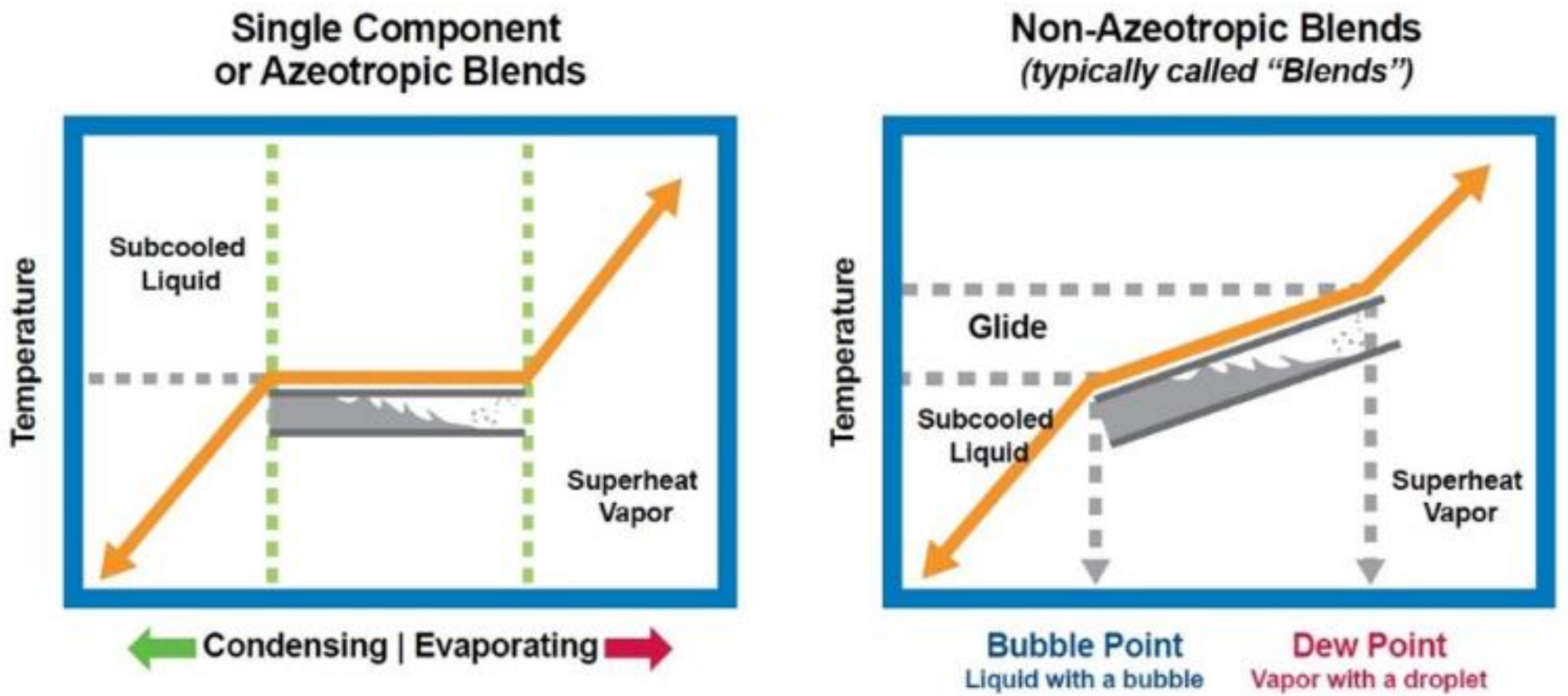
Refrigerant	Composition
R-410A	50% R-32 / 50% R-125
R-32	PURE 100% R-32
R-454B	68.9% R-32 / 31.1% R-1234yf

R-32 Dissemination in the World

*1 Daikin's estimation as of March 2025.

R-32 is Easy - Understanding Refrigerant Glide

Refrigerant Glide



A **Non-Azeotropic mixture** is a mixture with liquid components that have different boiling points.

R32 is a Pure Refrigerant. R454B is a Non-Azeotropic blend.

R-32 is Efficient

Cost savings *for an*

R-32 *air cooled chiller vs.*

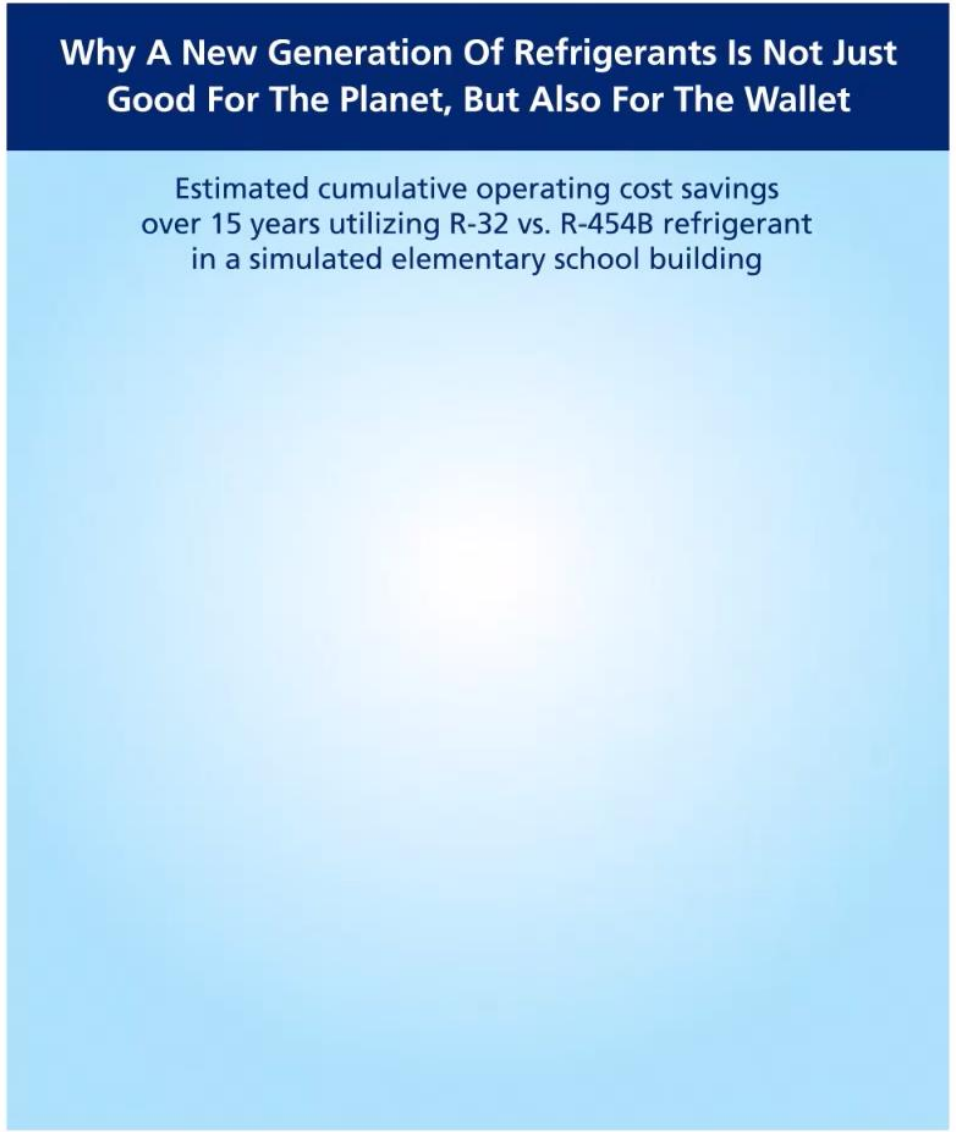
R-454B *air cooled chiller*

range from ***$41,000-$117,000***

depending on the climate zone,

making R-32 a highly

cost-effective choice



*The cumulative whole-building operating cost savings over a 15-year period for the Elementary School building model utilizing a commercially available R-32 air-cooled chiller compliant with ASHRAE Standard 90.1-2019, relative to a comparable R-454B chiller. A 2.67% annual utility cost escalation rate is assumed, derived from a 25-year U.S. national average reported by the U.S. Energy Information Administration (Source: US EIA).

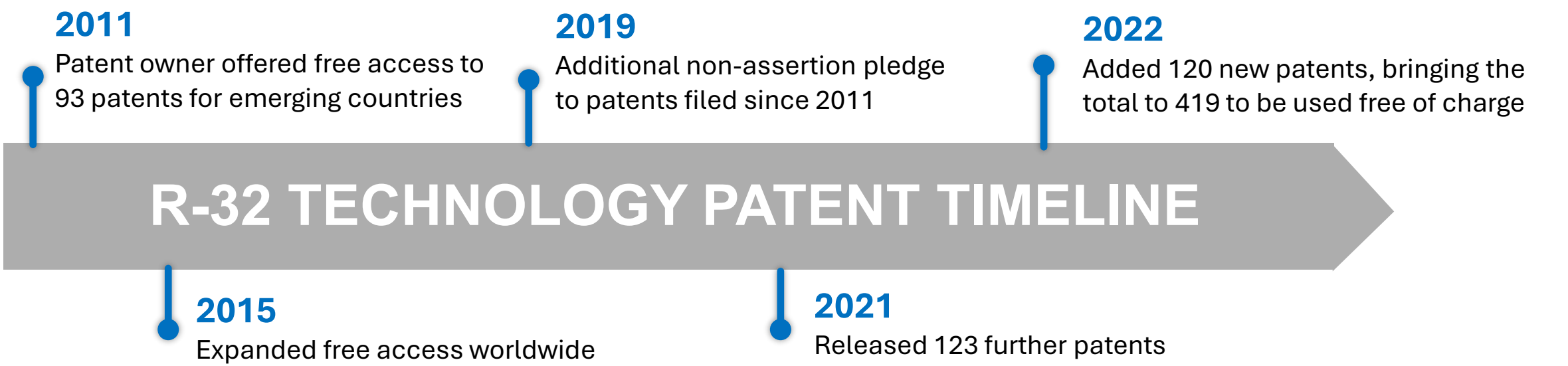
R-32 is Available - Intellectual Property & Patents

R-32

- No active patents on the chemical itself – used in R-410A
- Technology patents have been released to allow easier adoption

R-454B

- Proprietary and patented



The underlying concern is really cost, not patents, right…?

R-32 is Available - Cost

Is R-32 more expensive than R-454B?

R-410A 25lb Cylinder
$11.56 / lb

R-32A 20lb Cylinder
$14.95 / lb

R-454B 20lb Cylinder
$26.45 / lb

*Online retailer eRefrigerants lists R-32 for $299/20lbs and R-454B for $529/20lb cylinder (April 2026)

R-32: Common Misconceptions – ‘Is it as simple as GWP?’

Does the higher GWP of R-32 relative to R-454B mean R-32 is worse for the environment or will be phased down sooner?

-R-32’s GWP is higher than R-454B’s GWP <u>but…</u>

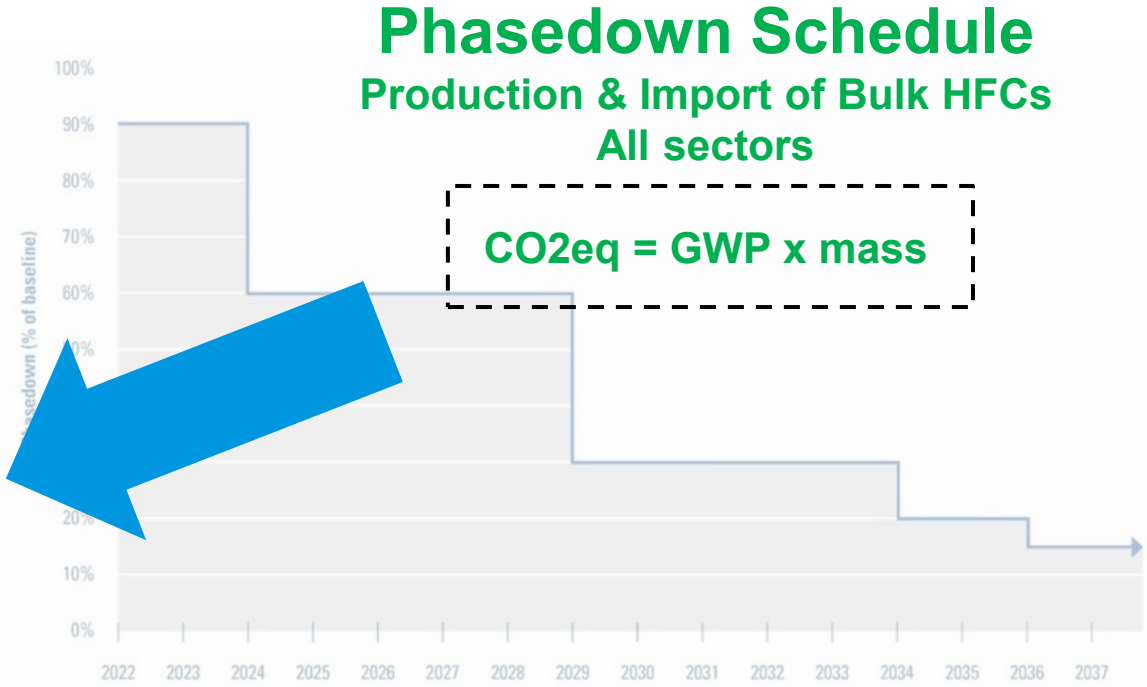
-Charge/ton is typically lower for R-32

-R-32 efficiency is superior

-Produced Mass * GWP is what matters

-Less mass of R-32 per ton of cooling is needed

Refrigerant	Safety Class	GWP100 (AR4)	Refrigerant charge level (R-410A baseline)	'Adjusted' GWP vs R-410A
R-410A	A1	2088	1	**2088**
R-32	A2L	675	~0.65	**~435**
R-454B	A2L	466	~0.9	**~419**

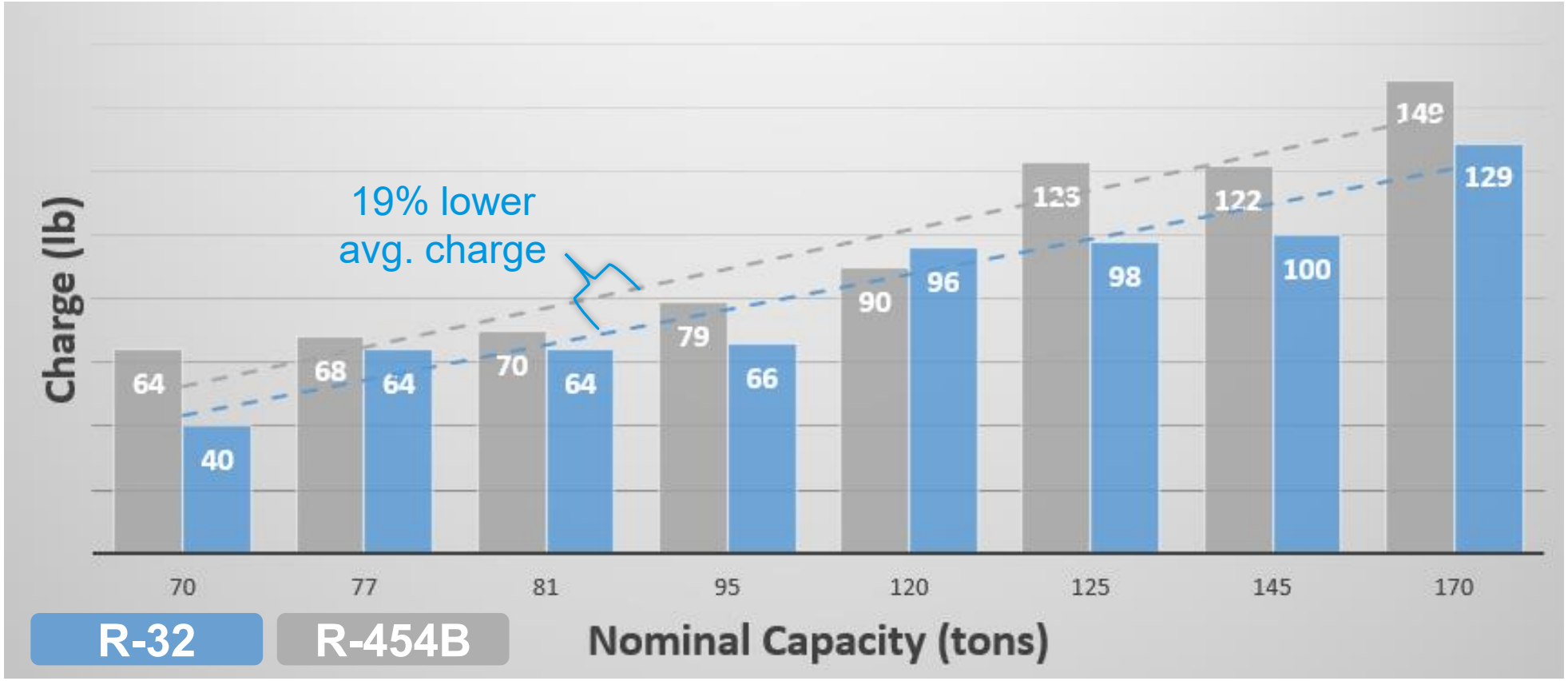


Source: US EPA

Efficiency and Refrigerant Charge

R-32 air-cooled scroll chiller vs. comparable R-454B scroll chiller

- Actual side-by-side comparisons will vary due to non-refrigerant design factors
- Tradeoff between efficiency and charge – maximizing efficiency would limit charge savings and vice-versa



R-32 Charge

19% Less

R-32 Efficiency

5% higher

Reduce, Reuse, Recycle

Recycle

- Extract refrigerant from an appliance and clean it for reuse in equipment for the same owner without meeting all the requirements for reclamation. Recycling normally takes place at the field job site.

Reclamation

- Used refrigerant reprocessed to meeting new product specifications (AHRI Standard 700-2016). Reclaimed refrigerant must meet strict purity standards, often requiring specialized, off-site equipment operation by EPA-certified reclaimers.

Reduce, Reuse, Recycle

	R-32	R-454B
Recycle	As a single component refrigerant, recycling is easily done without concern of refrigerant composition.	Recycled refrigerant composition is unknown which can affect system performance.
Reclamation	With no patents on the components itself and as a single component refrigerant reclamation efforts are easy.	Patents on R-454B limit reclamation efforts to distilling down to base components which is time consuming and costly.

What Standards Guide the Application of A2L Refrigerants

ASHRAE Standard 15-2022

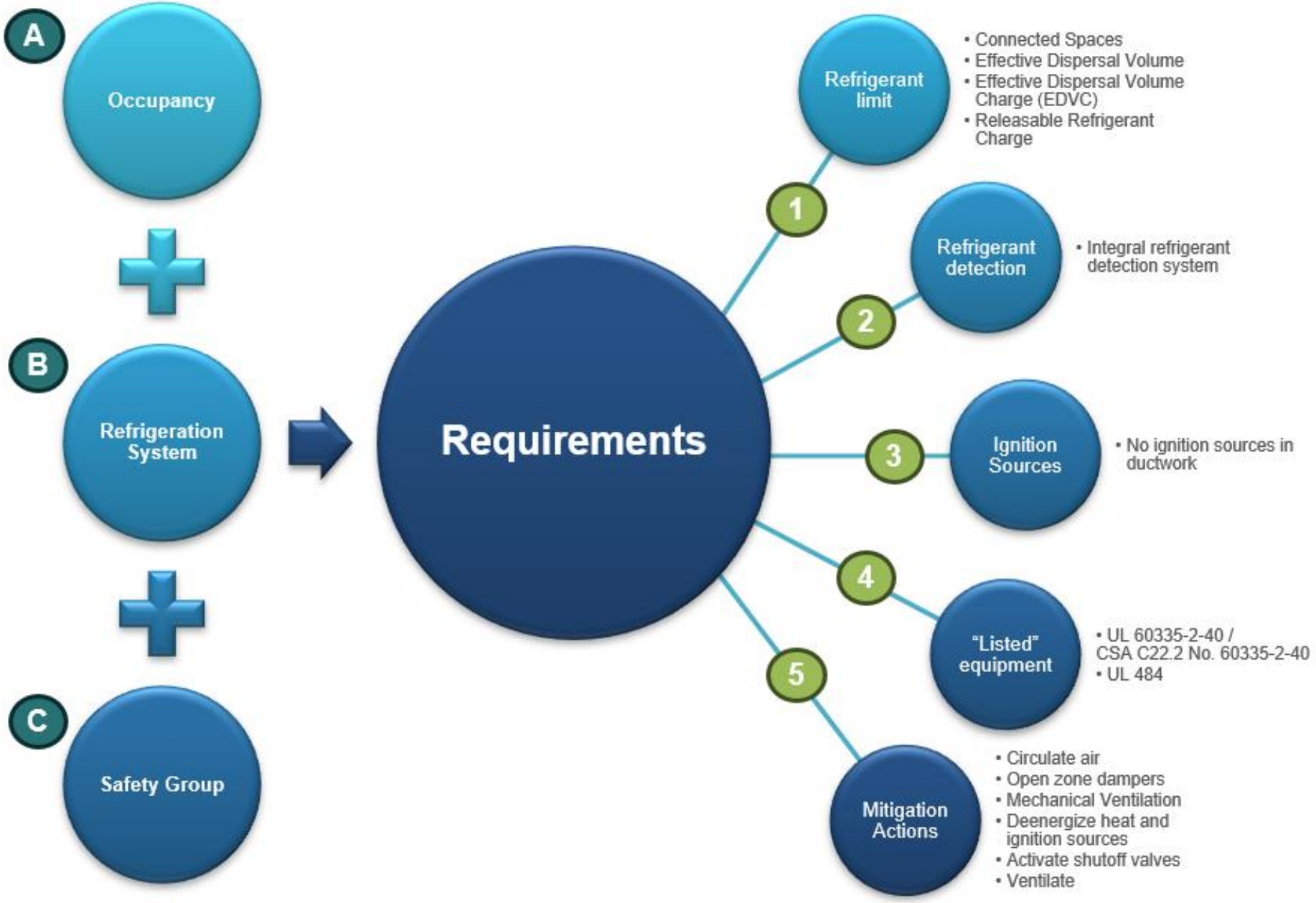
Safety Standard for Refrigerant Systems

ASHRAE Standard 15 specifies requirements for the safe design, construction, installation, and operation of refrigeration systems.

- Changes to **refrigerant use restrictions**, especially for A2Ls
- Refrigerant overpressure protection and **piping**
- Volume and **refrigerant charge limit** calculations
- **Refrigerant detector**/detection and mitigation actions
- Machinery room requirements

*ASHRAE web site has errata sheet corrections and interpretations. Download them.

ASHRAE Standard 15



ASHRAE Standard 15

A

Occupancy Classification

- ASHRAE Standard 15, Section 4

Classification
Institutional
Public assembly
Residential
Commercial
Large mercantile
Industrial
Mixed

- Different occupancy types may require different actions

B

Refrigeration System Classification

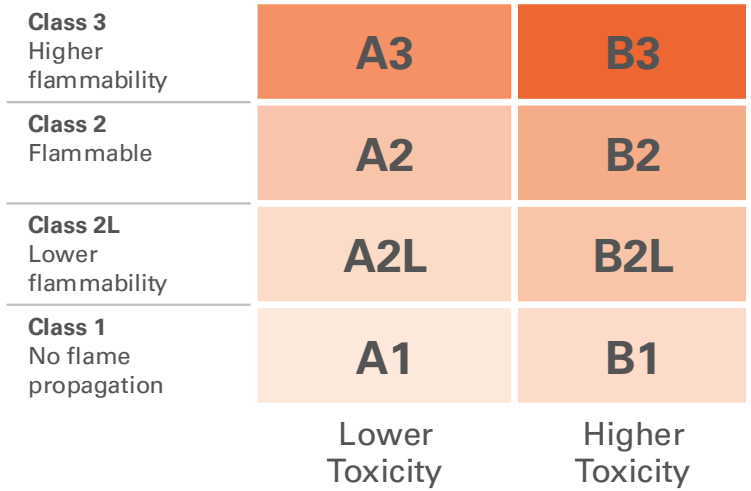
- ASHRAE Standard 15, Section 5

Classification
High Probability
Low Probability

C

Safety Group

- ASHRAE Standard 15, Section 6
- Per ASHRAE Standard 34



Refrigeration System Classification

B

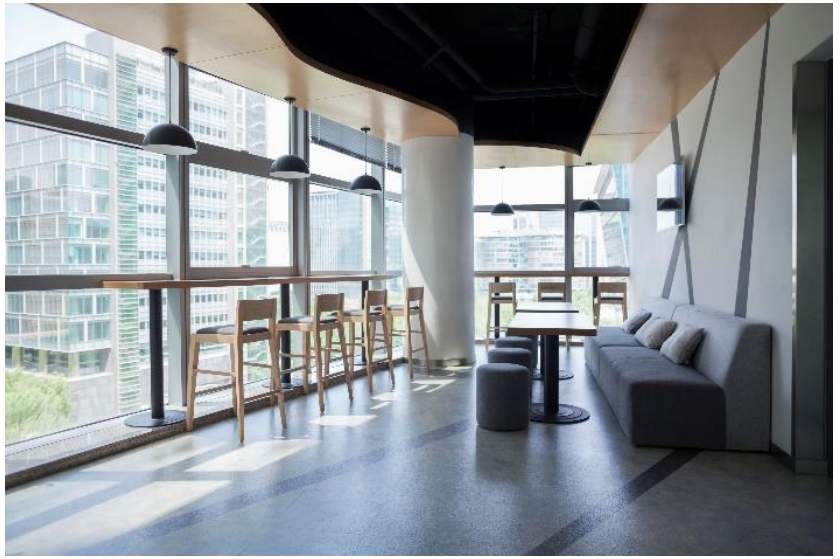
Classification	Definition	Examples
High Probability	Any system where leakage of refrigerant has **high probability to enter the occupied space**.	**Direct Systems** • Direct expansion (DX) split system • Packaged RTU • Water source heat pump • VRF • PTAC
Low Probability	Any system where leakage of refrigerant **cannot enter the occupied space**.	**Indirect closed systems** • Water-cooled chiller in machinery room • Air-cooled chiller outdoors • Water-to-water heat pump in machinery room

How Will ASHRAE 15-2022 Requirements Impact You?

System Design

- Unit refrigerant charge must be checked against the volume of the spaces it serves
  - Differs by occupancy type and refrigerant safety group
  - Both occupied and non-occupied spaces for A2Ls
  - Spaces with refrigerant piping must be included (some exceptions apply)
- Restrictions on type of system or refrigerant used in certain areas
  - E.g. lobbies, public corridors
- Refrigerant piping that passes through spaces may require special testing and/or construction

Lobbies



Institutional Occupancies

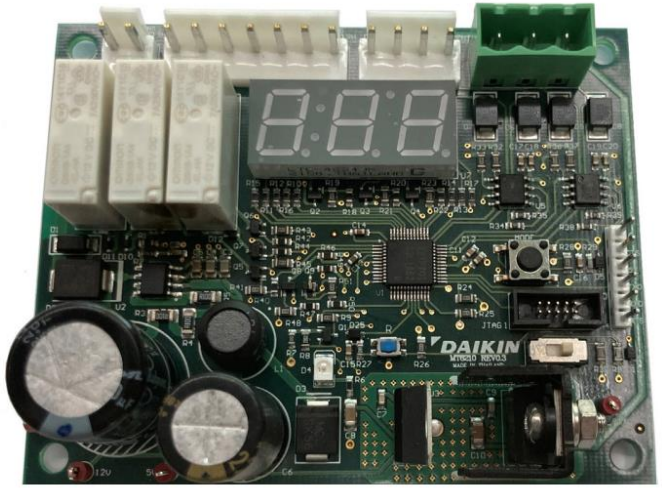
How Will ASHRAE 15-2022 Requirements Impact You?

Installation / Controls Integration:

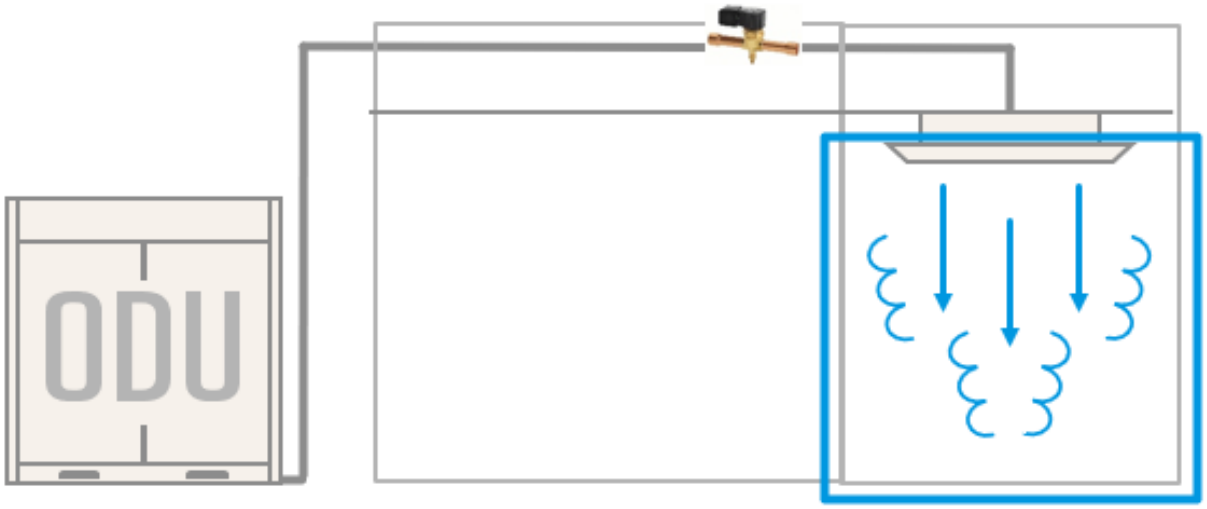
Units may require a ‘Refrigerant Detection System’ (RDS) or ‘Release Mitigation Controls’

- Hardware is required to complete certain functions and **output specific signals**
- **Installers may need to connect these signals** to other parts of the HVAC system
  - e.g. dampers, ventilation fans, electrical interlocks, release mitigation controls, etc
- Release Mitigation Controls:
  - Connected to RDS
  - Limits amount of refrigerant that can leak
  - Mostly used on smaller split systems, limited to indoor units of 5 Tons or smaller

Refrigerant Detection System



Release Mitigation Controls

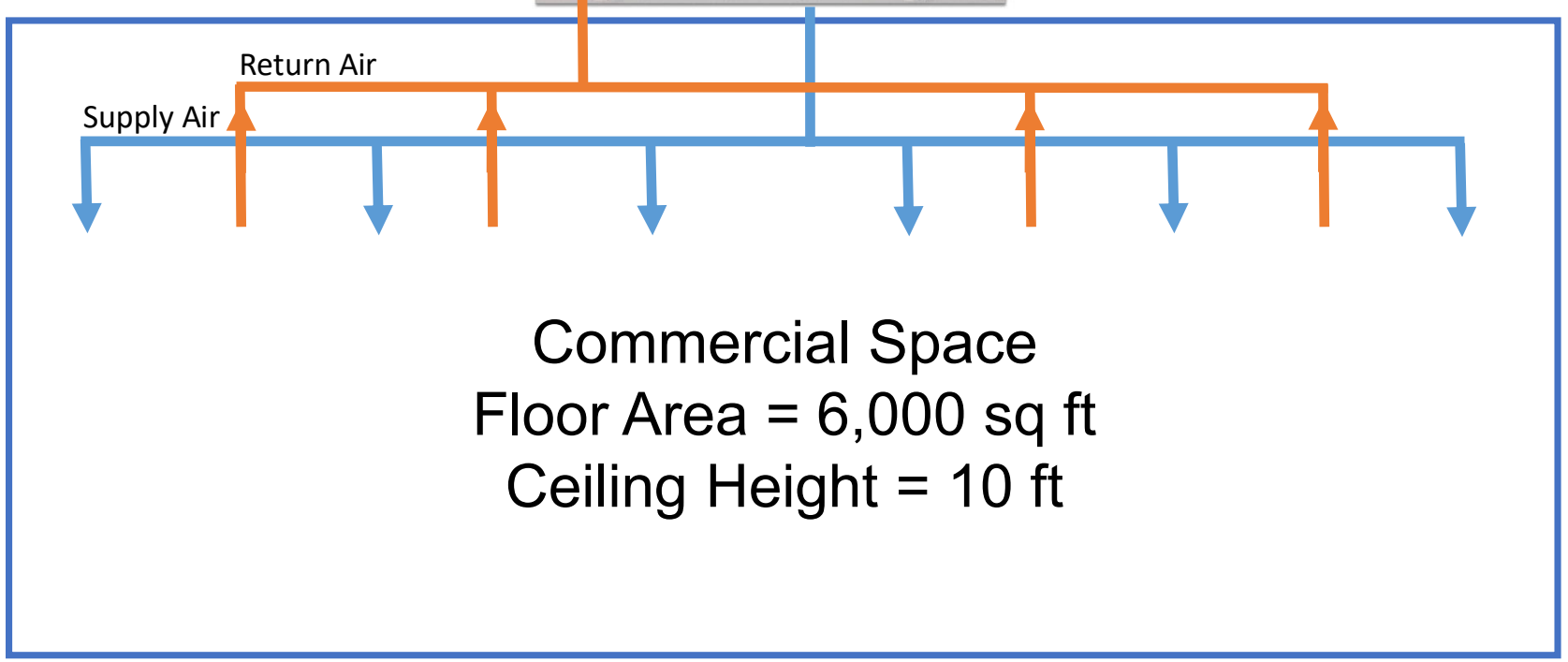


Refrigerant Limits: EDVC Calculation

1

20T HP RTU

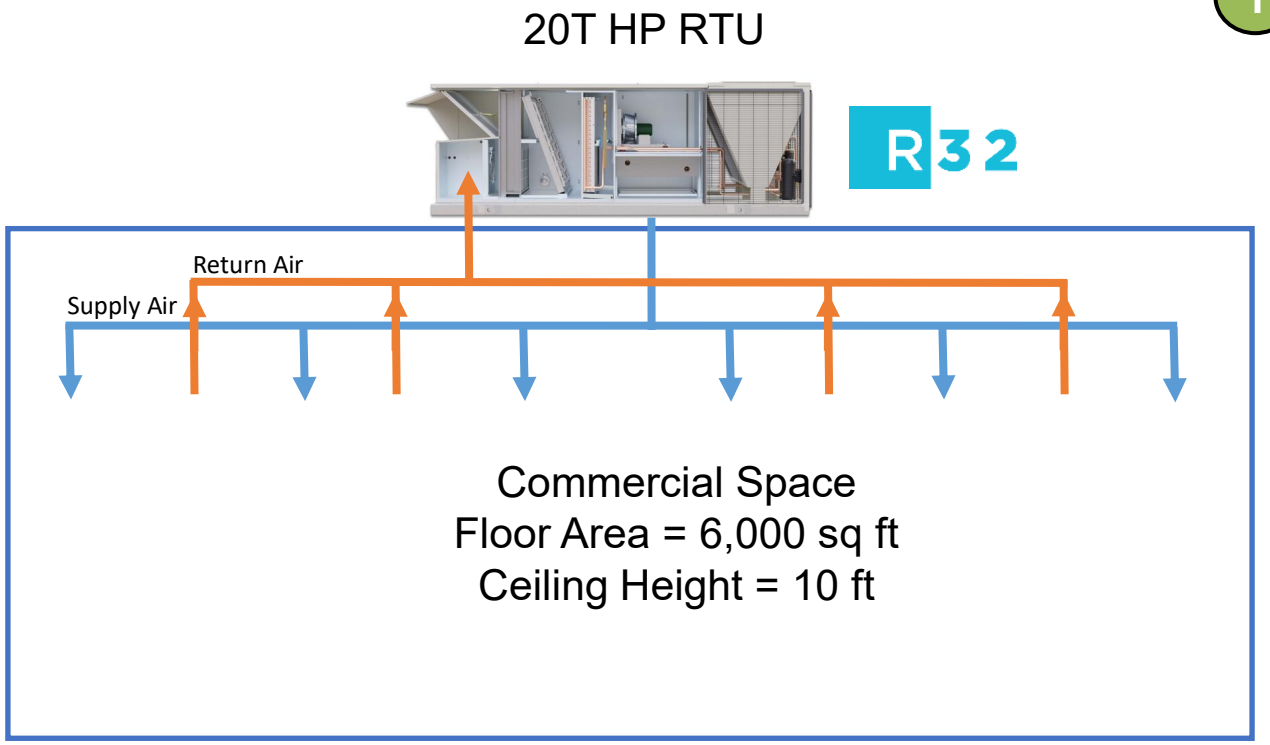
R32



Refrigerant Limits: Example EDVC Calculation

1

- Identify:
  - Occupancy classification: **Commercial, F_{occ} = *1.0***
  - Refrigeration system classification: **High probability**
- Look up:
  - Refrigerant LFL in ASHRAE Standard 34, Table 4-1 = **0.0191 lb/ft³**
- Determine the releasable refrigerant charge, m_{rel}
  - **m_{rel} = 31.2 lb**
- Calculate EDVC per ASHRAE Standard 15, Section 7.6.1.1, where unit has air circulation initiated by refrigerant detection



$$EDVC = Veff \times LFL \times CF \times Focc$$

$$EDVC = 573\ lb$$

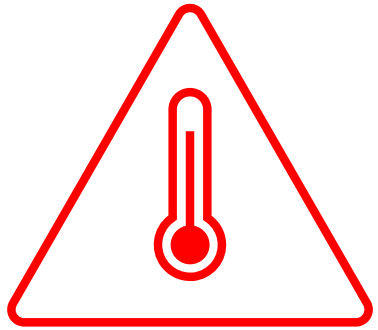
$$EDVC = 60{,}000\ ft^3 \times 0.0191 lb/ft^3 \times 0.5 \times 1.0$$

Ignition Sources for A2Ls

Ignition Sources in Ductwork

- Open flame producing devices shall not be permanently installed in ductwork
- Unclassified electrical devices shall not be located in ductwork
- No devices with hot surfaces exceeding 1,290°F
  - Unless air flow velocity exceeds 200 ft/min
  - And, there is proof of air flow when the device is energized

Generally, the idea is to have heat sources in a listed unit, rather than separately in the ductwork



Listed Equipment

Product Safety Standard(s)

- Refrigeration systems must be listed in accordance with **UL 484 or UL 60335-2-40 / CSA C22.2 No. 60335-2-40** for HVAC equipment with A2L refrigerants
- Requires certain information that OEMs must include in IOMs. For example:
  - Spaces where refrigerant pipes are allowed
  - Handling, installation, cleaning, servicing and disposal of refrigerant
- ***Always refer to the manufacturer's IOM for specific installation requirements!***

Refrigerant Piping

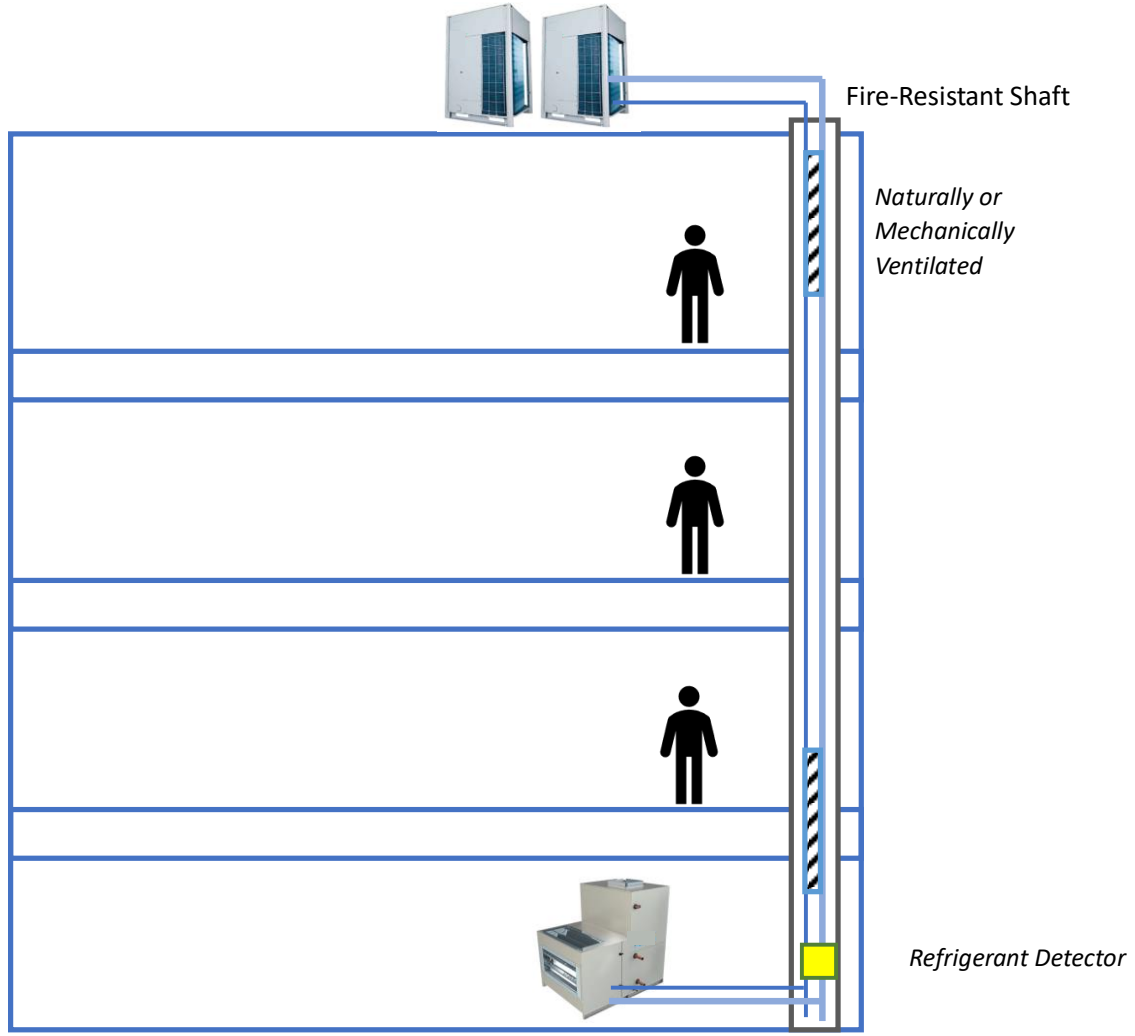
Are you penetrating two or more floor/ceiling assemblies?

Refrigerant piping requires special construction per ASHRAE Standard 15 Section 9.12. Some examples (there are more):

- Refrigerant piping **that penetrates multiple floor/ceiling assemblies shall be permitted to be enclosed in a fire-resistance-rated shaft enclosure**.
- Refrigerant pipe shafts with systems **using only Group A2L or B2L refrigerants shall be naturally or mechanically ventilated**.

IMC 1109.2.5 Refrigerant pipe shafts

- Refrigerant piping that **penetrates two or more floor/ceiling assemblies shall be enclosed in a fire-resistant rated shaft enclosure.** The fire-resistant-rated shaft enclosure shall comply with Section 713 of the *International Building Code.*



Summary

Transition is Underway	Refrigerant Change Supports Decarbonization	ASHRAE 15 High Probability Systems
• Our industry can safely commercialize low GWP refrigerants to reduce the impact of global warming • Keep an eye on the latest EPA rules • Order equipment in time to meet your project schedule!	• It isn't all about GWP • Efficiency is arguably more critical, especially in the near term • Your grid emissions factor has a big impact on the 'indirect' effect	• New equipment may ship with refrigerant detection or SSOVs • Contractors must interconnect these signals in the system • Check charge and refrigerant piping considerations in your designs

Where can I learn more?

Where Can I Go for Information?

General Guidance:

- https://www.daikinapplied.com/training
- https://www.ahrinet.org/saferefrigerant
- https://www.escogroup.org/training/lowgwprefrigerant.html
- https://www.acca.org/education/a2l-refrigerants
- https://www.rses.org/training/lowgwpa2l.aspx
- https://www.r32reasons.com/
- https://www.ashrae.org/technical-resources/bookstore/ashrae-refrigeration-resources
- https://www.achrnews.com/articles/153195-understanding-a2l-refrigerants
- https://www.esmagazine.com/articles/99996-a2l-refrigerants-safely-addressing-refrigerant-flammability-concerns

Where Can I Go for Information?

Building Codes:

- https://www.iccsafe.org/products-and-services/i-codes/a2l-refrigerants-transition/
- https://www.ahrinet.org/a2l-refrigerant-building-code-map?state=OH#map
- https://www.ashrae.org/technical-resources/standards-and-guidelines/read-only-versions-of-ashrae-standards
- https://www.iapmo.org/media/31999/2024-umc-code-changes-randy-young.pdf
- https://www.iccsafe.org/products-and-services/i-codes/a2l-refrigerants-transition/

Presentations and Podcasts

- https://www.ashrae.org/news/ashraejournal/ashrae-journal-podcast-episode-37
- AHRI Webcast Series
  - An Introduction to A2L Refrigerants
  - A2L Refrigerants Webinar Series Part 2 - Updates to Standards and Model Codes
  - A2L Refrigerants Webinar Series Part 3: State and Local Codes and Available Resources

Where Can I Go for Information?

For more information, contact:

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Thank you!