REFRIGERANTS: PAST, PRESENT AND FUTURE

Matthew Piscopo – Technical Sales Engineer
Carrier Corporation

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- Link is also available on landing page
- Complete the Knowledge Check within 60 days

SESSION OBJECTIVES

At the end you should be able to:

1. Identify the refrigerant types that are ozone depleting substances
2. Distinguish the regulations that phased out ozone depleting substances
3. Identify key aspects of how refrigerant emissions are related to climate change
4. Distinguish the regulations that phase down HFC refrigerants, along with key elements of their scope and requirements
5. Associate refrigerant safety classifications listed in ASHRAE Standard 34 with appropriate letter and number designations
6. Identify various direct and indirect product-related factors that impact global warming

REFRIGERANTS

Today’s Topics:

- Historical Perspective
- Refrigerants and the Environment
- Regulatory Activity
- Codes & Standards
- Planning for the Future

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EARLY REFRIGERANTS

Early Refrigerants

Ammonia (NH_3)	Toxic and Flammable
Methyl Chloride (CH_3Cl)	Toxic and Flammable
Sulfur Dioxide (SO_2)	Toxic

At that time, engineering and codes had not evolved to provide for safe usage of these toxic and flammable refrigerant types.

The Cold Storage Building at the 1893 Chicago World's Fair, known as the "Greatest Refrigerator on Earth" using Ammonia caught fire, killing 13 firefighters and 4 civilians.

Several fatal accidents occurred in the 1920s due to refrigerant leaks from domestic refrigerators, and people started leaving their refrigerators in their backyards.

In 1928, Thomas Midgley, a mechanical engineer and chemist working with GM's refrigerator division, Frigidaire, began the search for a **non-toxic**, **non-flammable** and **cheap** refrigerant.

https://www.history.com/news/cfcs-leaded-gasoline-inventions-thomas-midgley
https://www.firehero.org/2022/07/25/chicago-worlds-fair-cold-storage-fire/
https://www.energy.gov/energysaver/energy-saver-history-timeline-refrigeration-and-refrigerators

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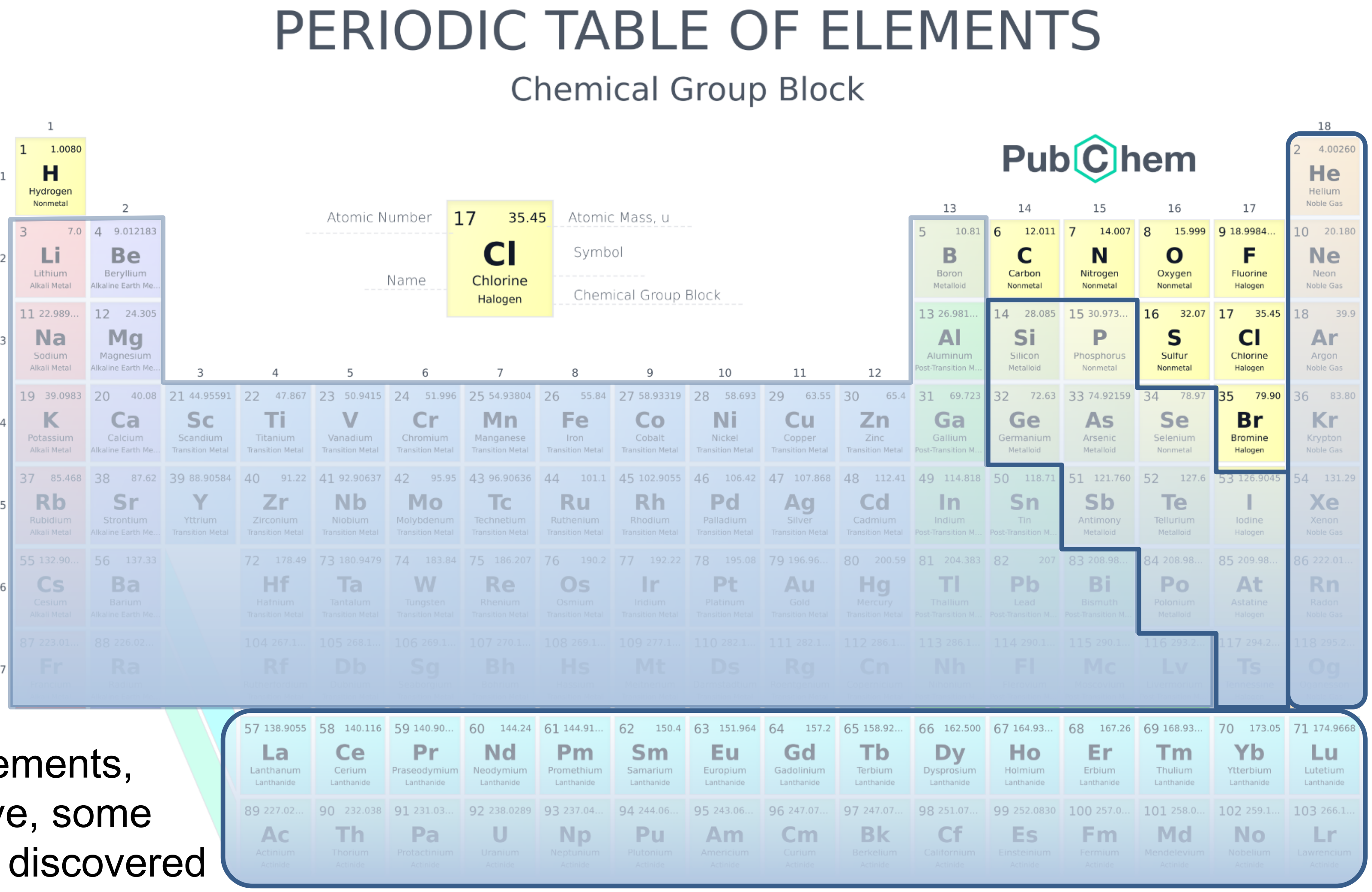
BASIC ELEMENTS



Metals, solids, or have the tendency to form solids

Inert gases do not react with other elements

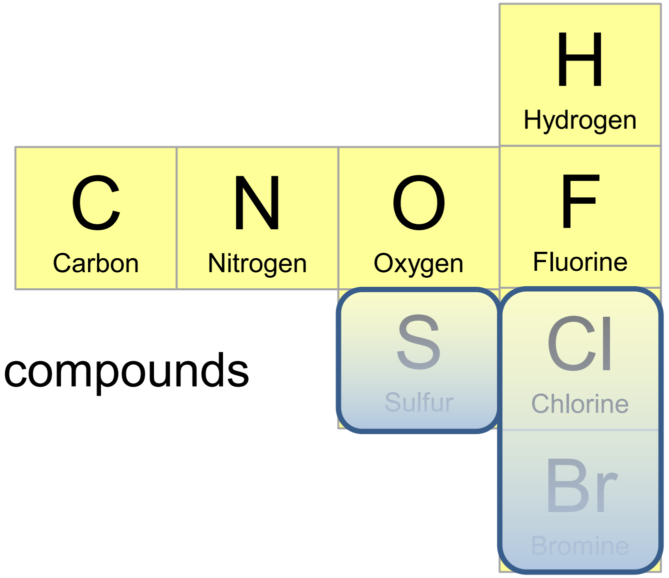
Unstable or toxic

Rare, expensive elements, some are radioactive, some were more recently discovered

https://pubchem.ncbi.nlm.nih.gov/periodic-table/

REFRIGERANT COMPOUNDS

Thomas Midgley identified 8 elements that could be used to create a refrigerant molecule.



Sulfur forms toxic compounds

When chlorine and bromine atoms come into contact with ozone in the stratosphere, they destroy ozone molecules.

1930: Thomas Midgley announced the development of a new refrigerant that would later become known as R-12 or Freon-12. First of the chlorofluorocarbons, better known as CFCs.

Low toxicity, non-flammable, and relatively inexpensive to make

https://www.epa.gov/ozone-layer-protection/basic-ozone-layer-science

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REFRIGERANTS

Composition Designating Prefixes

CFC-12	chlorofluorocarbons
HCFC-22	hydrochlorofluorocarbons
HFC-134a	hydrofluorocarbons
HFO-1234ze(E)	hydrofluoroolefins

Blends can be mixtures of HFC/HFO

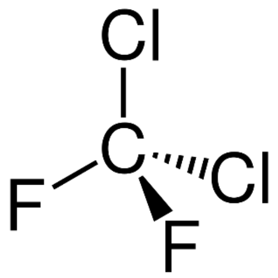
Ozone Depletion Potential (ODP)

ODP is compared to R-11, which is assigned a value of 1

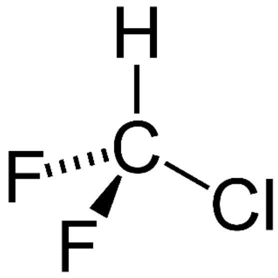
Global Warming Potential (GWP)*

GWP is compared to CO_2 with is set to 1

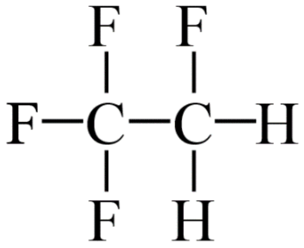
*IPCC AR4 Report for 100-year GWP levels



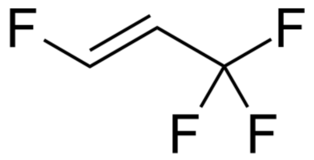
CFC-12
ODP = 0.82
GWP = 10,900
Lifetime = 102



HCFC-22
ODP = 0.04
GWP = 1810
Lifetime = 11.9



HFC-134a
ODP = 0.0
GWP = 1430
Lifetime = 13.4



HFO-1234ze(E)
ODP = 0.0
GWP = 0.79
Lifetime = 0.045

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OZONE DEPLETION

Ozone layer absorbs all UV-C rays and most UV-B rays
UV-B rays penetrate skin deepest, can cause melanoma cancer
UV-C rays are harmful to the eyes

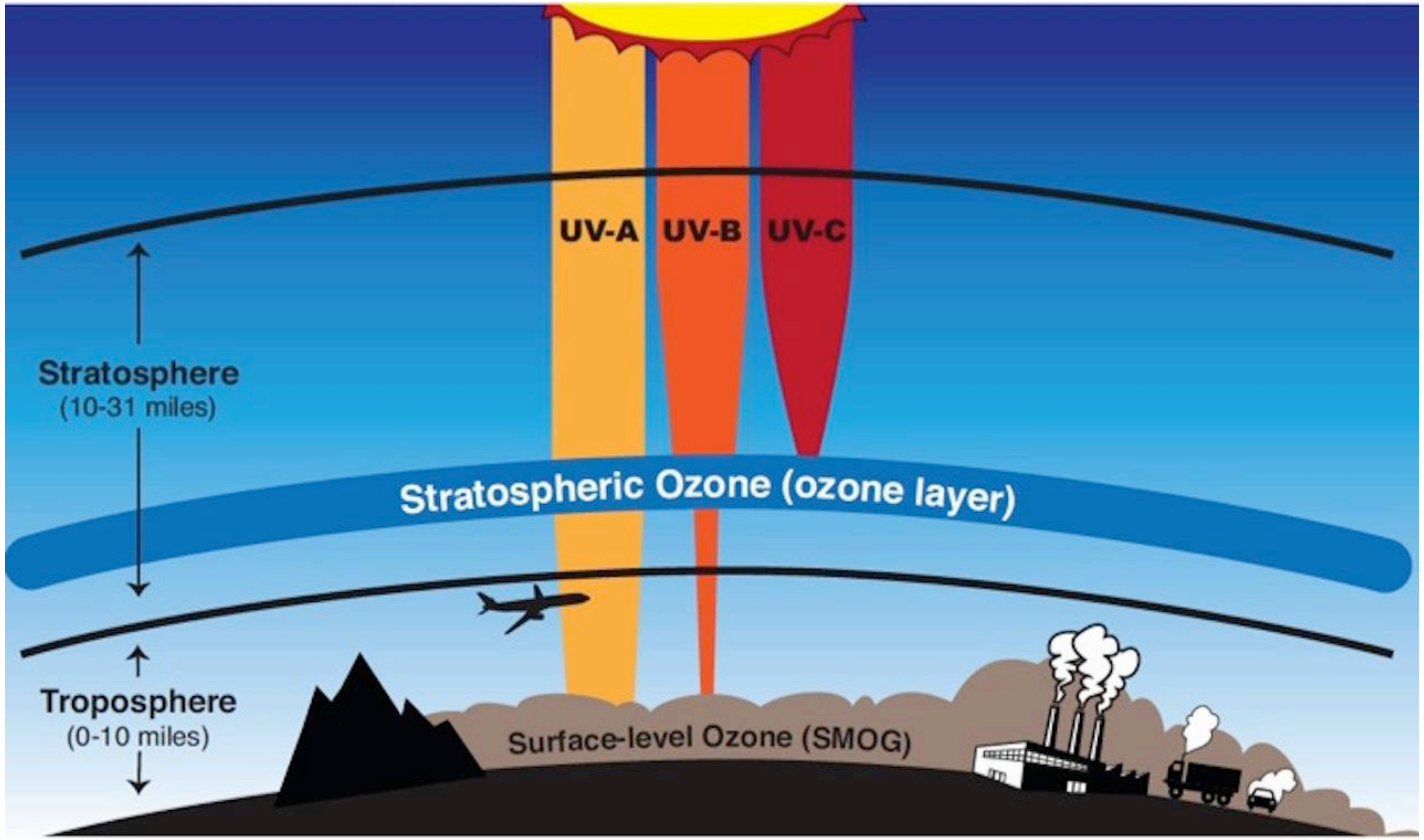


Image Credit: NASA

1974: Chlorofluorocarbons (CFCs) are determined to be ozone-depleting substances (ODS)

ODSs are carried into the Earth's stratosphere

- Cl-C and F-C bonds are very stable
- No natural process to remove them from the lower atmosphere
- ODSs release chlorine when exposed to intense UV light in the stratosphere
- Chlorine destroys ozone

Hydrochlorofluorocarbons (HCFCs) were introduced as a temporary replacement for CFCs due to their lesser potential to deplete the ozone layer

https://www.epa.gov/ozone-layer-protection/basic-ozone-layer-science
https://www.nist.gov/blogs/taking-measure/refrigerants-rescue-plugging-ozone-hole

ODS REGULATION

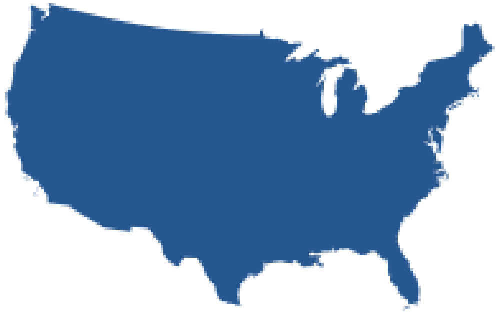
INTERNATIONAL

Montreal Protocol
ODS Regulation

1987: Generally considered one of the most successful international agreements

Complete phase out of CFCs and HCFCs, ozone depleting substances

U.S. FEDERAL



Clean Air Act
ODS Regulation

1990: Congress amended the Clean Air Act

Gave the EPA authority to regulate the use and production of ozone depleting substances.

Significant New Alternatives Policy (SNAP)

SNAP was established under Section 612 of the Clean Air Act to identify and evaluate substitutes for ozone-depleting substances.

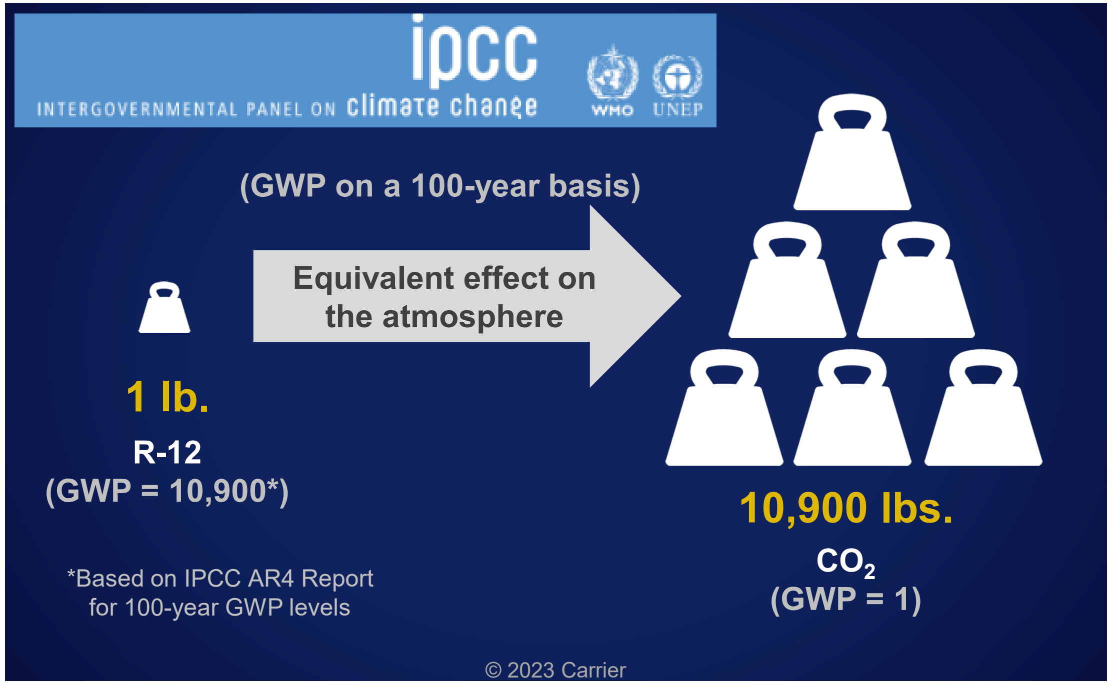
List acceptable alternatives

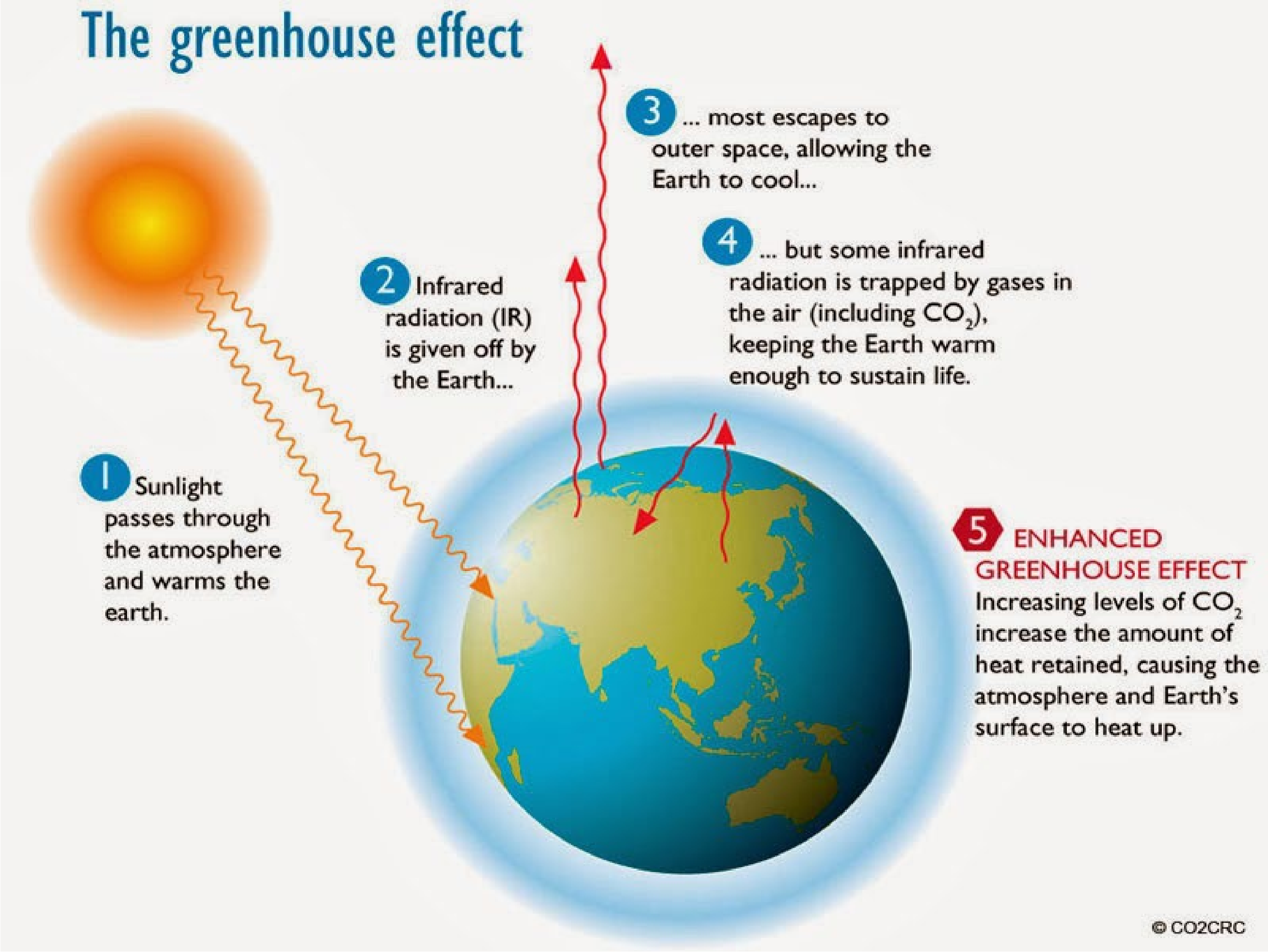
https://www.epa.gov/ozone-layer-protection/international-actions-montreal-protocol-substances-deplete-ozone-layer
https://www.epa.gov/ods-phaseout/phaseout-class-ii-ozone-depleting-substances
https://www.epa.gov/snap

CLIMATE CHANGE

Intergovernmental Panel on Climate Change (IPCC)

Established in 1988 by WMO and UNEP to:
- Assess available scientific information
- Assess the impacts of climate change
- Formulate response strategies





https://www.ipcc.ch/about/
http://www.co2crc.com.au/wp-content/uploads/2016/04/Generic-brochure_for-web.pdf
www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
https://www.ipcc.ch/

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HFC REGULATION

INTERNATIONAL

Kigali Amendment
HFC Phase Down Regulation

EUROPE

F-Gas Regulation
EU HFC Phase Down

U.S. FEDERAL

Clean Air Act
Significant New Alternatives Policy (SNAP) - Lists acceptable refrigerants

American Innovation and Manufacturing (AIM) Act
2020: Gave EPA authority to regulate HFC and HFC blends based on GWP

U.S. STATE

California Air Resource Board (CARB)
California SNAP implements Vacated SNAP Rules 20 & 21

State Adoption of Vacated SNAP Rule 21
11 additional states

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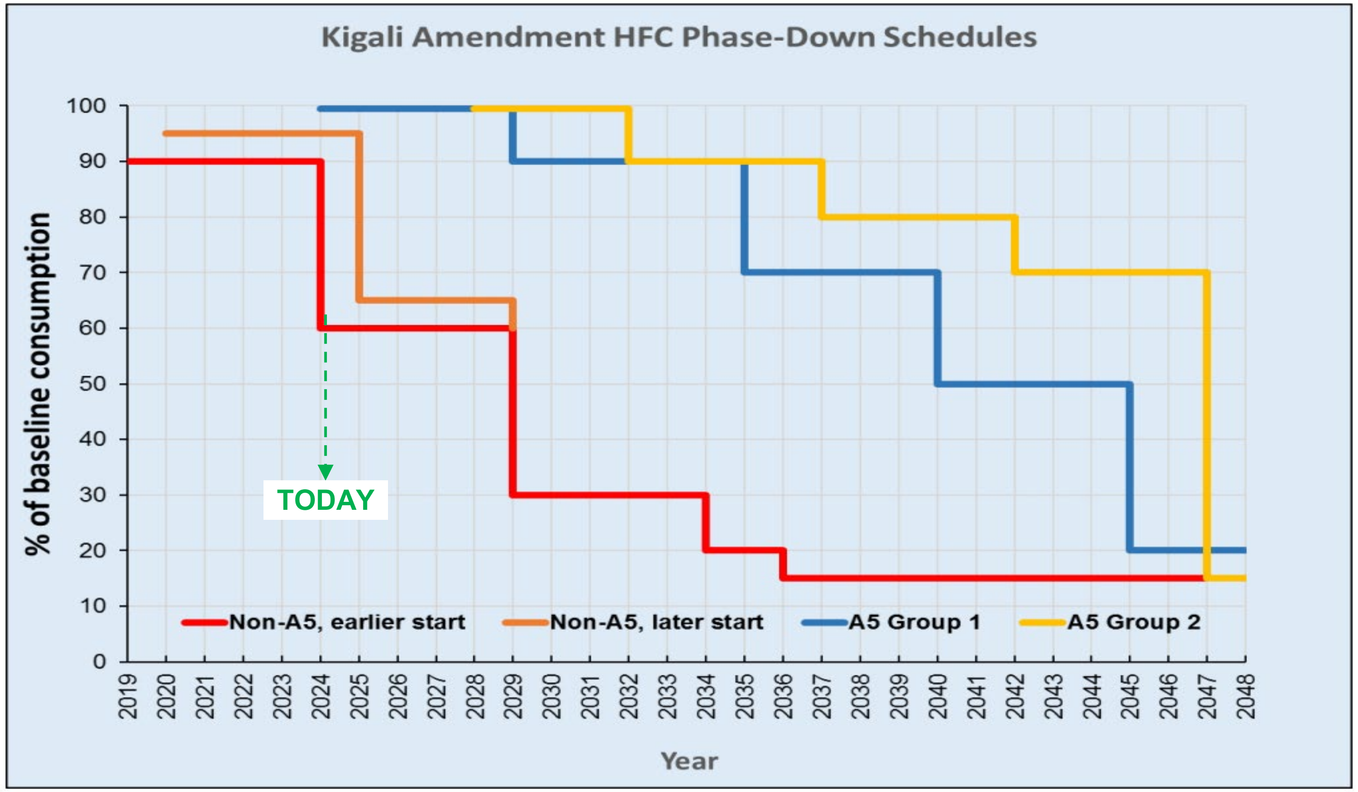
KIGALI AMENDMENT

2016: Kigali Amendment to the Montreal Protocol was adopted to phase down HFCs
Countries committed to cut production and consumption of HFCs by more than 80 percent over the next 30 years
US ratified the Kigali Amendment in 2022; 156 countries have ratified the Kigali Amendment as of Jan 2023



	A5 Group 1	A5 Group 2	Non-A5
Baseline	2020-2022	2024-2026	2011-2013
Formula	Average HFC consumption	Average HFC consumption	Average HFC consumption
HCFC	65% baseline	65% baseline	15% baseline*
Freeze	2024	2028	-
1st step	2029 – 10%	2032 – 10%	2019 – 10%
2nd step	2035 – 30%	2037 – 20%	2024 – 40%
3rd step	2040 – 50%	2042 – 30%	2029 – 70%
4th step			2034 – 80%
Plateau	2045 – 80%	2047 – 85%	2036 – 85%

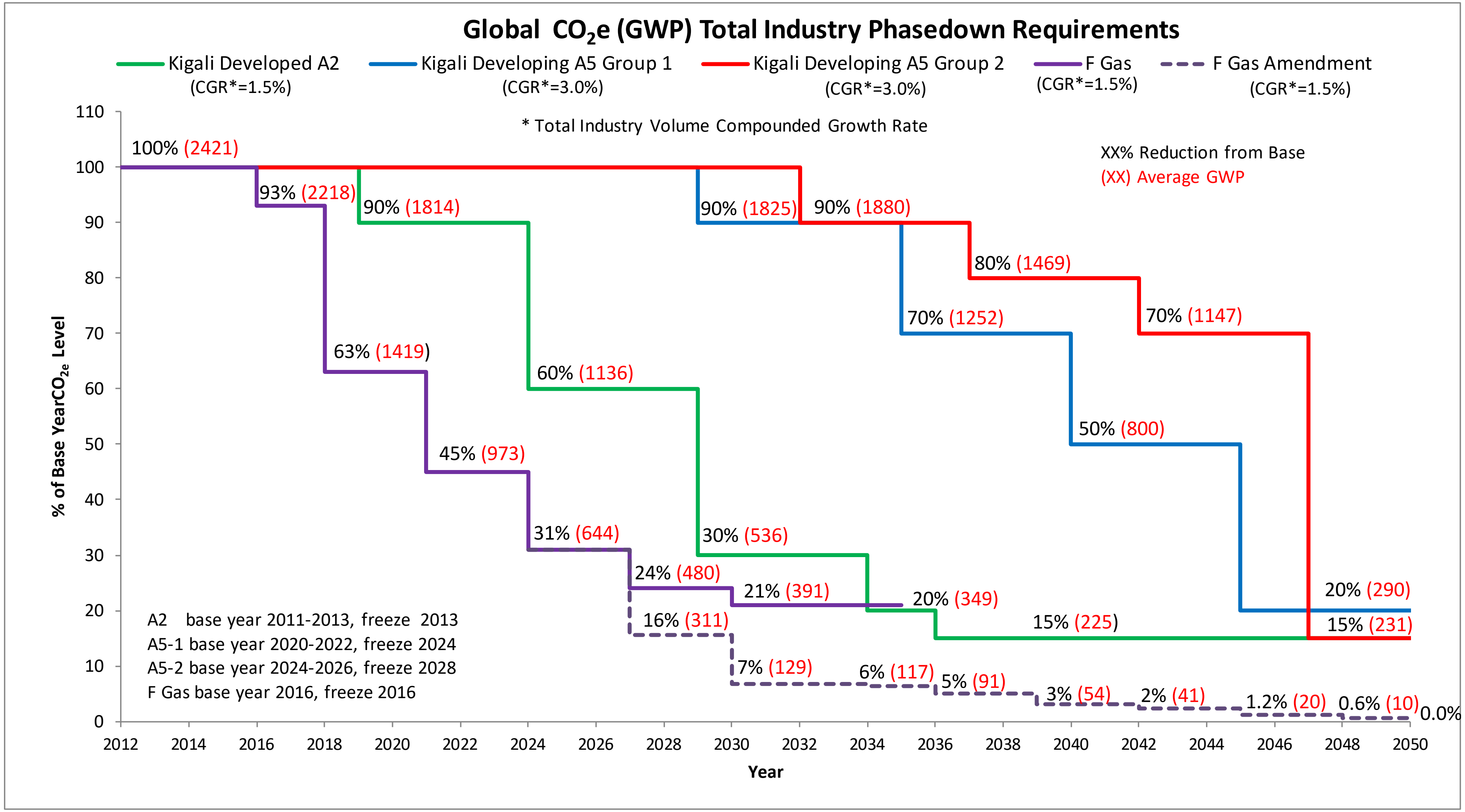
*For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan 25% HCFC component of baseline and different initial two steps (1) 5% reduction in 2020 and (2) 35% reduction in 2025

A5 Group 2: Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, United Arab Emirates

A5 Group 1: Article 5 parties not part of Group 2

https://www.epa.gov/ozone-layer-protection/recent-international-developments-under-montreal-protocol
https://ozone.unep.org/countries

EU F-GAS REGULATION



New EU F-Gas Regulation provisional agreement will accelerate phase-down of F-Gas quota in 3 steps between 2024 and 2030 (25%, 10%, 5%). Final vote in Jan 2024.

Applies to European Union only (does not include UK)

In 2030, refrigerants with GWP >> 100 (R-134a, R-32, R-513A) expected to be phased out in EU.

EU goal is to reach carbon neutrality in 2050.

https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/eu-legislation-control-f-gases_en

U.S. EPA – CLEAN AIR ACT

Significant New Alternatives Policy (SNAP)

Clean Air Act, section 612

EPA's list of acceptable refrigerant substitutes that do not present significant risk to:

- Human health &
- The environment

Criteria considered:

- Flammability
- Toxicity
- Environmental impacts on air quality & atmosphere

https://www.epa.gov/snap/substitutes-refrigeration-and-air-conditioning

https://www.epa.gov/snap

A few SNAP approved refrigerants listed by product type:

Residential & Light Commercial A/C and HP	Centrifugal & Positive Displacement Chillers
R-32	R-32
R-454B	R-454B
	R-513A
	R-514A
	R-515B
	R-1234ze(E)
	R-1233zd(E)

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U.S. EPA – AIM ACT

2020 American Innovation and Manufacturing Act of 2020 (AIM Act) signed into law

AIM Act regulates HFCs and HFC blends based on GWP:

1. Phase down production and consumption of HFCs & HFC blends
2. Maximize reclamation and minimize release of HFCs & HFC blends
3. Facilitate transition to substitutes through sector-based restrictions

2021 AIM Act rule: Phasedown HFC production and import by 85% by 2036

Follows the phasedown schedule of the **Kigali Amendment**

EPA **SNAP Rules** provide prescriptive requirements by product type

Year	Consumption & Production Allowance Caps as a Percentage of Baseline
2022–2023	90 percent
2024–2028	60 percent
2029–2033	30 percent
2034–2035	20 percent
2036 & after	15 percent

2023 AIM Act: Technology Transitions Program Interim Final Rule

1. Set a maximum GWP limit on HFCs and HFC blends
2. Prohibits manufacture and import of products that use higher-GWP HFCs
3. Prohibits installation of new RACHP systems that use higher-GWP HFCs

Based on information as of December 2023, may be subject to change.

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

https://www.epa.gov/climate-hfcs-reduction/regulatory-actions-technology-transitions

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U.S. EPA - AIM ACT

Technology Transitions Program Interim Final Rule - December 2023

The EPA makes a distinction between "Products" and "Systems"

"A product is functional upon leaving the factory." i.e., factory charged with refrigerant & a sealed refrigerant circuit

"Products":

- Max GWP level threshold by subsector
- **Manufacturing date** deadline
- Sale & export prohibited three years after compliance date

"A system is assembled, and refrigerant charged in the field using multiple components"

"Systems":

- Max GWP level threshold by subsector
- **Installation date** deadline **(new systems)**
- No restriction on maintenance or repair of existing systems

Based on information as of December 2023, may be subject to change.

https://www.epa.gov/climate-hfcs-reduction/frequent-questions-phasedown-hydrofluorocarbons#difference-products-systems

https://www.epa.gov/climate-hfcs-reduction/regulatory-actions-technology-transitions

U.S. EPA – AIM ACT

Technology Transitions Program Interim Final Rule – Products

Self-contained Refrigeration, Air Conditioning, and Heat Pump Products			
Subsector	**Products**	**Global Warming Potential Limit**	**Manufacture and Import Compliance Date**
Stationary residential and light commercial air conditioning and heat pumps	Stationary residential and light commercial air conditioning and heat pumps (e.g., window units, portable room air conditioning)	700	January 1, 2025
Chillers (as a stand-alone product)	Comfort cooling	700	January 1, 2025
Data centers, computer room air conditioning, and information technology equipment cooling	Data centers, computer room air conditioning, and information technology equipment cooling	700	January 1, 2027

https://www.epa.gov/climate-hfcs-reduction/regulatory-actions-technology-transitions

Information as of October 5, 2023, subject to change

U.S. EPA – AIM ACT

Technology Transitions Program Interim Final Rule – Systems

Refrigeration, Air Conditioning, and Heat Pump Systems			
Subsector	**Systems**	**Global Warming Potential Limit**	**Installation Compliance Date**
Stationary air conditioning and heat pumps	Residential and light commercial air conditioning and heat pump systems	700	January 1, 2025*
	Variable refrigerant flow systems	700	January 1, 2026
Chillers	Comfort cooling	700	January 1, 2025
Data centers, computer room air conditioning, and information technology equipment cooling	Data centers, computer room air conditioning, and information technology equipment cooling	700	January 1, 2027

* New systems with a GWP above 700 can be installed until January 1, 2026, so long as all components are manufactured or imported prior to January 1, 2025

Based on information as of December 2023, may be subject to change.

https://www.epa.gov/climate-hfcs-reduction/regulatory-actions-technology-transitions

STATE REGULATIONS

State adoption of vacated SNAP Rule 21 - restricts R-134a, R-410A & others for new chillers starting Jan 2024

California Cooling Act (SB1013 & SB1206) C.A.R.B. & 11 other states

CALIFORNIA AIR RESOURCES BOARD

New chillers (comfort cooling applications): GWP ≤ 750 as of ***January 1, 2024***.

CA, CO, DE, MA, MD, ME, NJ, NY, RI, VA, VT & WA

Research and understand the local and state laws for your area.

Projects must comply with BOTH federal & state regulations.

https://ww2.arb.ca.gov/
https://usclimatealliance.org/

Information as of September 2023, subject to change

U.S. STANDARDS AND CODES

Seminar SERIES

Refrigerant Standards

- ASHRAE 34 2022

Equipment Standards

- UL 60335-2-40 4th edition

Application Standards

- ASHRAE 15 and 15.2 2022
- ISO and EN (European Standards)

Building Codes
On a 3-year cycle

- International Building Code (IBC)
- International Fire Code (IFC)
- International Mechanical Code (IMC/UMC)
- International Residential Code (IRC)

Local Codes
May take an additional 1 to 8 years to complete

- State, county and local building codes
- Insurance codes

Model Codes approved all major A2L related proposals for the 2024 Edition of the IMC/UMC and IRC

State and local building codes need to be amended for A2L refrigerants

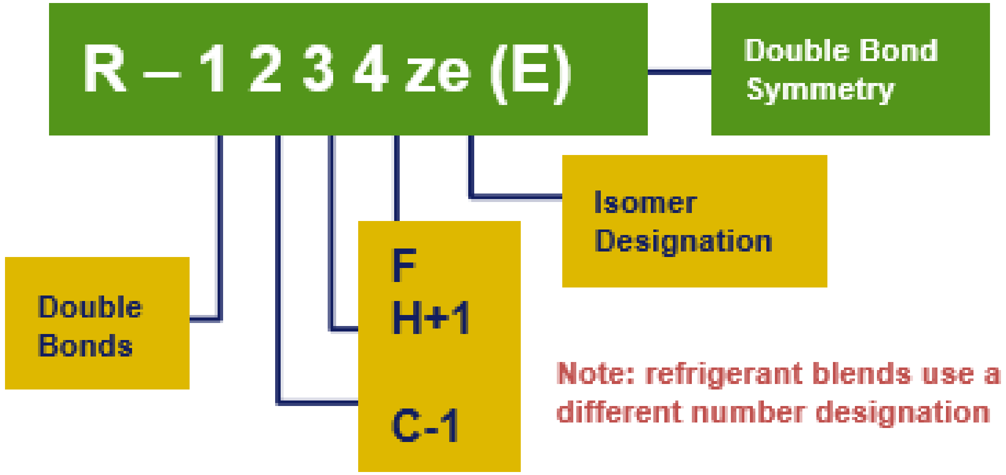
IMC: HVAC
IECC: HVAC
IRC: HVAC, Fire
IFC: Fire, HVAC
2021 Uniform Mechanical Code: HVAC

Completed
In Progress
Not Started

https://www.iccsafe.org/adoptions/

ASHRAE STANDARD 34

Refrigerant Nomenclature Basics



000 series: methane-based compounds (one-carbon)

100 series: ethane-based compounds (two-carbons)

200 series: propane-based compounds (three-carbons)

300 series: cyclic organic compounds

400 series: zeotropic blend

500 series: azeotropic blend (no glide)

An additional upper-case letter indicates a different ratio for the same chemical make up.

600 series: miscellaneous organic compounds

600s = hydrocarbons; 610s = oxygen compounds; 620s = sulfur compounds; 630s = nitrogen compounds

700 series: inorganic compounds

1000 series: unsaturated organic compounds (HFOs: Hydrofluoroolefin)

An additional (E) or (Z) are called stereoisomers

https://www.ashrae.org/technical-resources/standards-and-guidelines/ashrae-refrigerant-designations

ASHRAE STANDARD 34

Increasing flammability ↑

	ASHRAE Safety Classification		Example Refrigerants (Based on Flammability Class)
	Lower Toxicity	Higher Toxicity	
Higher Flammability	**A3**	**B3**	Propane (R-290), Isobutane
Flammable	**A2**	**B2**	R-152
Lower Flammability	**A2L**	**B2L**	R-454B, R-32, R-454A, R-454C, R-1234ze(E)
No Flame Propagation	**A1**	**B1**	R-410A, R-134a, R-513A, R-515B, R-1233zd(E)

Ignites very easily

Potentially Explosive

Ignites Easily
Relatively High Energy Release

"Mildly Flammable"
Difficult to Ignite
Relatively Low Energy Release
Low Flame Speed

Low Grade Coal

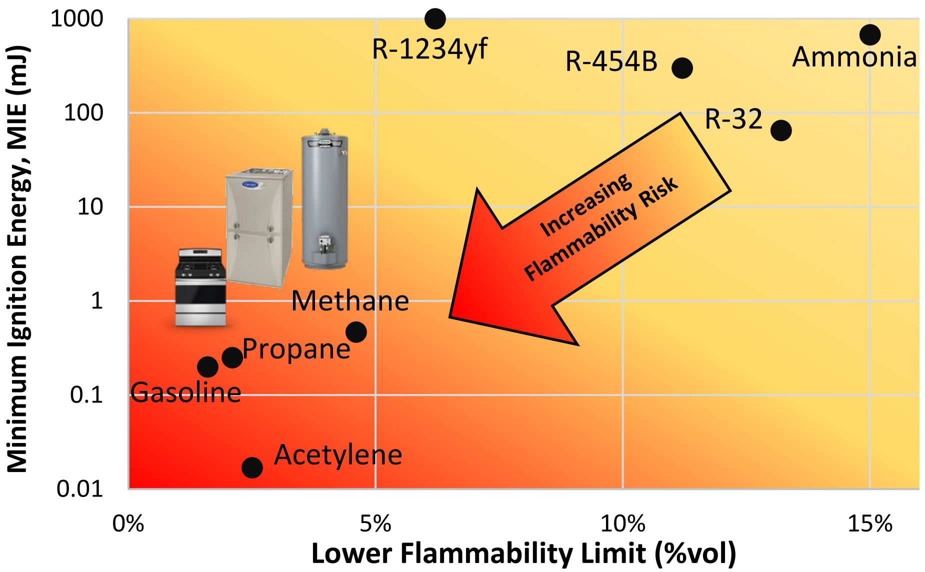
No Flame Propagation

https://www.ashrae.org/

A2L FLAMMABILITY

A2L refrigerant is a low risk...it is simply a new issue

A2L Refrigerants are difficult to ignite

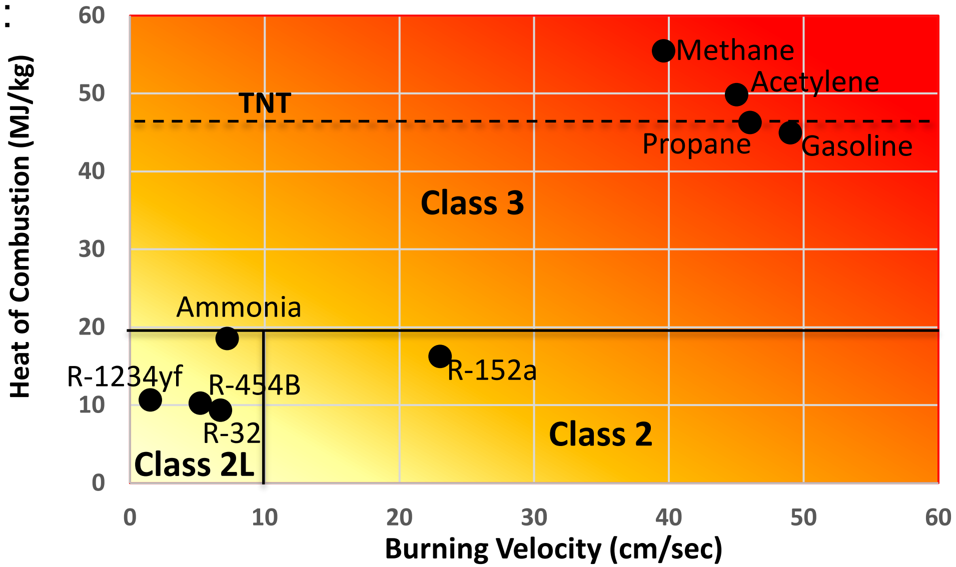


A2L Ignition requires:

High ignition energy

High concentration

If ignited, A2L energy release is low



Most Household Objects are NOT A2L ignition sources:

Receptable & Light Switches

Space Heaters

Kitchen Appliances

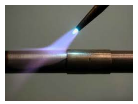
Barbecue Igniter

Cigarette

Potential A2L Ignition Sources:

Match or Lighter

Torch



Candle

Contactor

Addressed by Equipment Safety Standard UL 60335-2-40

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UL STANDARD 60335-2-40

Standard for Safety

Household and Similar Electrical Appliances – Safety – Part 2-40: Particular Requirements for Electrical Heat Pumps, Air-Conditioners and Dehumidifiers

Equipment Standard – basis for the design, evaluation, testing, and certification of HVAC equipment

Defines A2L mitigation requirements:

- Defines refrigerant leak detection system requirements
- Defines refrigerant charge limits based on the minimum occupied volume of the room where the equipment is expected to be used, and a safety factor to ensure any leaked refrigerant is diluted to well below the lower flammability limit (LFL).

As of 1/1/2024 it will replace **UL1995 which will be sunset** except for existing units but any change to an existing unit will require changing to UL60335-2-40

UL60335-2-40 is required for A2L refrigerants and was updated to the **4th edition** which was published in Dec 2022

ASHRAE STANDARD 15

Safety Standard for Refrigeration Systems

Application Standard - Specifies safe design, construction, installation, and operation of refrigeration systems.

Refers to ASHRAE Standard 34 for:

- Refrigerant Safety Classification
- Refrigerant Concentration Limit

The 2022 version of **ASHRAE 15** has been published

- Updated to align with the A2L requirements and mitigation approaches defined in UL60335-2-40 4^{th} edition
- Establishes procedures for operating equipment and systems when using those refrigerants.

ASHRAE Standard 15.2 for residential applications was released by not adopted by building codes yet

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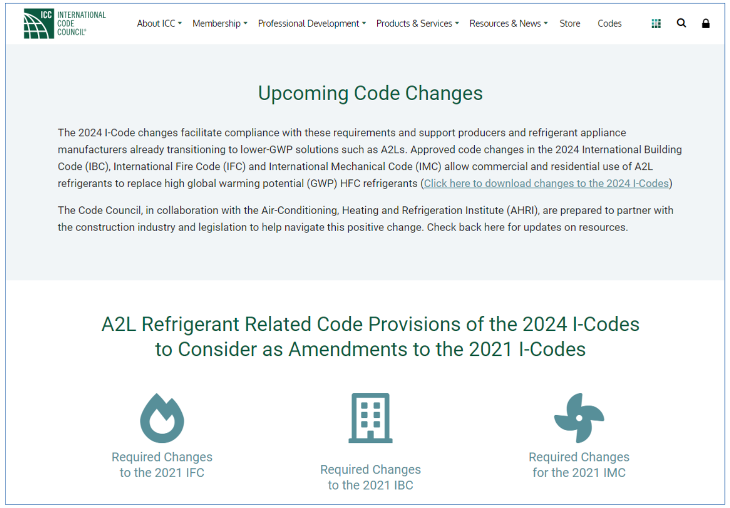
CODE ACCEPTANCE STATUS

2024 Model Codes ready for full acceptance of A2L refrigerants

States and Local jurisdictions will adopt 2024 Model Codes at their own pace – between 2025 and ~2036

State/Local Codes

45 States + DC and counting have enacted A2L acceptance through code changes and/or legislation



On track for **100% acceptance before 1 Jan 2025** (regulatory deadline)

Research and understand the local and state laws for your area.

Projects must comply with BOTH federal & state regulations.

FUTURE ACTIONS?

INTERNATIONAL

Paris Agreement
GHG Emissions

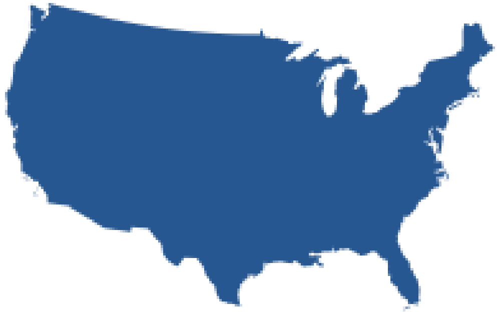
Goal of holding the increase in the global average temperature to well below 2°C above pre-industrial levels.
Countries submit Nationally Determined Contributions (NDC) and action plans.
Reporting begins in 2024.

EUROPE

PFAS Restrictions
EU Proposed PFAS Ban

Known as Forever Chemicals
Proposal to expand PFAS restrictions to band production of most PFAS substances, including many HFC and HFO refrigerants in EU.
Under review by ECHA with assessment due in 2024.

U.S. FEDERAL



American Innovation and Manufacturing (AIM) Act
HFC Phase Down

Next step change will occur in 2029, moving from 40% to 70% reduction versus baseline

U.S. STATE

U.S. Climate Alliance

25 state governors committed to achieving the goals of the Paris Agreement by advancing state-led, high-impact climate action.

https://usclimatealliance.org/
https://unfccc.int/most-requested/key-aspects-of-the-paris-agreement
https://unfccc.int/process-and-meetings/the-paris-agreement
https://echa.europa.eu
https://www.coolingpost.com/world-news/pfas-ban-affects-most-refrigerant-blends/

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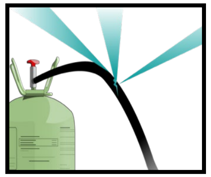
REDUCING EMISSIONS

Total Equivalent Warming Impact (TEWI) = Direct Emissions + Indirect Emissions



DIRECT = Emission x Equivalent CO_2

INDIRECT = Energy Usage x CO_2/kW-hr

Direct Emissions:
GWP of the refrigerant
Optimized selection for the refrigerant used
Quantity (lbs.) of the refrigerant charge
Preventative maintenance
Reclaim/recycle the refrigerant at end of life

EPD®

Environmental Product Declaration
Life Cycle Environmental Impact

Indirect Emissions:
Equipment energy efficiency
Sequence of operation / building automation system
System efficiency using free cooling, economizers, energy recovery & heat recovery
System commissioning for peak building performance
Cleanliness of the local power source
End-of-life disposal plan

https://www.environdec.com/home
https://www.ahrinet.org/system/files/2023-06/ANSI%20AHRI%20Standard%20550%20590-2023%20%28I-P%29.pdf
https://www.airah.org.au/Web/AIRAH/Navigation/Resources/Best_Practice_Guidelines/BPG.aspx?hkey=0d9dfc3a-997c-467f-8f9d-fa1e561042ab

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REFRIGERANTS

Refrigerant Considerations are Multifaceted

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