Refrigerants and Climate Change for Designers

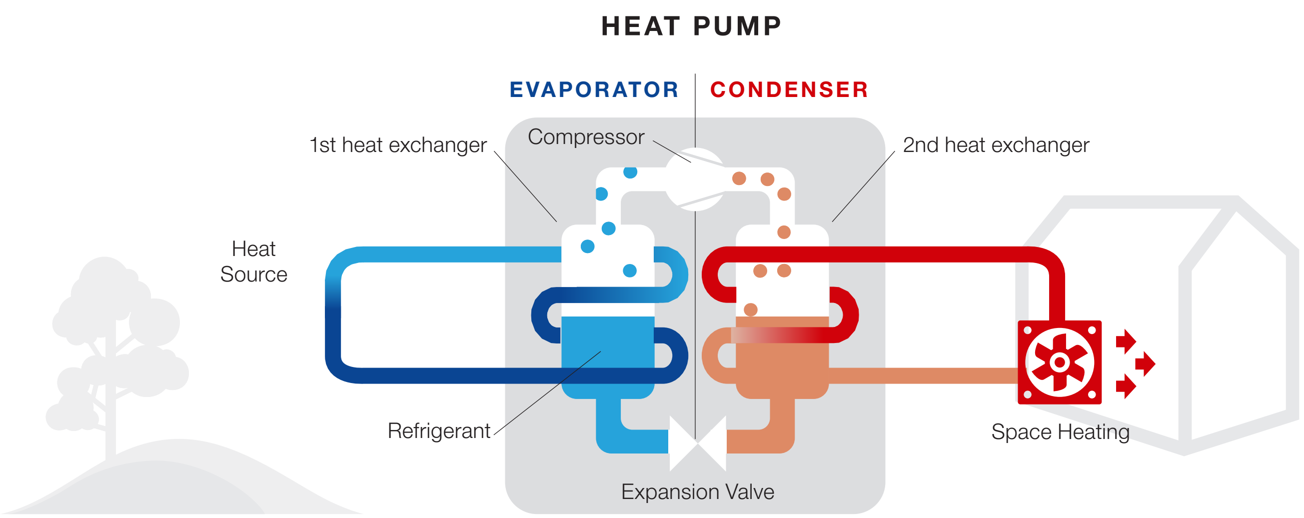
Why are Refrigerants of Concern?

Many refrigerants have a high global warming potential (GWP), so it is crucial that leaks from equipment be repaired promptly and that refrigerants be collected during maintenance and equipment end-of-life.

Fluorinated gas (F-gas) refrigerants are responsible for 2% of total global greenhouse gas (GHG) emissions. Older refrigerants, especially **chlorofluorocarbons (CFCs),** contain high ozone-depleting potential (ODP) and high global warming potential (GWP) ingredients. Modern refrigerants used in heat pumps have a lower ODP, but still have GWPs 2,000 times greater than that of carbon dioxide (CO_2) over a 100-year period. In addition, the most commonly used refrigerant in refrigeration systems, R-404a, has a GWP nearly 4,000 times greater than CO_2. Not all refrigerants are equal, though. There are tens of thousands of refrigerants and blends ranging from zero to 12,500 GWP. According to the International Energy Agency, global refrigerant demand is expected to grow four-fold by 2050 from a global increased demand for cooling and adoption of highly efficient heat pumps to electrify space heating equipment. If unregulated, this expansion in refrigerant use would lead to refrigerants making up a greater percentage of total GHG emissions.

What are Refrigerants?

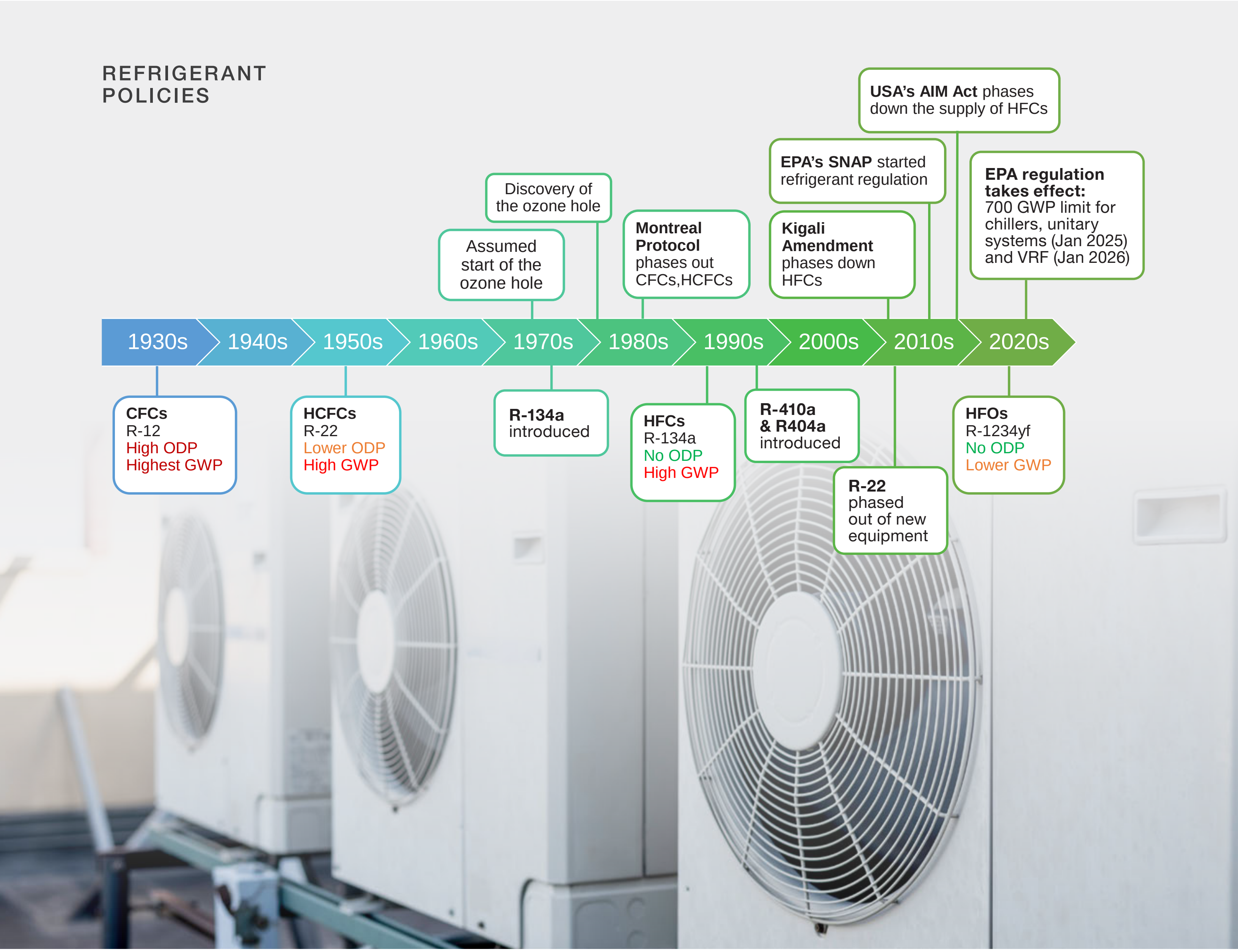
A refrigerant is a liquid or a gas with a very low boiling point. Refrigerants are used to transfer heat. For conventional air conditioning (AC), the refrigerant absorbs heat from the air inside a building and rejects it to the outdoors. The reverse is true for heat pumps in heating mode.



Refrigerant Regulation

In 1987, the **Montreal Protocol** was finalized to phase out ozone depleting refrigerants known as CFCs, like R-22, shifting manufacturers toward **hydrofluorocarbons (HFCs),** like R-410a.

In 2016, the Montreal Protocol was modified via the **Kigali Amendment** to phase down the global supply of HFC refrigerants due to their high GWP. Although the U.S. has not ratified the Kigali Amendment, the **American Innovation and Manufacturing (AIM) Act,** which mandates an 85% phase down in HFC supply by 2036, was enacted in 2020. Due to the Act, the U.S. **Environmental Protection Agency (EPA)** started to phase down the supply of HFCs in January 2022 and will essentially ban R-410A for use in new equipment in January 2025. The AIM Act is aligned with the HFC phase down of the Kigali Amendment of the Montreal Protocol and is slated to reduce the supply of atmospheric refrigerant emissions equivalent to more than four billion metric tons of carbon dioxide by 2036.



Minimize the Impacts of Refrigerants:

There are four primary ways that project teams can limit the environmental impact of refrigerants:

1 Design for the Lowest HVAC GWP Impact

Since refrigerants are infrequently substituted during operations, equipment selection, paired with refrigerant selection is a critical low-carbon building design consideration. During the design phase, designers should evaluate the lifecycle GWP impact of HVAC system options to capture the impact of refrigerant GWP, refrigerant charge, installation leakage, annual operational leakage, end-of-life leakage, and system efficiency that determines the resulting CO_2e from local grid-delivered electricity to run the HVAC system over its lifetime. As part of the **MEP 2040 Challenge**, Carbon Leadership Forum is developing a refrigerant impact calculator to assist designers in estimating the lifecycle impacts of refrigerants in their HVAC and refrigeration system selections. The tool allows users to select the life expectancy, refrigerant type, refrigerant charge (kg), and leakage rate database to quickly quantify lifetime leakage, global warming potential, and ozone depletion potential from installation, operation, and end-of-life leakage.

2 Select Low-GWP Refrigerants

Grocery store refrigeration and freezer systems with 50 pounds of refrigerant should aim to use a refrigerant that has a GWP of up to 150 (CO_2e-100 year). For room AC, residential and commercial AC, as well as VRF systems, the refrigerant should have a GWP of up to 750. The California Air Resources Board (CARB) lists 14 refrigerants lower than 125 GWP and 23 between 150 and 750 GWP, including natural refrigerants such as ammonia. As regulations are implemented, industry innovation will bring new mixes and alternatives to the market. According to The North American Refrigeration Council (NARC), HFC refrigerants account for 65% of an average food retailer's Scope 1 GHG emissions. In addition, NARC states that an average supermarket leaks about 25% of its refrigerant load annually, in part due to piping distance and numerous joints, so reducing the GWP of the refrigerant is a priority. See Global Warming Potential of Refrigerants on page 4 to view a list of common refrigerants and their GWP.

3 Limit Leakage

With proper installation and maintenance, leak rates can be reduced. However, if building HVAC equipment is not maintained correctly, leak rates can range from 1-10%, with an average of 3%. Applications with building-scale refrigerant loops, like VRF systems, come with higher leakage risks: large refrigerant volumes, long pipes, many flared or brazed joints, and variable installation quality. Proper installation requires pressure checks, vacuum checks, and leak checks. Early detection ensures that leaks do not become large enough to impact emissions and energy efficiency. Properly managing leaks can limit the cost of recharging refrigerant and service, and maximize system energy efficiency while limiting GHG emissions. Leak detection can be performed manually and/or through electronic controls in the system. Manual inspection requires the examiner to evaluate joints using a hand-held chemical detector, visually check for bubbles using soap applied to joints, or with a UV lamp to check for escaping dye that is injected into the system. Several different electronic technologies can be permanently installed in the HVAC system to provide more precise and efficient confirmation of leaks. Technologies include heated diodes and infrared detectors. Electronic technologies require annual maintenance to ensure they are working correctly.

4 Develop and Implement a Refrigerant Management Plan

Owners and operators of refrigeration systems containing more than 50 pounds of 150+ GWP refrigerant should conduct and document periodic leak inspections, promptly repair leaks, and keep service records on site. Refrigerant management programs safeguard system operations. The plan often includes maintenance actions, key roles and responsibilities, and compliance needs. Plans may also include initial equipment cutsheets, registration, related organizational policies, reporting, leak repair, maintenance logs, refrigerant phasedown plans, leak rate calculations, and correction opportunities. While no two plans are alike, plans should be evaluated on a set schedule.

A2L: The Next Generation of Refrigerants

A2L refrigerants are sometimes referred to as next-generation or fourth-generation refrigerants because they have lower GWP values and short atmospheric lifecycles. However, A2L refrigerants have a safety classification meaning they have low toxicity but are slightly flammable, further necessitating refrigerant management.

A2L refrigerants have been well-studied and safe to use in buildings where the building code allows them. In 2019, A2L refrigerants were introduced as a separate safety group with their own requirements in several conventional standards, including ASHRAE 15, ASHRAE 34, and UL 60335-2-40. The table illustrates the different classes of refrigerants and their associated toxicity and flammability rating.

Class 3 (A3 and B3) refrigerants are the most flammable and are listed as "Higher Flammability." Examples include hydrocarbons like propane and isobutane. Class 1 refrigerants are the least volatile and are listed as "No Flame Propagation," such as R-410A or R-22. Class 1 refrigerants are often described as "nonflammable," but many can still combust and burn at higher pressures and temperatures. "Slightly flammable" can be a worrying term, but research has shown that A2L refrigerants do not need to cause concern for flame spread.

Air-Conditioning, Heating, and Refrigeration Institute (AHRI) conducted research with the UL Firefighter Safety Research Institute and members of the fire service to test the differences between refrigerants in real fire scenarios. One test studied the "heat release rate" to quantify the amount of heat an A2L refrigerant added to a fire and found that the heat release rate was higher for R-410A, a common non-A2L refrigerant than for R-32, the A2L refrigerant in the study. The heat the refrigerant created was equivalent to a small plastic trashcan fire. There was no flash fire or deflagration observed. AHRI concluded that overall average risks related to using A2L refrigerants are significantly lower than the risks of everyday hazard events associated with other causes and well below risks commonly accepted by the public.

GLOBAL WARMING POTENTIAL OF REFRIGERANTS

Source: California Air Resources Board

Refrigerant Name	Trade or Common Name	Global Warming Potential*
R-717	Ammonia	0
R-1234ze(E)	Solstice ze	1
R-1224yd(Z)	AMOLEATM 1224yd	1
R-744	CO_2	1
R1234zd(E)	Solstice zd	1
R-514A	Opteon XP30	2
R-290	Propane	4
R-600a	Isobutane	5
R-170	Ethane	6
R-601	Pentane	11
R-161	HFC-161	12
R-123	HCFC-123	77
R-225ca	HCFC-225ca	122
R-152a	HFC-152a	124
R-454B	Opteon XL41	466
R-225cb	HCFC-225cb	595
R-450A	Solstice N13 (R-134a)	601
R-124	HCFC-124	609
R-513A	Opteon XP10	631
R-32	HFC-32	675
R-452B	Opteon XL55	676
R-141b	HCFC-141b	725
R-466A	R-32/R-125/ R-131	733
R-401C	Suva MP-52 (R-22)	933
R-134a	HFC-R134a	1430
R-410a	Puron, AZ-20	2088
R-404a	HFC-404A	3922
R-12	CFC-12	10900

*Over a 100 year time period.

California's Refrigerant Recovery, Recycle, and Reuse (R4) Program

The R4 program was developed before the enactment of the **American Innovation and Manufacturing (AIM) Act** and intended to jump-start demand for reclaimed refrigerant, encouraging recovery at the end-of-life of equipment when a system is decommissioned due to the resale value of refrigerant.

The refrigerant can be recovered for later use when a system is decommissioned. In California, California Air Resources Board was tasked with educating and protecting communities from climate change, and estimatesthat only 2% or less of refrigerant is recovered from smaller air-conditioning units in California, which has the best recovery and enforcement in the country.

- **Recovered** refrigerant is removed from an appliance and stored in an external container without necessarily testing or processing it in any way before returning to the same system or another system owned by the same owner.
- **Recycled** refrigerant is extracted from an appliance and cleaned for reuse in equipment of the same owner without meeting all of the reclamation requirements.
- **Reclaimed** refrigerant is extracted from equipment and sent to a reclaimer to clean it. The purity must meet levels as specified in the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Standard 700-2016, and verify this purity using the analytical methodology prescribed in the standard.

With the enactment of the AIM Act, demand is increasing for reclaimed refrigerants, and every pound of reclaimed high-GWP refrigerant is essential to avoiding another pound of production and release into the atmosphere.

Resources

NBI maintains a collection of building decarbonization resources, including case studies, research, tools, and guides. Visit **gettingtozeroforum.org/resource-hub**.

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