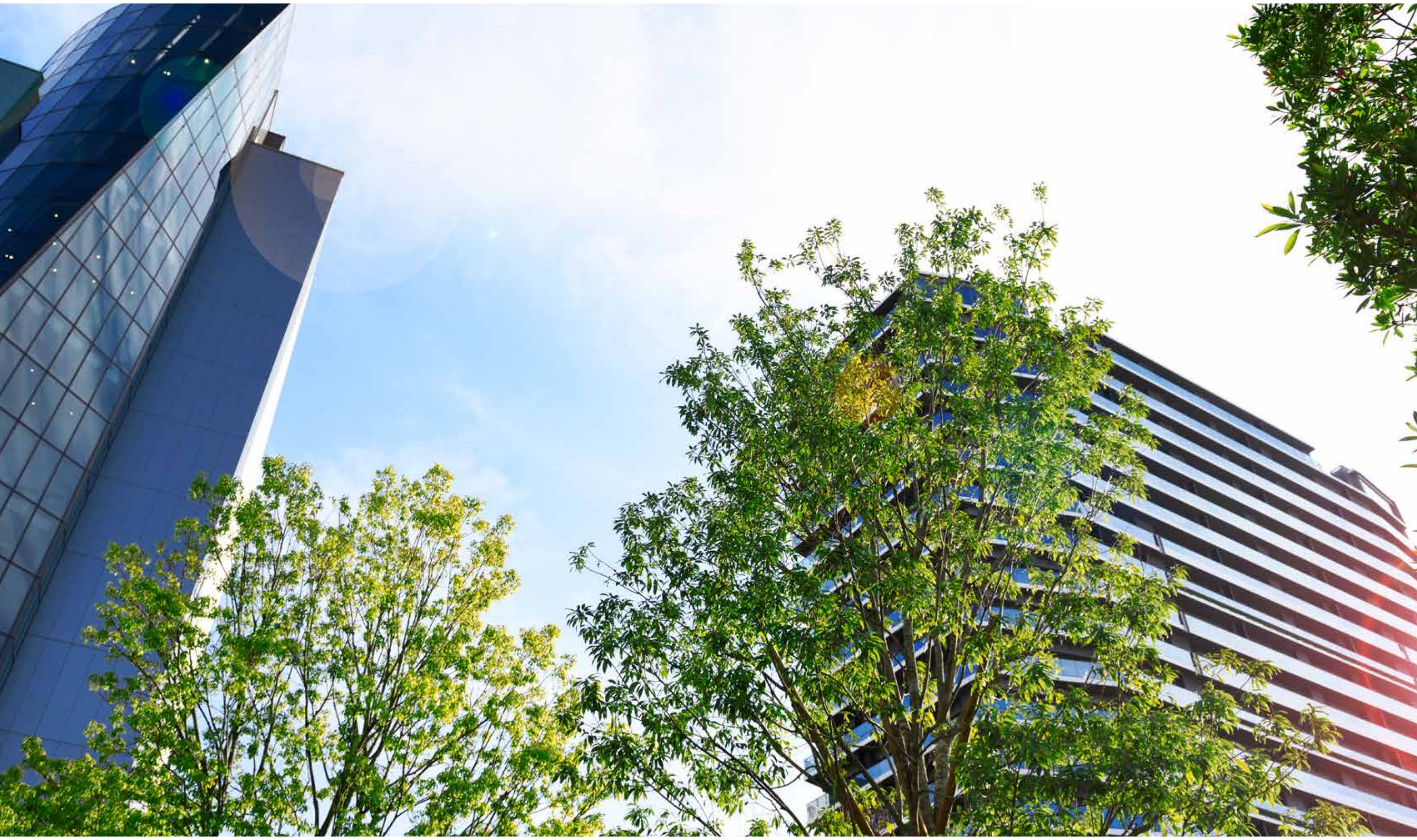
Chiller refrigerants: Minimizing carbon footprint



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Johnson Controls

For much of the past decade, regulators around the world have increased focus on curbing greenhouse gas emissions to reduce carbon footprint – reductions and limits on several established refrigerants, including the widely used R-134a and R-410A HFCs are among the latest approaches to curb greenhouse gas emissions. This caused a flurry of questions in our industry, specifically: What's the best refrigerant choice for chillers and other HVAC equipment? The answer to this question can vary based on equipment type, system design, and even region of the world. Understanding all factors that contribute to HVAC equipment carbon footprint is key to making the right refrigerant choices.

Focus on energy efficiency

A typical water-cooled centrifugal chiller will contribute 65,000 pounds of CO_2 emissions associated with energy consumption per 100 tons of cooling capacity each year. This value may be twice as high for air-cooled chiller equipment and 30 to 50 percent higher without the use of energy-saving technology within chillers, including variable speed drives. Emissions associated with energy consumption are called indirect emissions. Conversely, with typical equipment leakage rates, the annual carbon footprint associated with refrigerant leaks would be close to 5,000 pounds of refrigerant for every 100 tons of cooling when utilizing common HFCs. Emissions associated with refrigerant leaks are called direct emissions. For system designers and owners keen on solutions that reduce carbon footprint, understanding the climate impact of chilled water systems and designing or specifying higher efficiency products will have the greatest impact on reducing carbon footprint.

Factors of HVAC equipment carbon footprint

Design, specify or buy high-efficiency chiller equipment and systems

Carbon emissions associated with energy production typically account for over 95 percent of the carbon footprint of a chilled water system. Improving system energy efficiency by three percent with high-efficiency equipment will nearly offset the entire carbon footprint of leaked refrigerant.

Maintain equipment for ultimate performance and leak prevention

Proper equipment maintenance at the recommended service intervals reduces system carbon footprint by maintaining peak performance and reducing risk for refrigerant leaks.

Choose sustainable refrigerants

Refrigerant leaks happen. Typical chillers leak up to two percent of their refrigerant each year. The lower the Global Warming Potential (GWP) of the fluid, the lower the carbon footprint associated with refrigerant leaks.

The Johnson Controls Refrigerant Stewardship Model

Refrigerant guiding principles

At Johnson Controls, our refrigerant choices – past, present and future – are governed by a stewardship model that has guided us through previous transitions and will serve us and our customers well in changing times ahead.

Safe and Reliable

Toxicity and flammability must be addressed for all refrigerant options. Systems must be designed for new refrigerants and undergo long-term testing.

Efficient and Sustainable

Future refrigerant choices must present equal or better overall performance values than current refrigerants. Energy efficiency is the ultimate priority to reduce the carbon footprint of HVAC products.

Available and Affordable

Local availability at a reasonable cost is critical for building owners' bottom line.

Key factors to consider are:

- **The energy source:** What is the carbon intensity or emission factor of the energy supplied to the plant?
- **The technology:** What is the latest in energy-saving technology for theequipment type required? How efficiently does the equipment perform in all operating conditions (loads, temperatures) that the site will see?
- **The operating sequence:** How and when will equipment stage on and off? Are there efficiencies in pumping and piping strategies? If carbon intensity changes throughout the day, how can thermal energy storage be used to shift demand?

Maintain peak performance

After efficient design, maintenance is the next most critical component of reducing CO_2 emissions of HVAC equipment. These reductions are in both direct and indirect emissions. Indirect emissions being the largest component of chiller footprint, consider that simply increasing the interval between routine maintenance activities such as condenser cleaning may result in efficiency penalties of three to five percent, or over 3,000 additional pounds of CO_2 annually.

Refrigerant available in Johnson Controls HVAC/R Products

Refrigerant	Designation	ODP	GWP* (AR4)	GWP* (AR5)	ASHRAE Safety Classification	Pressure
R-22	HCFC	0.055	1810	1760	A1	High
R-134a	HFC	0	1430	1300	A1	Medium
R-404A	HFC	0	3922	3943	A1	Medium
R-407C	HFC	0	1774	1624	A1	High
R-407F	HFC	0	1825	1824	A1	High
R-410A	HFC	0	2088	1924	A1	High
R-507A	HFC	0	3985	3985	A1	High
R-32	HFC	0	675	677	A2L	High
R-448A	HFO Blend	0	1387	1273	A1	High
R-449A	HFO Blend	0	1397	1282	A1	High
R-454B	HFO Blend	0	466	467	A2L	High
R-513A	HFO Blend	0	631	573	A1	Medium
R-1233zd	HFO	~0	4.5	<1	A1	Low
R-1234ze	HFO	0	7	<1	A2L	Medium
R-290 (Propane)†	Natural	0	3	–	A3	High
R-704 (Helium)	Natural	0	0	0	A1	Cryrogenic
R-717 (Ammonia)	Natural	0	0	0	B2L	High
R-718 (Water)	Natural	0	0	0	A1	Very Low
R-744 (Carbon Dioxide)	Natural	0	1	1	A1	Very High
R-1270 (Propylene)†	Natural	0	2	–	A3	High

*GWP values as per the Fourth Assessment Report (AR4) or Fifth Assessment Report (AR5) of the IPCC
†Additional Hydrocarbon refrigerants are available for specific Industrial Refrigeration applications

Direct emissions, too, can be mitigated with proper maintenance. Frequent checks on refrigerant level can alert the plant room operator to potential leaks, allowing early inspection and mitigation before significant refrigerant leakage occurs, maintaining a lower carbon footprint of the equipment. Well-maintained chiller equipment operates with annualrefrigerant leakage rates of below one-half percent, while poorly maintained equipment may leak up to five percent of its charge annually.

Consider alternative refrigerants

In recent years, there has been significant research and development in the space of refrigerants. A key focus is reducing the direct global warming potential (GWP) of the fluids used in HVAC equipment. Dozens of new fluids are now available on the market, a few of which have been identified by multiple chiller vendors as potentially promising solutions for new equipment where regulations or other initiatives necessitate a change in working fluid. For low-pressure refrigerant, typically found in centrifugal chillers, the only low-GWP fluid utilized by multiple chiller vendors is R1233zd. The legacy refrigerant in this pressure range was R123, which was banned from new equipment in 2020. The dominant refrigerant for centrifugal chillers, however, is medium pressure R134a. For medium pressure refrigerant, typically found in centrifugal or screw chillers, the low-GWP fluids most commonly utilized by multiple vendors include R513A, R1234ze and R515B. The dominant refrigerant in this pressure range is R134a, which remains a permitted fluid for new equipment and has no production end-

date in North America.
For high-pressure refrigerant, typically found in scroll chillers, the low-GWP fluids most commonly utilized by multiple vendors include R454B and R32. The dominant refrigerant in this pressure range is R410A, which remains a permitted fluid for new equipment and has no production end-date in North America.

A change in the refrigerant used in a piece of equipment can have both immediate and lifecycle impacts. Immediate impacts can include increases in equipment footprint, plant-room accommodations for flammable fluids and additional refrigerant relief piping if the different refrigerants used in the same equipment room operate at very different pressures. Additionally, refrigerant choice can have impacts throughout the life of the equipment, including changes in the annual consumption of energy, changes to the direct emissions from the equipment and the cost or availability of replacement fluid in the event of leaks.

The Johnson Controls Refrigerant Stewardship Model contains three guiding principles with which refrigerant choice should be evaluated, given the available options. These principles are availability and affordability, efficiency and sustainability and safety and reliability.

Availability and affordability

R134a and R410a have strong supply chains behind them and are permitted for consumption in both the U.S. and Canada to the tune of millions of tons with no phase-out date.

Much of the world's population resides in countries that are permitted to continue the manufacture of equipment utilizing these fluids for years to come. Further, R134a is a core ingredient in one of the leading candidates for its replacement. Wide, global production and consumption from numerous refrigerant producers and equipment manufacturers suggest that equipment that utilizes these fluids will benefit from available and affordable fluid through its operating life. Conversely, the choice to utilize a new, low-GWP alternative fluid will likely come with cost penalties. First, the equipment cost is increased to account for the higher cost of refrigerant. Second, tradeoffs in many alternatives to R134a result in equipment becoming larger for the same performance. This, independent of fluid cost, may drive up both the cost of the equipment and the construction cost of the plant-room space around it. Last, insurance premiums associated with any safety classification changes of alternative fluids may drive up the annual operating cost of the chiller plant.

Efficiency and sustainability

R134a is the most efficient refrigerant in its class of medium-pressure refrigerants, making it a challenge to replace it as a working fluid for centrifugal and screw chiller applications. One approach for centrifugal applications is to migrate designs to low-pressure equipment using R1233zd – an offering now available from multiple manufacturers, including Johnson Controls.

While this approach can achieve similar or higher efficiency levels, it comes at a footprint tradeoff. Low-pressure machines must move three to four times as much refrigerant volume to produce the same cooling capacity, significantly increasing the size of equipment. This creates practical concerns when replacing already-existing equipment or for plant rooms where space is a constraint. Low GWP fluids within the medium-pressure class all come with an efficiency tradeoff. In many cases, these tradeoffs can be mitigated by increasing the size of heat exchangers to improve performance back to the level of R134a, so as to not increase lifecycle indirect emissions.

Equipment using R513A, which operates at a nearly identical pressure to R134a, would see a limited impact on footprint, while equipment using R1234ze or R515B will see more notable increases in size due to their lower operating pressure. Future low GWP replacements for R410A, including R454B and R32, both have similar operating efficiencies and pressures. Viewing these two alternatives through the lens of efficiency and sustainability, both fluids offer similar energy consumption with lower direct emissions.

Safety and reliability

Many of the commercial refrigerants coming onto the market today carry a mildly flammable safety classification. In response, standards and codes are being developed that establish rules for how equipment and building design must accommodate these fluids and how the flammable refrigerants can be used safely. As refrigerant alternatives are considered for commercial HVAC applications, it is important to incorporate the necessary plant-room considerations to safely manage flammable fluids. New refrigerants must also be tested for reliability to ensure compatibility with HVAC system gaskets, elastomers and materials of construction. They must prove long-term stability, as well; if a refrigerant begins to break down over time, it can impact system performance and operating costs or cause damage to the equipment.
For those reasons, new technologies must be properly vetted before being introduced to the market. In keeping with our Stewardship Model, Johnson Controls works closely with refrigerant suppliers to ensure product reliability. In addition to the battery of tests typically conducted by the supplier, Johnson Controls requires suppliers to run specific tests, engages third-party independent labs to conduct testing and does its own endurance and accelerated lifecycle testing of refrigerants. Plus, although such rigorous testing takes time, it's time well spent. Without a thorough pre-market vetting, customers may find themselves with a poor quality or unsafe product, and manufacturers may find themselves with unrecoverable costs and damaged reputations.

Johnson Controls family of products using refrigerants

Frick Industrial Refrigeration · YORK Process Systems · LUXAIRE Heating & Air Conditioning · GUARDIAN
FRASER-JOHNSTON Heating & Air Conditioning · TEMPMASTER · QUANTECH · YORK
Johnson Controls · YORK VRF · Coleman Heating and Air Conditioning · evcon
CHAMPION Heating and Cooling · SMARTFLEX · SABROE

Compressor Packages · Condensers · Evaporators · Replacement Parts · Packaged Refrigeration Systems · Compressors · Air-Cooled Chillers · Condensing Units · Pressure Vessels · Hygienic Air Handlers · Heat Exchangers · Heat Pump Water Heaters · Absorption Chillers · Rooftop Units · Indoor Packaged Equipment · Split Systems · Variable Refrigerant Flow Systems · Mini-Split Systems · Water-Cooled Chillers · Air Source Heat Pumps · Water Source Heat Pumps

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