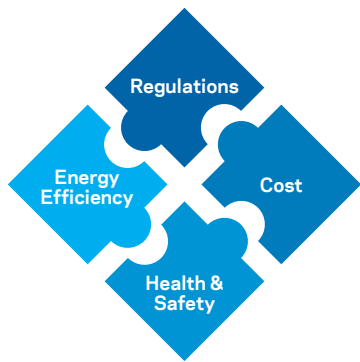


SMART REFRIGERANT SELECTION FOR ICE RINKS

**Part I. What you need to know
about refrigerants, regulations,
system design, energy efficiency,
costs, and health/safety**



EXECUTIVE SUMMARY

The global refrigeration industry is in the midst of a regulatory-driven transition toward a new generation of environmentally sustainable refrigerant solutions. This shift has major impacts on all private and community ice rinks, both large and small, operating in North America.

For rink operators and owners, this white paper (Parts I and II) details key factors impacting the selection of refrigerants and refrigeration systems in today's changing environment. Part I covers what you need to know about refrigerant and system-design options, including energy efficiency and environmental impacts, total cost of ownership, and health/safety factors to consider. Part II will take a deeper look at health and safety considerations, including toxicity, flammability, and high-pressure hazards. These white papers are designed to enable decision makers to be fully educated to continue successful business operations.

The content of this white paper is the sole responsibility of The Chemours Company.

Aging Rinks, Aging Refrigeration Systems

An estimated three quarters of currently operating National Hockey League (NHL) ice arenas were built in the mid-1990s. In addition to these larger arenas, there are thousands more private, community, and locally owned rinks across North America. Many of these rinks are much older and are nearing, if not well past, the expected usable lifetime of the refrigeration systems that enable ice making. To keep these facilities up and running, now is the time to plan for the future of your rink, including considering if, when, and how to retrofit, upgrade, and/or replace your ice-making chiller.

Even for rinks constructed more recently, many of the refrigerants currently used in chillers face an uncertain future with increased safety and environmental regulations. This includes a ban on the production and importation of R-22 in the U.S. and Canada beginning December 31, 2019.

Hydrofluoroolefins (HFOs) like Opteon™ refrigerants are among the newest and most environmentally sustainable refrigerants for ice rinks on the market today offering:

- Non-ozone depleting/low global warming potential (GWP)
- Long-term regulatory compliance
- Optimal balance of performance, safety, and cost for many applications

100+ Years of Refrigerants

Timeline of Refrigerant Technologies

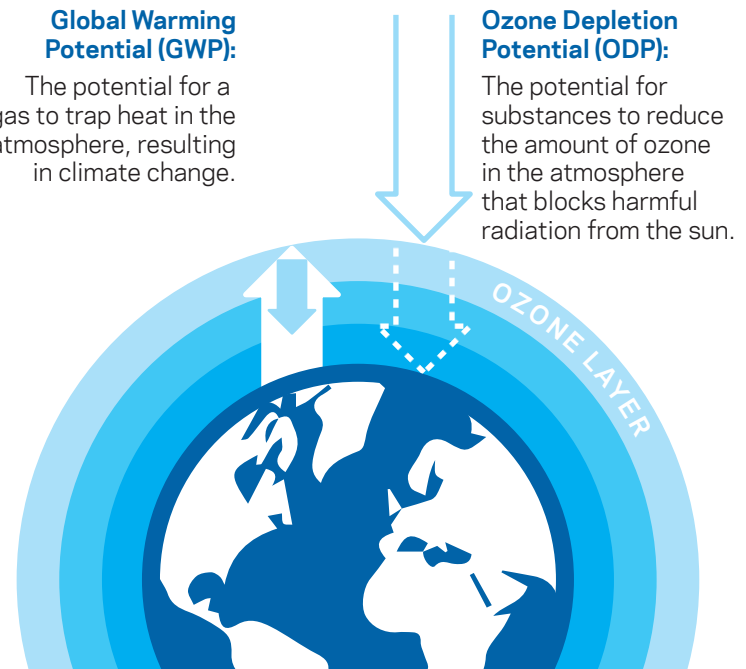
| 1800s-1920s | 1930s | 1950s | 1990s | Today |
|---|--|--|---|--|
| Industrial Chemicals Methyl Chloride, Sulfur Dioxide, Ammonia, etc. | CFCs (R-12) Chlorine Single Bond | HCFCs (R-22) Less Chlorine Single Bond | HFCs (R-134a) No Chlorine Single Bond | HFOs and HFO Blends No Chlorine; Double Bond |
| Toxic Flammable | High ODP Highest GWP | Lower ODP High GWP | No ODP High GWP | No ODP Low GWP |

When chlorofluorocarbons (CFCs) were first introduced as refrigerants, they were applauded as “miracle compounds” for replacing dangerous industrial gases (e.g., sulfur dioxide, ammonia, methyl chloride, etc.). However, following many decades of use, more concerns over ozone depletion and, more recently, climate change have driven the refrigeration industry to innovate a new generation of more environmentally sustainable solutions.

Whether you’re talking about environmentally driven regulations or technology, the change in today’s refrigerant landscape is directly tied to two concepts:

- Ozone depletion potential (ODP)
- Global warming potential (GWP)

Although they are related, ODP and GWP are not synonymous. ODP defines the potential for substances to reduce the amount of UV-blocking ozone in the atmosphere; whereas, GWP is the potential for a gas to trap heat in the earth’s atmosphere, resulting in climate change. These concerns have driven both new regulations and technological innovation in recent years.





Complex Rules: A Shifting Global Regulatory Landscape

The refrigerant and equipment regulations impacting rink operators vary by country, region, and even by state or municipality. Here's an overview of what you need to know.

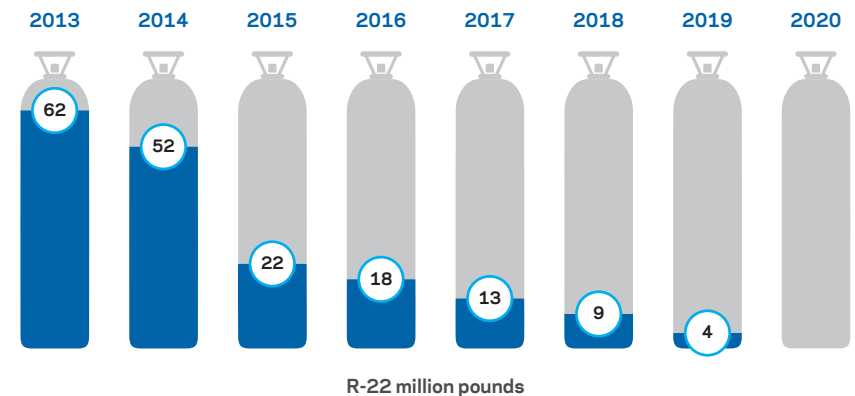
R-22 Phaseout

The U.S. and Canada, along with much of the developed world, are in the final years of the Montreal Protocol-initiated R-22 phaseout. Having eliminated R-22 refrigerant in new equipment for some time, the supply of R-22 for service is now being limited—with a total ban on the production and importation of R-22 beginning December 31, 2019.

Kigali Amendment

In an effort to align global regulations to the Montreal Protocol, the Kigali Amendment was agreed to in October 2016. This agreement provides a framework for both developed and developing countries to phase down the use of high GWP HFCs globally. As of November 2017, 20 countries had ratified the amendment, which means it will go into effect on January 1, 2019. Upon ratification of the amendment, participating countries committed to a tiered HFC reduction from an established baseline, on a CO₂ equivalent, or GWP, basis.

HCFC Regulations: R-22 Is Going Away



After December 31, 2019, the entire HVACR industry will be totally dependent on reclaimed R-22 for servicing any systems still in operation.

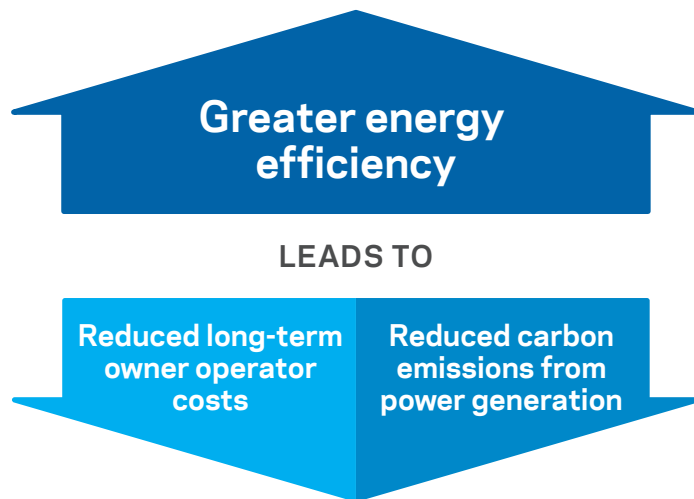


Energy Efficiency: Impact on Costs and the Environment

It comes as no surprise to rink operators that running a large chiller to maintain a high-quality ice pad requires a lot of electricity. System design and refrigerant choice are critical because they not only directly impact the electric bill, but they also contribute to environmental carbon emissions from power generation. In the long run, energy use represents a large percentage of a chiller's operational cost; therefore, selecting an energy-efficient refrigerant and an efficient system design is most desirable.

New generations of traditional system designs have incorporated many energy-efficient features that allow use of low GWP refrigerants, such as HFOs, while at the same time improving energy performance. These energy savings during simple gas conversions (retrofits) with chiller barrel replacements or minor service-style changes including oil, filter, and gaskets are due to a number of factors including improved thermodynamic properties of the new refrigerants as well as a "tune-up," or recommissioning effect, on the chiller.

Finally, when thinking about the carbon footprint of the ice plant, it does not make sense to choose a refrigerant with a very low GWP value if the energy efficiency of the system is not good. For example, CO₂-based systems, when operating in a trans-critical mode during warmer outdoor temperatures above ~70° F, have poor energy performance, which results in increased energy consumption/costs and carbon emissions.





Financial Considerations: Counting the Costs

When considering a new system, or major modification to an existing ice plant, many rink owners are strongly influenced by the capital cost of the chiller system itself. Over the lifetime of perhaps 20 to 30 years, the total cost of ownership (TCO) should also take into account energy costs, service and maintenance costs (including service refrigerant), and even specialized training costs. In some areas, regulations require trained operators to be on site during operation with highly toxic refrigerants like ammonia (R-717)—this could become a significant cost as well.

For many systems, the TCO is strongly impacted by energy, followed by capital and maintenance, with the cost of the refrigerant itself representing a very small percentage of the total. Therefore, selection of a sustainable refrigerant should trend towards choosing an energy-efficient system design that minimizes operating and maintenance costs, mitigates safety hazards, and can be supported by the existing workforce of skilled technicians.

Total Cost of Ownership for Typical Rink Refrigeration System over 20 Years



Reference: Typical cost based on data in "Comparative Study of Refrigerant Systems for Ice Rinks," CanmetENERGY, July 2013.



Health and Safety: Important Considerations

The safety of rink workers—and the large number of customers, players, and guests who visit rinks each day—is of paramount concern to every owner/operator. Part II of this white paper series will delve into the detailed safety information that must be considered when selecting a refrigerant and chiller system. As an owner/operator, you should consider the short (acute)- and long (chronic)- term toxicity properties of potential refrigerants as well as their flammability potential, asphyxiation risks, and high-pressure hazards.



Is It Time to Upgrade Your Rink's Chiller?

Based on the evolving refrigerant regulatory landscape, change is necessary. Whether it's now or later, a retrofit or a new system, for an existing facility or new construction—change is critical to ensure refrigerant availability, compliance, and business continuity.

There's no one-size-fits-all solution, but a holistic approach to refrigerant selection will ensure the best decision for your rink and your bottom line.



Existing Systems

While regulations may not require an immediate change for your chiller system, if it is still running on HCFC-22 and leaks, the depleting supply of R-22 could make the repair more expensive than it's worth. Eventually, a repair may not even be possible, depending on the availability and remaining inventory of reclaimed gas supplies.

When deciding to retrofit or remodel, here are some factors to consider:

- **Cost and future availability of installed refrigerant**
- **System age and reliability**
- **System design (flooded, DX, etc.) and conversion costs (time, labor, and components)**
- **Replacement refrigerant performance (capacity and energy efficiency)**
- **Safety, health, and environmental properties of replacement refrigerant (see Part II)**
- **Compliance with current and future regulations**
- **Availability of skilled mechanical contractors/operators**
- **Timeline/window for system changes**
- **Government, energy, or other available financial incentives**

Is It Time to Replace Your Rink's Chiller?



New System

Whether replacing an aging ice rink chiller or installing one for a brand new rink, there are additional considerations:

- **Initial capital and installation costs**
- **Ongoing maintenance costs**
- **Availability of skilled mechanical contractors/operators**
- **System types and designs (turnkey versus build-up system, etc.)**
- **Compatibility with existing infrastructure (machine rooms, brine, etc.)**
- **Safety, health, and environmental properties of replacement refrigerant (see Part II)**
- **Costs for code and regulatory compliance (on site trained/certified operators, etc.)**
- **Refrigerant performance (capacity and energy efficiency)**
- **Impact of potential leak on surrounding communities, businesses, etc.**
- **Compliance with current and future regulations**
- **Government, energy, or other available financial incentives**

Fortunately, technology has advanced in the 20 or more years since the original chiller equipment was installed in most existing ice rinks. A number of leading OEMs now produce chillers based on safe, low GWP HFO refrigerants, such as Opteon™ XP40 (R-449A) or XP10 (R-513A). HFOs have competitive energy performance and have been selected for many new ice plant installations.

Looking Ahead: The Future of Ice Rink Chillers

In the 100 years since modern refrigeration systems made their debut, the technology has significantly evolved. The array of options makes decision-making complex and leaves some professionals wondering whether it's worth making a switch when another technology may be around the corner.

HFOs Offer Long-Term Solution

HFO refrigerants, such as Opteon™, have been in commercial use for nearly a decade and are a well-established and thoroughly researched category of replacement refrigerants. This technology was specifically developed to address the environmental limitations of former refrigerants and provide a long-term solution that doesn't sacrifice safety and health performance.

HFOs also have properties very similar to the refrigerants they're replacing, making it simple for the limited supply of skilled contractors to adapt to these low GWP refrigerants and install, operate, and service them efficiently and safely in both existing chillers and new systems.

With low GWP and zero ODP, HFOs like Opteon™ refrigerants are among the most environmentally sustainable refrigerants on the market. While they may not be the right solution for every application or system, HFOs are excellent choices for ice rinks looking to achieve long-term compliance with an optimal balance of performance, safety, and cost. As leaders in the refrigeration industry for nearly 100 years, Chemours and our OEM and mechanical partners are here to answer all your questions and help you navigate through this transition.

Please reach out to us through your local Chemours contact or at [opteon.com](https://www.opteon.com).



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