COOLING CHOICES: BALANCING SAFETY, PERFORMANCE, AND COST – COMMERCIAL REFRIGERATION

COMMERCIAL REFRIGERATION (40 KW – 150 KW)

As the EU continues to prioritise industrial competitiveness within its policy agenda, the role of sustainable cooling solutions has never been more critical for businesses and consumers alike. Hydrofluoroolefins (HFOs), a widely adopted refrigerant technology, are now at the centre of a potential regulatory shift.

Moving away from HFOs would require availability of suitable alternatives. However, the current industrial alternatives in commercial refrigeration including Propane, CO_2 and Ammonia could add cost increases to industry due to lower performance, increased maintenance, inferior energy efficiency and retrofitting as drop-in solutions are not viable. In addition, unlike the alternatives, HFOs are non-toxic and have low flammability reassuring end users with safety concerns.

MAIN APPLICATIONS

Supermarkets and Grocery Stores: Used to keep produce, dairy, meat, and frozen foods fresh for consumers.

Cold Storage Warehouses: Designed for long-term storage of large quantities of perishable goods.

Healthcare Facilities: Used in hospitals and clinics to store medicines, blood, and laboratory samples safely.

Office Buildings: Helps maintain comfortable environments and precise climate control.

Industrial Processing: Critical in food and beverage industries for processing and preserving products.

Restaurants and Hotels: Vital for kitchen operations, storing ingredients, and serving guests.

HFOS VS ALTERNATIVES – COMMERCIAL REFRIGERATION (40 KW - 150 KW)

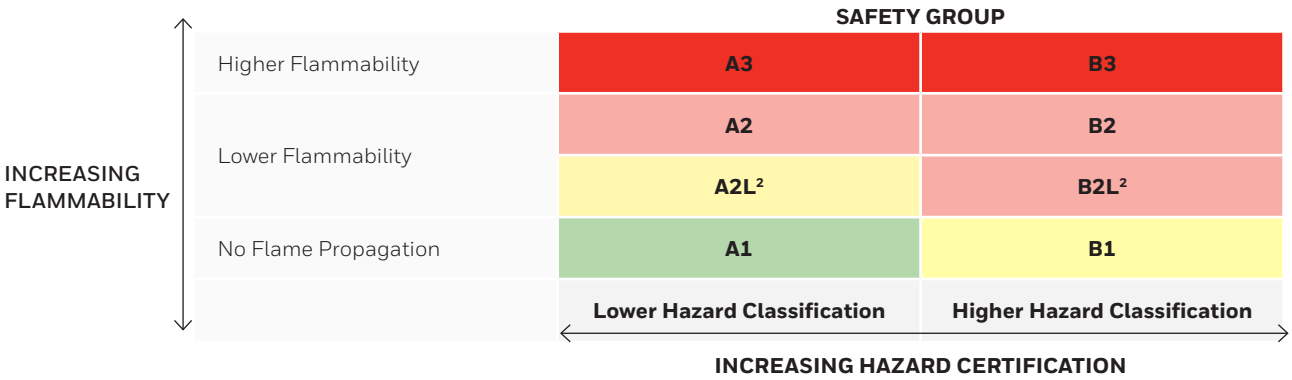
As you can see in the table below, across nearly all metrics; from Energy Efficiency to Hazard Classification and Managed End of Life - HFOs perform to or above expectations. This clearly demonstrates the unmatched utility of HFOs when compared with other industrial alternatives within Commercial Refrigeration.

	HFOs and HFO-blends (454C / 455A)	Propane	CO_2	Ammonia*
Energy Efficiency (device & system)	454C and 455A considered against 410-A[1]	Lower efficiency (5% to 21% more energy than HFO blends)[1]	Lower efficiency (8% to 50% more energy than HFO blends)[1]	N/A
Technical System Feasibility	Technically feasible with standard system cost[2]	Technically feasible, but higher system cost[3]	Technically feasible, but higher upfront system cost[4]	Technically feasible, but higher system cost[5]
ASHRAE Rating	A2L[7]	A3[7]	A1[7]	B2L[7]
Hazard Classification (CLP)	H280 – Gas under pressure [8] 	H280 – Gas under pressure [10] 	H280 – Gas under pressure [11] 	H280 – Gas under pressure [12]  H331 – Toxic if inhaled [12] H314 – Severe skin burn / eye damage [12] H400 – Very toxic to aquatic life [12] H411 – Aquatic lasting effects [12*] 
Atmospheric Products	TFA, % varies with blends [13]	Contributes to ground-level ozone and aldehydes [14, 15]	Atmospheric accumulation [16]	Low air quality, fine particles, and nitrogen oxides (NOx) [17, 18]
Managed End of Life	Recovery or destruction as mandated by EU F-gas Regulation (Art. 8) [19]	Recovery and recycling for commercial systems [20]	Not mandated, usually released to atmosphere [21]	Mandated, however technically complex / costly, requires incineration or an aqueous treatment [20]
Current Availability of Refrigerant	Acceptable[8, 9]	Acceptable[10]	Acceptable[11]	Acceptable[12]
Equipment / System Adoption	Broad Range (Food Retail, Food Service, Chillers, Data Centres) [23]	Smaller Applications (Charge Limited, or Cascade) [23]	Hybrid Systems (Cold Storage, Supermarkets, Data Centers) [23]	Commercial (Cascade w/ CO_2 (warm climates >38 °C), Industrial [23, 24]
Payback Period / ROI	Assumed baseline [2, 22]	Increased (multiple compressors, extra leak detection / alarms) [3]	Increased (custom electronics, additional components / software) [4]	Increased (higher upfront costs, net cost increases over 20-years)
Future Development**	Enables next-gen high-efficiency turbo-compressor [25]	Enables next-gen high-efficiency turbo-compressors – with limited availability to date [25]	Incompatible with turbo-compressors, requires lubricants [25]	Incompatible with turbo-compressors, material limitations [25]

* Niche applications in commercial

** Turbo compressor refrigeration uses high-speed centrifugal compressors to compress and cool refrigerants, achieving efficient temperature control for large-scale industrial and commercial applications, such as air conditioning or process cooling

ASHRAE Designations and Safety Classifications of Refrigerants[1]



1 ASHRAE https://www.ashrae.org/file%20library/technical%20resources/refrigeration/unep---ashrae-factsheet--english----april2023.pdf

2 A2L and B2L are lower flammability refrigerants with a maximum burning velocity of < 3.9 in/s (10 cm/s)

COMMERCIAL REFRIGERATION REFERENCES:

1. Oak Ridge National Laboratory (2023). Technology Option for Low Environmental Impact Air-Conditioning and Refrigeration Systems. Pub200582.pdf (ornl.gov)
2. Carrier (2019). Case Study: Gatwick Airport Ultra Low GWP. Case study - Gatwick Airport Ultra Low GWP | Carrier Europe
3. Climate & Clean Air Coalition (2016). Lower-GWP Alternatives in Commercial and Transport Refrigeration: An expanded compilation of propane, CO2, ammonia and HFO case studies (pg 56-58). Climate and Clean Air Coalition (CCAC)
4. Climate & Clean Air Coalition (2016). Lower-GWP Alternatives in Commercial and Transport Refrigeration: An expanded compilation of propane, CO2, ammonia and HFO case studies (pg 70-73). Climate and Clean Air Coalition (CCAC)
5. Climate & Clean Air Coalition (2016). Lower-GWP Alternatives in Commercial and Transport Refrigeration: An expanded compilation of propane, CO2, ammonia and HFO case studies (pg 20-23). Climate and Clean Air Coalition (CCAC)
6. Climate & Clean Air Coalition (2016). Lower-GWP Alternatives in Commercial and Transport Refrigeration: An expanded compilation of propane, CO2, ammonia and HFO case studies (pg 52-55). Climate and Clean Air Coalition (CCAC)
7. American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2022). ANSI/ASHRAE Standard 34-2022: Designation and Safety Classification of Refrigerant. (ASHRAE)
8. Safety Data Sheets – 454C and 455A
9. European Chemical Agency (ECHA) (2025). REACH Registration Dossier – 1234ze
10. European Chemical Agency (ECHA) (2025). REACH Registration Dossier – Propane
11. European Chemical Agency (ECHA) (2025). REACH Registration Dossier – Carbon Dioxide
12. European Chemical Agency (ECHA) (2025). REACH Registration Dossier – Ammonia, *Harmful to aquatic life with lasting effects
13. United Nations Environment Programme (UNEP). (2022). Montreal Protocol on Substances that Deplete the Ozone Layer: 2022 Assessment Report of the Environmental Effects Assessment Panel. Nairobi, Kenya: UNEP. (ISBN: 978-9914-733-91-4), Fig 12.
14. Rosado-Reyes, C. M. and J. S. Francisco (2007). "Atmospheric oxidation pathways of propane and its by-products: Acetone, acetaldehyde, and propionaldehyde." J.Geophysic.Res. Atmo. 112(D14). https://doi.org/10.1029/2006JD007566
15. Huo, Erguang et al. (2022). The combustion mechanism of leaking propane (R290) in O2 and O2/H2O environments: ReaxFF molecular dynamics and density functional theory study. https://doi.org/10.1016/j.psep.2022.03.080
16. Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (2023), Frequently Asked Questions (FAQ) 5.1, 5.3. IPCC_AR6_WGI_FAQ_Chapter_05.pdf
17. Li et al (2020). Human Ammonia Emission Rates under Various Indoor Environmental Conditions. Human Ammonia Emission Rates under Various Indoor Environmental Conditions (acs.org)
18. Jan Willem Erisman (2021). How ammonia feeds and pollutes the world. Science (374),685-686. https://doi.org/10.1126/science.abm3492.
19. Regulation 2024/573/EU of the European Parliament and of the Council on fluorinated greenhouse gases (2024), OJ 20.2.2024,(Article 8) L_202400573EN.000101.fmx.xml
20. Association of European Refrigeration Component Manufacturers (ASERCOM) (2019). Guideline: Safety Standards and Components for flammable refrigerants. English_SafetyStandardsandComponentsforFlammableRefrigerants.pdf
21. Commercial CO2 Product Guide (Emerson, pg 10) (2021). CO2 product guide
22. Climate & Clean Air Coalition (2014). Low-GWP Alternatives in Commercial Refrigeration: Propane, CO2, and HFO case studies. Low-GWP_Alternatives_in_Commercial_Refrigeration-Case_Studies-Final.pdf (pg 27).
23. Nordic Council of Ministers (2024). End-of-life treatment of Hydrofluoroole-fins (HFOs). End-of-life treatment of Hydrofluoroolefins (HFOs).
24. Climate & Clean Air Coalition (2016). Lower-GWP Alternatives in Commercial and Transport Refrigeration: An expanded compilation of propane, CO2, ammonia and HFO case studies (pg 16-19). Climate and Clean Air Coalition (CCAC)
25. El Samad, T., et al. (2024). "A review of compressors for high temperature heat pumps." Thermal Sci & Engineering Prog. 51: 102603. https://doi.org/10.1016/j.tsep.2024.102603