OzonAction

OzonAction Kigali Fact Sheet 4

Low GWP Fluids and Technologies

UN environment

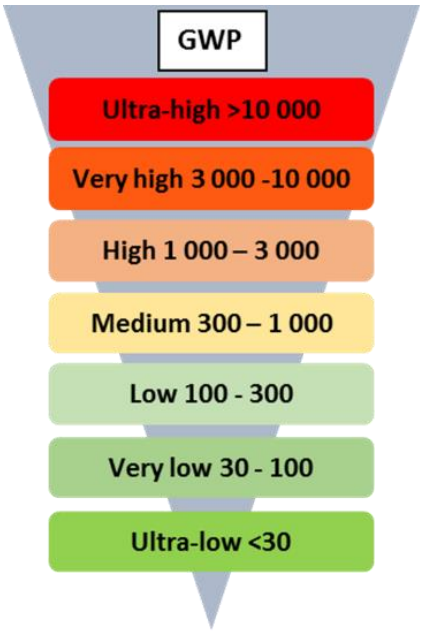
Background:

Kigali Fact Sheet 2 described the main markets for HCFCs and HFCs. Key uses for these gases are RACHP (refrigeration, air-conditioning and heat pumps), foam blowing agents and aerosol propellants. Most HCFCs and HFCs used in these applications have GWP[1]s in the range 1 000 to 4 000. To achieve the objectives of the Kigali Amendment it will be necessary to use fluids with much lower GWPs.
To maximise the long-term benefits of an HFC phase-down, end users need access to technologies that use fluids with the lowest practical GWP. It can be expected that the final product mix will include many products that use an "ultra-low" GWP fluid together with some products that have a higher GWP. See Kigali Fact Sheet 3 for further details about the range of GWPs for existing and future technology options.

Selection of Lower GWP Alternatives:

The most widely used HCFCs and HFCs all have "high" or "very high" GWP. Ideally, all applications would switch to the "ultra-low" category. This category includes the three most common not-in-kind (NIK) fluids – ammonia, CO_2 and hydrocarbons (HCs) together with several recently introduced fluorocarbons called HFOs[2].
However, not all applications are suited to the currently available ultra-low GWP fluids. For example:

- HCs are well suited to small sealed refrigeration products (such as domestic refrigerators) but cannot be used for many types of larger equipment because of the safety issues related to flammability.
- HFOs are well suited to medium and large sized air-conditioning water chillers, but cannot achieve the same level of energy efficiency as higher GWP fluids for small and medium sized split air-conditioning.



Based on TEAP Task Force Report

The designers of products and equipment that currently use HFCs need to seek lower GWP alternatives that provide the best compromise in terms of a range of different performance criteria, including:

1) High energy efficiency
2) Safe operation
3) Competitive capital and operating costs
4) Good environmental performance

It is important to remember that good environmental performance in most HCFC and HFC markets is a combination of high energy efficiency (to minimise emissions of energy related CO_2) and low GWP. The best overall environmental performance could be based on the use of a medium GWP fluid if that provides the highest energy efficiency and if leakage emissions can be minimised.

Safe operation with flammable alternatives:

Most HCFCs and HFCs are non-flammable – it is a property that makes them very popular fluids in a wide range of markets. Many of the ultra-low and low GWP alternatives have some degree of flammability – this can restrict their use in some market sectors.

---

[1] See Kigali Fact Sheet 14 for a glossary of all acronyms used

[2] HFOs = hydro-fluoro-olefins, also called "unsaturated HFCs". Molecules of carbon, fluorine and hydrogen that include a double-bond between 2 carbon atoms. All recently introduced HFOs have a GWP below 10.

During the phase-out of ODS we have seen various highly flammable fluids successfully and safely introduced into a range of different markets. For example:

a) Consumer aerosols (e.g. personal care products) use hydrocarbon (HC) propellants

b) Parts of the polyurethane foam panel sector have switched to HC blowing agents.

c) Domestic refrigerators use HCs in the refrigeration circuit and for foam insulation.

When ODS phase-out was first agreed in 1987 it was not known whether flammable fluids could be used in these applications, but product designers addressed the safety issues and found long-term financial benefits because the HCs were a cheaper raw material than the CFCs they replaced.

During HFC phase-down, similar developments are required to support the introduction of flammable alternatives. Barriers created by safety standards, building codes and national legislation may need to be addressed before the full market potential for flammable fluids can be reached. See Kigali Fact Sheet 10 for details about flammability and Kigali Fact Sheet 11 for comments on safety standards.

Use of Interim Medium and High GWP Fluids:

The HFC phase-down journey takes place over a 15 to 20 year period. It is likely that some new products will be introduced on an interim basis and replaced later with other lower GWP products.

An example relates to new refrigerant blends introduced as alternatives to R-404A, which has a very high GWP of 3 922. Two new blends with GWPs of around 1 400 have recently been introduced as alternatives to R-404A. They are in the "high" GWP category and well above the long-term target required to achieve an 85% HFC phase-down. However, they both have a considerably lower GWP than R-404A and can make a useful contribution to the early phase-down steps. Both these new blends are non-flammable – this will be a significant advantage in the short term as it allows them to be used without any major design changes.

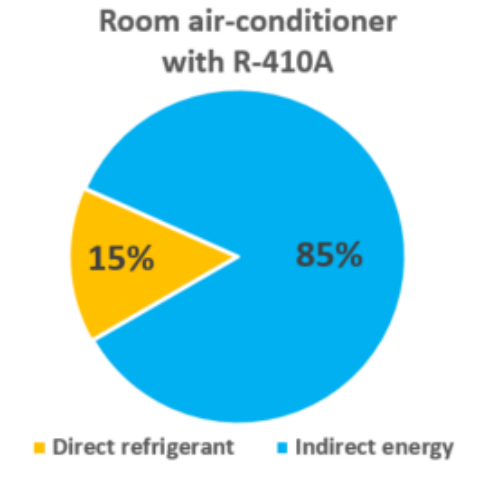
The market will need products using fluids in the high and medium GWP categories during the next 10 years. However, it may be impossible to achieve the longer-term phase-down cuts if significant quantities of such fluids are still used in the 2030s.

The Importance of Energy Efficiency

It is crucial to consider the total global warming impact of products and equipment. This includes two separate elements:

- the **direct** impact of the fluid used (e.g. leakage of a refrigerant with a high GWP)
- the **indirect** impact of energy used to operate equipment (e.g. refrigeration or air-conditioning)

In most RAC applications it is the indirect energy related emissions that are the dominant proportion of the total global warming impact, even if a high GWP fluid is used. It is crucial that new technologies using lower GWP fluids also have high energy efficiency. The pie chart shows a typical split of total global warming impact for a room air-conditioner. The refrigerant has a high GWP (2 088) but it is the CO_2 from electricity use that represents most of the GHG emissions. High energy efficiency and low refrigerant leakage levels for this type of equipment is crucial.



Market Developments with Lower GWP Fluids:

The tables below summarise the way in which low GWP fluids are being introduced into the various market sectors and sub-sectors.

Domestic refrigerators and freezers	
Small factory built refrigeration systems containing 0.05 to 0.25 kg refrigerant	
Typical ODS (GWP)	CFC-12 (10 900)
Typical HFC	HFC-134a (1 430)
Lower GWP fluorocarbon	HFO-1234yf (4)
Not-in-kind	HC-600a (iso-butane, 3)
From 2000, there is wide usage of hydrocarbons in Europe and some other regions. Hundreds of millions of HC refrigerators already in use. HFC-134a still used in USA, but HCs likely to enter that market. Good potential for HCs in most A5 countries. HFO-1234yf a possible option if a higher flammability fluid is unacceptable in a specific application.	

Car air-conditioning	
Small mobile air-conditioning systems containing 0.4 to 0.8 kg refrigerant	
Typical ODS (GWP)	CFC-12 (10 900)
Typical HFC	HFC-134a (1 430)
Lower GWP fluorocarbon	HFO-1234yf (4)
Not-in-kind	R-744 (CO_2, 1)
Global car industry began a move from HFC-134a to HFO-1234yf in 2013, initially driven by legislation in the EU that banned new mobile air-conditioning in cars if GWP > 150. Tens of millions of cars will use HFO-1234yf by the end 2017. A few car manufacturers have been concerned about flammability issues and are still considering a switch to CO_2.	

Food and drink retail refrigeration: large central systems	
Multi-compressor central systems for refrigerated displays in supermarkets. Low temperature (-20°C) for frozen food, medium temperature (+4°C) for chilled food. Large distributed systems connecting numerous retail displays and storage rooms, containing 50 to 200 kg of refrigerant	
Typical ODS (GWP)	HCFC-22 (1 810)
Typical HFC	R-404A (3 922) HFC-134a (1 430)
Lower GWP fluorocarbon	Non-flammable blends R-448A, R-449A (1 400) Lower flammability blends e.g. R-454A (239)
Not-in-kind	R-744 (CO_2, 1) HC-290 (propane, 3)
Historically a very large consumer of HCFCs and HFCs; supermarket central systems have large system charge and high average leak rates – often more than 20% per year. Supermarket companies are at forefront of developing new lower GWP options. There is significant momentum behind transcritical CO_2 systems, especially in cooler climates. Cascade CO_2 systems can be used in hot climates. Some central systems are being replaced by small sealed propane systems cooled via a chilled water loop. Non-flammable blends are a good interim option with a GWP 65% lower than R-404A. Where possible R-404A should be avoided as a zero ODP alternative to HCFC-22; it has a very high GWP and it does not deliver the best energy efficiency compared to various lower GWP options.	

Food and drink retail refrigeration: condensing units

Condensing unit (one compressor / condenser) connected to one or two retail displays, either for chilled or frozen food. Usually quite small systems in small shops or convenience stores containing 5 to 10 kg of refrigerant.

Typical ODS (GWP)	HCFC-22 (1 810)
Typical HFC	R-404A (3 922) HFC-134a (1 430)
Lower GWP fluorocarbon	Non-flammable blends R-448A, R-449A (1 400) Lower flammability blends e.g. R-454A (239)
Not-in-kind	R-744 (CO_2, 1)

Currently a difficult market to find a very low GWP option – equipment often too big to use flammable refrigerants but too small to use CO_2 cost effectively. Likely to become a good market for lower flammability HFO blends.

© Shutterstock

Food and drink retail refrigeration: small sealed systems

Small factory built systems e.g. stand-alone bottle coolers, ice cream displays, serve-over counters, typically containing 0.1 to 1 kg refrigerant

Typical ODS (GWP)	R-502 (4 657) CFC-12 (10 900)
Typical HFC	R-404A (3 922) HFC-134a (1 430)
Lower GWP fluorocarbon	HFO-1234yf (4) Lower flammability blends e.g. R-455A (148)
Not-in-kind	HC-290 (propane, 3) R-744 (CO_2, 1)

Growing usage of hydrocarbons as refrigerant charge is low enough to meet safety standards in many applications. Millions of HC units already operating by 2017. CO_2 systems developed for bottle coolers and other small systems for markets where a flammable fluid is not acceptable. Lower flammability fluids (e.g. HFO-1234yf and R-455A) will also be used in this market sector.

Industrial refrigeration

Wide variety of medium and large sized systems (<50 kg to >1 000 kg of refrigerant), including indirect systems (with liquid chillers) and direct use of refrigerant (e.g. direct expansion, flooded or pumped systems).

Typical ODS (GWP)	HCFC-22 (1 810)
Typical HFC	R-404A (3 922) HFC-134a (1 430)
Lower GWP fluorocarbon	Non-flammable and lower flammability blends For chillers: HFO-1234ze (4) HFO-1233zd (7)
Not-in-kind	R-717 (ammonia, 0) R-744 (CO_2, 1)

Safety issues can be cost-effectively dealt with on large plants, so ammonia is popular. New HFOs likely to grow in usage for industrial chillers.

© Shutterstock

Transport refrigeration

Road transport and container refrigeration units, containing 3 to 10 kg of refrigerant and mainly used for transporting chilled and frozen food.

Typical ODS (GWP)	HCFC-22 (1 810)
Typical HFC	R-404A (3 922) HFC-134a (1 430)
Lower GWP fluorocarbon	Non-flammable blends R-452A (2 140)
Not-in-kind	R-744 (CO_2, 1)

Safety issues important, so current alternatives are all non-flammable. Lower flammability blends may also enter this market if safety issues can be resolved.

© Shutterstock

Small and medium sized single split air-conditioning

Single evaporator in room being cooled connected to outdoor condensing unit (compressor / condenser) containing 0.5 to 5 kg refrigerant. Used for residential and small commercial applications (e.g. shops, offices)

Typical ODS (GWP)	HCFC-22 (1 810)
Typical HFC	R-410A (2 088)
Lower GWP fluorocarbon	HFC-32 (675) Lower flammability blends e.g. R454B (466)
Not-in-kind	HC-290 (propane, 3)

Currently a difficult market to find a very low GWP option – propane can only safely be used in very small systems at the bottom end of the size range for this market sector. Use of the lower flammability HFC-32 has grown rapidly in some markets, especially Japan. Tens of millions of HFC-32 units in operation by 2017. Blends of HFOs with HFC-32 also being developed by some equipment manufacturers.

© Shutterstock

Large sized multi-split, VRF and packaged air-conditioning

Multiple room evaporators connected to large outdoor condensing units. VRF (variable refrigerant flow) systems can offer simultaneous heating and cooling in different rooms. Packaged units used with ducted air systems. Typically contain 5 to 50 kg refrigerant.

Typical ODS (GWP)	HCFC-22 (1 810)
Typical HFC	R-410A (2 088)
Lower GWP fluorocarbon	HFC-32 (675) Non-flammable blends e.g. R-450A (605) Lower flammability blends e.g. R454B (466)
Not-in-kind	None

Lower flammability refrigerants (HFC-32 and HFO blends) being used in smaller systems where safety codes allow. Larger VRF systems currently a problem as they require non-flammable refrigerant and nothing currently available with a GWP below that of R-410A. Larger packaged systems can use non-flammable blends such as R-450A.

Air-conditioning water chillers

Medium and large sized factory built water chillers used for cooling of large buildings. Typically contain 50 to 500 kg refrigerant.

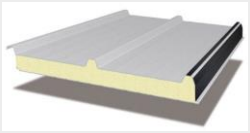
Typical ODS (GWP)	HCFC-22 (1 810) HCFC-123 (77)
Typical HFC	HFC-134a (1 430) R-410A (2 088)
Lower GWP fluorocarbon	HFO-1234ze (7) HFO-1233zd (4) R-514A (5) HFC-32 (675) R-450A (605)
Not-in-kind	HC-290 (propane) R-717 (ammonia)

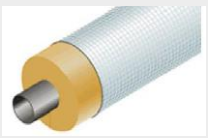
Water chillers are usually located in areas with restricted access e.g. a special machinery room or a roof-top. The refrigerant is only used in this restricted access location. This makes it easier to make use of flammable or toxic refrigerants. Various ultra-low GWP options are becoming widely available including several HFOs. HFO-1234ze is an alternative to HFC-134a in medium pressure chillers. It has lower flammability. HFO-1233zd and a recently introduced blend R-514A are alternatives to HCFC-123 in low pressure chillers – they are both non-flammable. In addition, it is also possible to consider using ammonia or propane.

Technical aerosols	
Non-domestic aerosols e.g. for supplying lubricants, solvents, foam, air dusters	
Typical ODS (GWP)	CFC-12 (10 900)
Typical HFC	HFC-134a (1 430)
Lower GWP fluorocarbon	HFO-1234ze (7)
Not-in-kind	Hydrocarbons (3), DME (dimethyl ether, 1)
Historically most aerosols used CFC propellants. After CFC phase-out, a large part of market, especially consumer products, moved to NIK. Some of the remaining market requires a non-flammable propellant. HFO-1234ze likely to become dominant where this is a requirement. HCs and DME can be used safely in some current HFC applications.	

Medical aerosols (MDIs)	
MDIs (metered dose inhalers) are small aerosols used to administer drugs for lung diseases such as asthma. Each MDI contains around 20 grammes of HFC propellant.	
Typical ODS (GWP)	CFC-12 (10 900)
Typical HFC	HFC-134a (1 430) HFC-227ea (3 220)
Lower GWP fluorocarbon	None currently available
Not-in-kind	Many MDI drugs can be administered via dry powder inhalers (DPIs).
Currently MDIs are being excluded from HFC phase-down regulations, such as that in EU, as the costs and timescales to develop alternatives to HFCs in MDIs are very high / long. This situation may change if an alternative low GWP fluorocarbon can be identified (trials are on-going).	

Polyurethane (PU) type insulation foam	
Various types of closed cell foam including PU, PIR (polyisocyanurate) and phenolic foams. A “blowing agent” is used to create cells in a polymer matrix. Blowing agent is trapped in the cells and can make significant contribution to the thermal resistance of the product. Used in a wide range of applications including steel faced panels, laminated panels, spray foam, pipe and vessel insulation and domestic appliance insulation.	
Typical ODS (GWP)	HCFC-141b (725)
Typical HFC	HFC-245fa (1 030) HFC-365mfc (794)
Lower GWP fluorocarbon	HFO-1233zd (4) HFO-1336mzz (9)
Not-in-kind	Hydrocarbons (pentane, 5)
Hydrocarbons replaced a significant proportion of ODS blowing agents as properties were acceptable and raw material cost low. Part of the market has moved from HCFCs to HFCs. New ultra-low GWP HFO blowing agents showing very promising thermal performance (i.e. very low thermal conductivity) which may justify use despite higher cost.	





Extruded polystyrene (XPS) insulation foam	
XPS closed cell foam is used for making boards for wall, floor and ceiling insulation.	
Typical ODS (GWP)	HCFC-142b (2 310)
Typical HFC	HFC-134a (1 430)
Lower GWP fluorocarbon	HFO-1234ze (7)
Not-in-kind	CO_2 (1)
Parts of the market moved to CO_2 but this is a difficult blowing agent to use. New HFO blowing agents showing good performance, but cost is a potential barrier.