

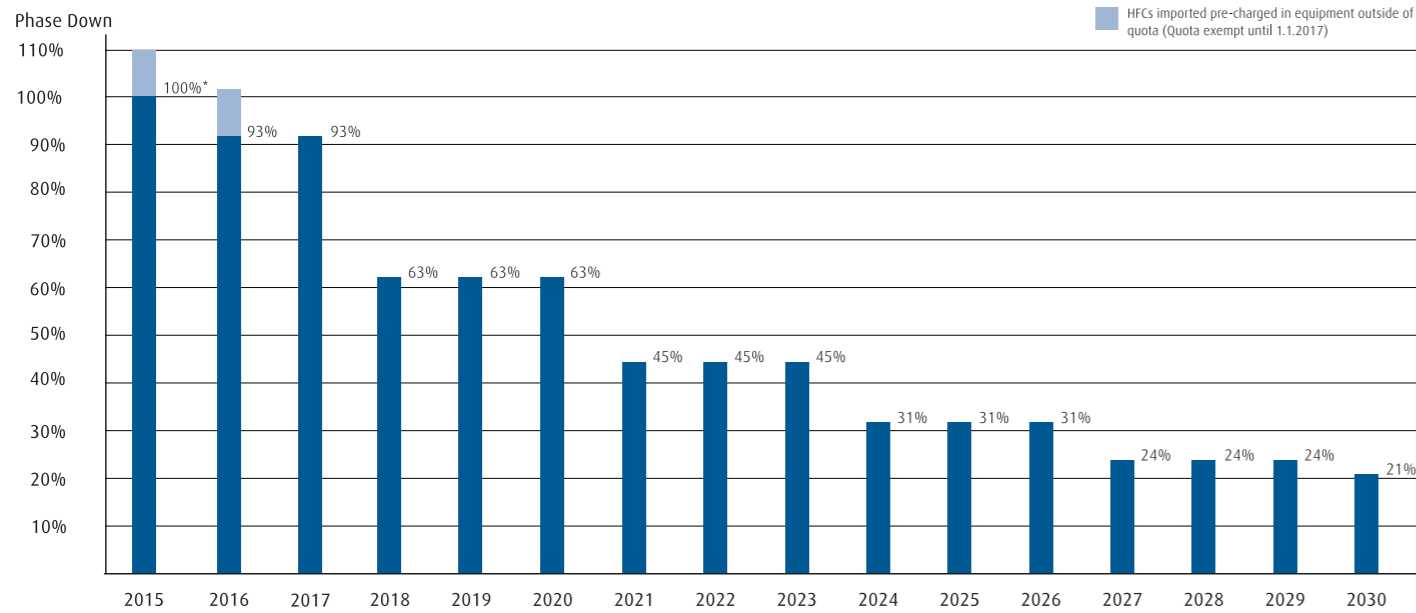
Making our world more productive



F-Gases and alternatives

Be cool, protect the environment and get ready for flammable refrigerants

Diagram 1: HFC phase down schedule (CO₂e basis, in %)



The environmental challenge

Fluorinated gases (f-gases) are used in a number of applications including refrigeration and air conditioning, foam blowing, propellants, semiconductor manufacture and electrical switchgear. Many f-gases have a high global warming potential (GWP). When released to the atmosphere, they have been identified as one of the contributors to climate change. The implementation of f-gas regulation 517/2014 since 1.1.2015 targets to the substantial reduction of greenhouse gas emissions. Every sector needs to find solutions to quickly switch to low GWP refrigerants. However, due to different thermodynamic and safety properties of the alternatives, there is no 'one size fits all' solution.

Refrigerants main use and Safety groups

Refrigeration

- Commercial refrigeration
- Industrial refrigeration
- Domestic refrigeration
- Transport refrigeration

Air conditioning

- Stationary air conditioning
- Mobile air conditioning

Each substance is assigned to a safety group specified as follows:

	Lower toxicity	Higher toxicity
No flame propagation	A1	B1
Lower flammability	A2	B2
	A2L*	B2L*
Higher flammability	A3	B3

* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤ 10 cm/s

Commercial refrigeration



Commercial refrigeration applications

Stand-alone (plug-in) equipment

Used in small stores and supermarkets, such as vending machines relying on hydrocarbons, has become available in recent years throughout the world. CO₂-based systems have also been introduced.

Centralized systems

Large refrigeration systems for supermarkets, CO₂ cascade systems are an alternative to commonly used HFC systems in many climates. Hydrocarbons have also proven to be highly efficient alternatives in most applications under high ambient temperatures.

Condensing units

The same situation as for centralized systems except for hydrocarbons which can not be used in larger condensing units for safety reasons.

Stand-alone (plug-in) equipment:

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R600a (isobutane)	3	-	A3	R134a

Centralized systems:

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R134a, R404A, R407A
	R717 (ammonia)	-	-	B2L	R134a, R404A, R407A
	R744 (CO ₂)	1	-	A1	R134a, R404A, R407A
HFC-HFO blends	R448A (Solstice N40)	1 387	R32/125/1234yf/1234ze/134a	A1	R404A
	R449A (Opteon XP40)	1 282	R32/125/1234yf/134a	A1	R404A

Condensing units:

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R134a, R404A, R407A
	R717 (ammonia)	1	-	A1	R134a, R404A, R407A
	R744 (CO ₂)	-	-	B2L	R134a, R404A, R407A
HFC-HFO blends	R448A (Solstice N40)	1 387	R32/125/1234yf/1234ze/134a	A1	R404A
	R449A (Opteon XP40)	1 282	R32/125/1234yf/134a	A1	R404A
	R452A* (Opteon XP44)	1 945	R32/125/1234yf	A1	R404A
	R454C (Opteon XL20)	148	R32/1234yf	A2L	R404A
	R513A (Opteon XP10)	573	R1234yf/134a	A1	R134a

*For low temperature applications

Industrial refrigeration

Large cooling facilities for:

- Food processing or
- Process cooling in chemical industry

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R134a, R404A, R407A
	R717 (ammonia)	-	-	B2L	R134a, R404A, R407A
	R744 (CO ₂)	1	-	A1	R134a, R404A, R407A
	R1270 (propene)	2	-	A3	R134a, R404A, R407A
HFC-HFO blends	R449A (Opteon XP40)	1 282	R32/125/1234yf/134a	A1	R404A
	R450A (Solstice N13)	605	R1234ze/134a	A1	R134a
	R513A (Opteon XP10)	573	R1234yf/134a	A1	R134a
HFOs	R1233zd	4,5	-	A1	R134a, R404A
	R1234ze	1	-	A2L	R134a, R404A

Domestic Refrigeration



- Refrigerators (optimum temp. 3 to 6°C)
- Freezers (optimum temp. at or below -18°C)

In Europe, hydrocarbon refrigerants have replaced the use of HFCs since the mid-1990s.

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R600a (isobutane)	3	-	A3	R134a

Stationary air conditioning (AC)



Designed to control the thermal comfort of living and working rooms.

Movable room AC

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R407A, R410A
HFCs	R32	675	-	A2L	R407A, R410A

Single split

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R407A, R410A
HFCs	R32	675	-	A2L	R407A, R410A

Multi split/VRF

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R407A, R410A
HFOs	R1234yf	4	-	A2L	R407A, R410A
	R1234ze	1	-	A2L	R407A, R410A
HFCs	R32	675	-	A2L	R407A, R410A

Chillers

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R134a, R407A, R410A
	R717 (ammonia)	-	-	2BL	R134a, R407A, R410A
	R718 (H ₂ O)	-	-	A1	R134a, R407A, R410A
	R744 (CO ₂)	1	-	A1	R134a, R407A, R410A
	R1270 (propene)	2	-	A3	R134a, R404A, R407A
HFC-HFO blends	R452B (Opteon XL55)	676	R32/125/1234yf	A2L	R410A
	R454B (Opteon XL41)	467	R32/1234yf	A2L	R410A
	R455A Solstice L40X)	148	R32/1234yf/CO ₂	A2L	R404A
	R513A (Opteon XP10)	573	R1234yf/134a	A1	R134a
HFOs	R1233zd	4,5	-	A1	R134a, R410A
	R1234ze	7	-	A2L	R134a, R407A, R410A
HFCs	R32	675	-	A2L	R407A, R410A

In chillers, hydrocarbons and ammonia are safe and energy-efficient alternatives to HFCs, both under moderate and high ambient temperature conditions.

Heat pumps

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R290 (propane)	3	-	A3	R134a, R407A, R410A
	R718 (H ₂ O)	-	-	A1	R134a, R407A, R410A
	R744 (CO ₂)	1	-	A1	R134a, R407A, R410A
HFC-HFO blends	R454C (Opteon XL20)	146	R32/1234yf	A2L	R410A
	R513A (Opteon XP10)	573	R1234yf/134a	A1	R134a
HFOs	R32	675	-	A2L	R134a, R407A, R410A

Heat pumps are also used with hydrocarbons, additionally CO₂ is available on the market.

Transport refrigeration



- Refrigerated vehicles
- Refrigerated containers

R448A (Solstice N40), R449A (Opteon XP40) and R452A (Opteon XP44) will be quite common replacement of R404A in road transport refrigerated vehicles.

For refrigerated containers, CO₂ can be used as a long-term alternative.

Refrigerated vehicles

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R744 (CO ₂)	1	-	A1	R134a, R404A, R410A
HFC-HFO blends	R448A (Solstice N40)	1 387	R32/125/1234yf/1234ze/134a	A1	R404A
	R449A (Opteon XP40)	1 282	R32/125/1234yf/134a	A1	R404A
	R452A (Opteon XP44)	1 945	R32/125/1234yf	A1	R404A

Refrigerated containers

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R744 (CO ₂)	1	-	A1	R134a, R404A, R410A
HFC-HFO blends	R452A (Opteon XP44)	1 945	R32/125/1234yf	A1	R404a
	R513A (Opteon XP10)	573	R1234yf/134a	A1	R134a

Mobile air conditioning (MAC)

- MAC for cars
- MAC for buses
- MAC for trains

Use of R134a is prohibited in new cars as a consequence of the EU Directive 2006/40/EC on mobile air-conditioning systems ('MAC Directive'). R1234yf is the main substitute almost exclusively used.

MAC for cars

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R744 (CO ₂)	1	-	A1	R134a
HFOs	R1234yf	4	-	A2L	R134a

MAC for buses

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R744 (CO ₂)	1	-	A1	R134a
HFC-HFO blends	R450A (Solstice N13)	605	R1234ze/134a	A1	R134a
	R513A (Opteon XP10)	573	R1234yf/134a	A1	R134a

MAC for trains

	Substance	GWP	Composition	Safety group	Replacement for
Natural refrigerants	R729 (air)	-	-	A1	R134a
	R744 (CO ₂)	1	-	A1	R134a



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Linde – Ideas become solutions.

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