ENGINEERING TOMORROW

Brochure | Lower-GWP refrigerants

Let's bring the **refrigerant transition down to earth**

Danfoss' product portfolio for low-GWP (Global Warming Potential) refrigerants enables you to build climate friendly and sustainable solutions while saving money on price increases or government taxes. Update August 2018.

More than **25** refrigerants with GWP <2500 qualified by Danfoss for HVACR applications

refrigerants.danfoss.com

Danfoss and low-GWP refrigerants

Sustainable solutions are in the best interests of all stakeholders in our industry. Sustainability safeguards long-term investments and ensures compliance with Corporate Social Responsibility. Today, when talking about refrigerants and long-term sustainability, Danfoss considers three main parameters that must be aligned to accomplish a real sustainable balance: **affordability, safety, and environment**. In order to enable the market to achieve these CO_2 eq reduction targets, Danfoss is actively working on **solutions for alternative refrigerants** with a pragmatic approach, keeping system efficiency, costs and safety in mind.
The company offers **a wide range of products and solutions for low-GWP** synthetic and natural refrigerants for both refrigeration and air-conditioning applications.

For more product information, **coolselector.danfoss.com**

Main applications and refrigerant types

GWP values are decreasing due to phase downs and energy efficiency demands (MEPS) are increasing. HVAC-R professionals will focus on using components that allow for the lowest possible charge and on technologies with the best cost/performance ratio for a given refrigerant type. Choosing a refrigerant is no simple task; it depends on the timing of regional regulations as well as applied standards and building codes. In the last year, the situation has been further complicated by massive price increases and the decreased availability of fluorinated refrigerants.

Chillers:

Depending on their size and the compressor technology they use, chillers operate with low to high pressure refrigerants and are divided into two categories: low/medium (L/M) and medium/high (M/H) pressure.
L/M chillers transitioning from R123 can stay non-flammable using HCFO solutions like R1233zd (fig.1). But this refrigerant is banned in some countries because, while its ODP is negligible, it's still above zero. R134a applications have non-flammable, A1 solutions with GWP less than 640, such as HFO blends R513A and R450A. A2L classified refrigerants need to be accepted according to applied safety standards and building codes. GWP level can come very close to zero using the pure HFO R1234ze (fig.1).
We expect industry professionals will adopt this ultra-low GWP refrigerant as a long-term solution for these kinds of systems.
For M/H pressure chillers, there is no ideal non-flammable alternative for incumbent refrigerants such as R410A. Instead, industry professionals must accept A2L or even A3 solutions like R290. A2L alternatives are in the 500 – 700 GWP range like R32/R452B/R454B.
Their use should be acceptable for systems installed outdoors or in machine rooms, but their placement must always follow local safety standards and building codes.

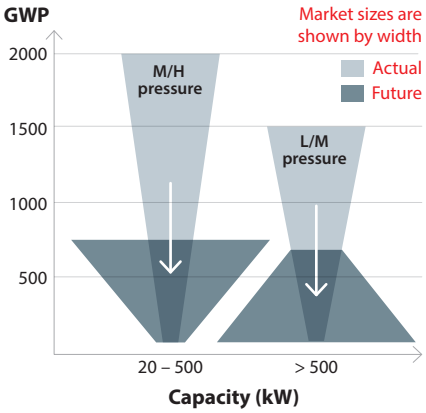


Figure 1: Market transition and GWP level per Chiller size. Most of the M/H Chillers will use refrigerants with a GWP around 750, and most L/M chillers will use ultra-low GWP refrigerants.

We foresee that the high density/pressure refrigerant choice will fall into two groups: the majority with a GWP around 500 – 750 and a smaller but still significant group applying A3 refrigerants like R290.
In the longer term, we may even experience lower GWP levels in the main market. It's dependent on refrigerant availability and cost. The F-gas phase-down has so far caused high GWP-related price increases.

VRF systems:

VRF systems use a relatively large amount of refrigerant per unit, compared to ducted systems, due to their decentralized evaporators and subsequent piping. Minimizing piping size requires medium to high density refrigerants where the only alternatives to R410A are A2L refrigerants such as R32 or R452B/R454B.
Innovative, alternative fluids are under constant development–water is an obvious choice and even CO_2 has been proposed.

Industrial Refrigeration:

From a glance, Industrial Refrigeration seems to be an easy sector regarding low GWP refrigerants, but we still see potential pitfalls as well as room for innovation. NH_3 (ammonia) has been the preferred refrigerant due to its excellent efficiency and it continues to be used as demands for sustainable refrigerants increase. However, safety concerns may potentially limit the success of NH_3 as it is toxic, necessitating comprehensive measures in order to be utilized safely. We have learned, as an industry, some important lessons such as avoiding large charges and careful planning the location of larger plants. This has led to find new, innovative ways to reduce charge sizes for example when combining NH_3 with CO_2: CO_2 takes on the role of thermal carrier and is circulated inside the larger storage facilities.

Commercial Refrigeration:

Commercial Refrigeration applications are very diverse regarding systems types and refrigerants used. It includes cold rooms, glass door merchandizers, and display and islands cabinets, either in centralized or plug-ins – hermetic or autonomous cooling circuits with condensing units. Commercial Refrigeration applications are grouped into three main categories.

1. Hermetically sealed applications today use various refrigerants with GWP up to 4000. They are suited for using low GWP refrigerants, which are safe due to their low charge amounts. Many of these systems already use hydrocarbons like R600a and R290 and the EU phasedown has required GWP values below 150 since 2016 (Fig. 2).

2. Condensing units have a refrigerant charge that is typically between 1 and 20 kg and safety on flammability is imperative as many of these systems can be accessed by the public. High GWP refrigerants like R404A have been used for many years, but new alternative A1- classified HFCs like R452A have a GWP of less than 60% of R404A . Nevertheless, the impact of higher compressor discharge temperatures on the operating envelope and the impact of refrigerant glide on cooling performance present new challenges. We believe that most of the market will quickly move to an average GWP level of around 1500, like R448A and R449A, before slowly seeking for more, lower -GWP solutions like CO_2, R290 (Hydrocarbons), or lower GWP HFO Blends (Fig. 2).

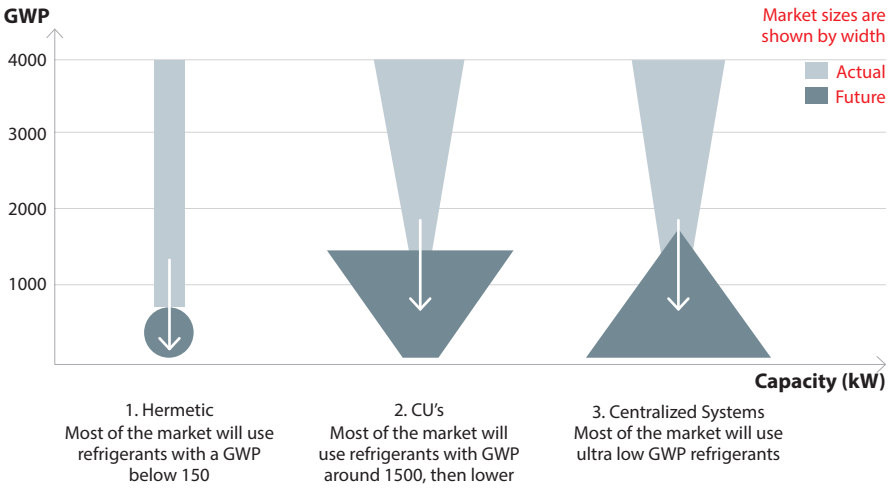


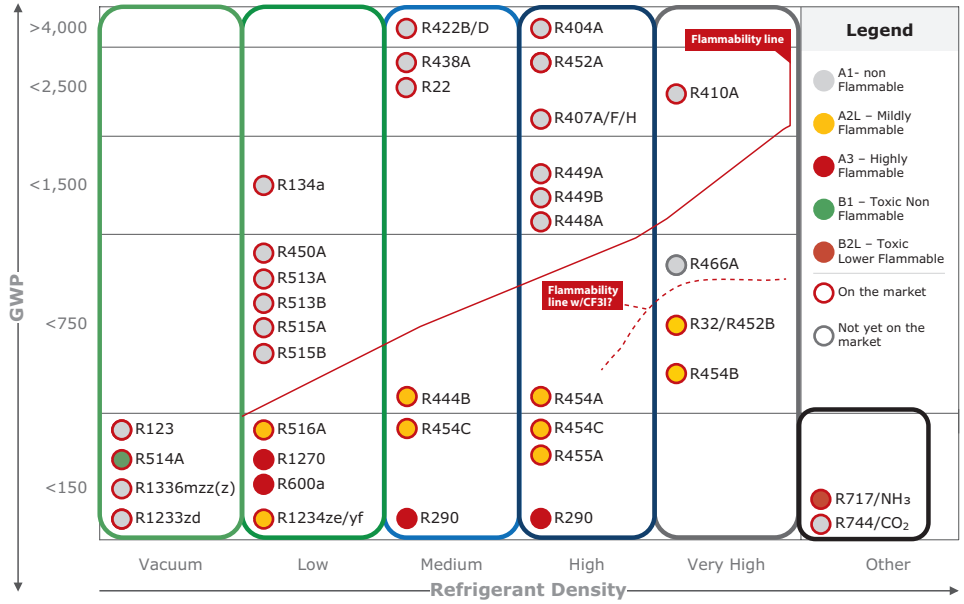
Figure 2: Market transition and GWP levels for Commercial Refrigeration applications

3. Centralized DX systems are by far the highest refrigerant-consuming application due to their large charge sizes and high leakage rates. In the EU phasedown, they are estimated to use more than 40% of the baseline amount of refrigerant recommended by the phasedown. During the last ten years, CO_2 has become a viable refrigerant and can be used in different system setups:

- Transcritical systems where CO_2 is used in all circuits (MT and LT). CO_2 transcritical systems have also been driving the development of integrated heating and cooling systems, linking the refrigerant choice to the type of system.
- Indirect systems where a chiller-like rack using HFCs, HCs, or NH_3 cools the CO_2 in a receiver, which is then circulated in the MT circuit, cooling the MT circuit. LT is also covered by CO_2 and condenses either directly to the chiller on top or the CO_2 MT circuit.
- Cascade systems where CO_2 is used only in the LT circuit and cascaded into the MT circuit which uses HFC. This type of system still uses around 80% of the HFC refrigerant used in a conventional system.

Geographical location affects the energy efficiency of any system due to outdoor ambient temperature. Transcritical CO_2 systems have been known to be extraordinary sensitive to outdoor temperatures. However, the latest developments with ejector technologies have seriously increased CO_2 system efficiency even in very warm climates, and we're now seeing a market breakthrough which will gain momentum in the coming years.

Main refrigerants at Play - A Complex Picture in Continuous Evolution



GWP versus Density (pressure) of the main refrigerant groups

Products for refrigerants with a GWP <2500

Product grouping	Product	Product descriptionz	Pressure [bar]	R1233zd	R1234ze	R134a	R290, R600a	R32	R407A R407F
Electronic controllers [1]	AK-PC 7XX	Advanced pack controllers		●	●	●	●	●	●
	AK-PC 351/ 5XX	Standard pack controllers			●**	●	●	●	●
	AK-CC 550/750	Case controller for electronic expansion valves			●**	●	●	●	●
	AK-CC 250/350/450	Case controller for thermostatic expansion valves					●	●	●
	EKC 326a	CO_2 gas pressure controllers							
	MCX	Programmable controllers		●	●		●	●	●
	EIM 336	Electronic superheat controllers			●	●	●	●	●
	EKE 1A, EKE 1B, EKE 1C (1V)				●	●	●	●	●
	EKC 313	Cascade injection with CO_2		●	●		●	●	●
	EKC 315a	Superheat controllers		●	●		●	●	●
	EKC 361	Temperature controllers		●	●		●	●	●
	EKE 347	Liquid level controllers		●	●			●	●
	ERC IIx / ETC	For commercial refrigeration		●	●	●	●	●	●
Compressors for air conditioning	DSH / DCJ	Scrolls with IDVs for air conditioning						●*	
	HLJ / HCJ+ / SH	Scrolls for air conditioning							
	PSH	Scrolls heating optimized							
	SZ	Scrolls for air conditioning							
	VZH	Inverter scrolls for air conditioning						●*	
	TT, TG, VTT	Turbocor oil-free centrifugal compressors			●	●			
Compressors for refrigeration	MTZ	Maneurop reciprocating compressor for medium temp.				●			●
	NTZ	Maneurop reciprocating compressor for low temp.							
	MLZ	Scroll compressor for medium temperature				●			●
	LLZ	Scroll compressor for low temperature							
	PL/TL/DL/FR/NL/SC/GS/ B/U/L/P/X/S	Light Commercial AC Compressors for LBP/MBP				●	●		
	SLV, NLV, DLV, XV	Variable speed reciprocating compressor for LBP/MBP					●		
	BD	Light Commercial AC/DC compressors for mobile cooling				●	●		
Condensing units	Optyma™	Condensing Units for medium temperature refrigeration				●	●		●
	Optyma™	Condensing Units for low temperature refrigeration					●		
	Optyma™ **Slim Pack**, Optyma™ **Plus**	Condensing Units for medium temperature refrigeration				●			●
	Optyma™ **Slim Pack**, Optyma™ **Plus**	Condensing Units for low temperature refrigeration							
	Optyma™ **Plus INVERTER**	Condensing Units for medium temperature refrigeration							●
Electronic expansion valves	AKV	Electronic expansion valves	28 – 52			●			●[5]
	AKVA	Electronic expansion valves	42			●			●
	AKVH	Electronic expansion valves	90			●			●
	ETS Colibri®	Electronic expansion valves	50		●	●	●	●	●
	ETS 12.5 - 400	Electronic expansion valves	45.5/34		●	●			●
Electronic Pressure & Temperature regulating Valves	CCM	Standstill capable electronic backpressure regulators	90			●			
	CCMT		140			●			
	CTM	Multi Ejector	140						
	CTR	3-Way Heat Reclaim Valve	140						
	KVS	Electronic suction modulating valves	45.5/34		●	●			●
	ICM	Industrial motorized regulating valves	52/65		●	●			●
	ICMTS	High pressure industrial motorized regulating valves	140					●	
Sensors & transmitters	AKS	Pressure sensors with 4 – 20 mA, volt., and ratiometric outputs	100	●	●	●	●	●	●
	AKS 4100	Liquid level sensors	100						●
	MBS 8200	Pressure sensors with 4 – 20 mA, and ratiometric outputs	160	●	●	●	●	●	●
	AKS Temperature	Sensors with Pt1000, Pt 1000 and thermistor elements		●	●	●	●	●	●
	GD	Gas detecting sensors			●		●		
	DST P100	Pressure Sensor with Ratiometric output and diagnostic capabilities	50	●	●	●	●	●	●
Heat exchangers	BPHE	Brazed Plate heat exchangers			●	●	●	●	●
	MPHE	Micro Plate heat exchangers			●	●	●	●	●
	MCHE	Micro Channel heat exchangers			●	●	●	●	●

[1] *Parameters for other refrigerants can be entered manually. please refer to refrigerant constants for ADAP-KOOL*
● Qualification in progress --- ●** Only in the latest versions of the controller software --- ●*** except AKV20 with media temperature constantly below 0 °C*
[5] *Only for solder version*
[7] *Models and map restrictions might apply - Contact Danfoss*
[8] *Can be defined by the user*

Refrigerants																
R407C	R410A	R422B	R422D	R444B	R448A	R449A	R449B	R450A	R452A	R452B	R454A	R454B	R454C	R455A	R513A	R744 (CO_2)	R717 (NH_3)
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For any refrigerants not listed and for the detailed information per product, please contact Danfoss or check in Coolselector: coolselector.danfoss.com

Products for refrigerants with a GWP <2500

Product grouping	Product	Product description	Pressure [bar]	R1233zd	R1234ze	R134a	R290, R600	R32	R407A R407F
Thermostatic expansion valves	TU	Stainless steel thermostatic expansion valves	45.5					●	
	TU		34		●	●	●		●
	TC		45.5		●	●	●	●	●
	T2	Thermostatic expansion valves	34			●			●
	TD1		34			●	●		
	TG		46		●	●	●	●	●
	TE5-TE55		28			●			●
	TEA	Industrial thermostatic exp. valves							
Solenoid valves	EVR v2 [2]	Allround solenoid valves	32 – 45.2		●[6]	●	●[6]	●[6]	●
	EVRA/T	Solenoid valves	42			●			●
	EVRH	High pressure solenoid valves	45.2		●	●		●	●
	EVU	Semi-hermetic solenoid valves	70						●
	EVUL	Fully-hermetic solenoid valves	90				●	●	●
	ICLX	Flexline™ solenoid valves	52			●		●	●
Valve stations	ICF	Flexline™ valve stations	52/65			●			●
Mechanical pressure & temperature regulating valves	KVD	Receiver pressure regulators				●	●		●
	KVC	Capacity regulators				●	●		●
	KVL	Crankcase pressure regulators				●	●		●
	KVP	Evaporating pressure regulators				●	●		●
	KVR	Condensing pressure regulators				●	●		●
	CPCE	Hot gas bypass regulating valves				●	●		●
	CVC / CVP	Pilot valve for ICS	65			●			●
	ICS	Mechanical backpressure regulators	52/65		●	●	●	●	●
	REG-S	Flexline™ regulating valves	52			●	●	●	●
Switches	AKS 38	Electro-mechanical float switches	28		●			●	●
	KP	Pressure switches	46		●	●	●		●
	RT					●			●
	MP	Differential pressure switches				●	●	●	●
	RT					●			●
	ACB	Cartridge pressure controls	45		●	●	●	●	●
	CCB		165						
Water regulating valves	WVFX	Pressure operated water valves				●	●		●
	WVO					●	●		●
	WVS					●	●		●
Filters & driers	DCR	Receiver filter driers with replaceable solid cover	28/46	●	●	●			●
	DMC / DCC	Receiver filter driers	42	●	●	●	●	●	●
	DML / DCL	Liquid line filter driers	46	●	●	●	●[3]	●[3]	●
	DMB / DCB	Bi-flow filter driers	46	●	●	●	●[3]	●[3]	●
	DAS	Burn-out filter driers	35	●	●	●	●[3]	●[3]	●
	DMT	Filter driers for transcritical applications	140						
	DMSC	Filter drier for subcritical applications	52						
Check valves	NRV	Piston check valves	46		●	●	●[4]	●[4]	●
	NRVA		40			●	●	●	●
	CHV-X	Flexline™ check valves	52/65			●			●
	SCA-X	Flexline™ check & stop valves	52/65			●			●
Shut-off valves	GBC	Shut-off ball valves	45		●	●	●[4]	●[4]	●
	BML	Shut-off diaphragm valves	28		●	●	●[5]		
	SNV / SVA	Gauge valves / Flexline™ stop valves	52/65		●	●	●	●	●
Sight glasses	SG	Sight glasses for low pressures	35			●			●
	SGP	Sight glasses for high pressures	52		●	●	●[5]	●[5]	●

Qualification in progress
[2] New EVR: 45.2 bar
[3] Filter Driers with connection sizes below 25 mm for solder version (copper/cu-plated) - Qualification of DMSC/52 bar for CO_2 in progress
[4] NRV with connection sizes below 22 mm for solder version / GBC with connection sizes below 25 mm
[5] only for solder version
[6] EVR v2 2 to 22 with solder connection and without manual stem

Refrigerants																	
R407C	R410A	R422B	R422D	R444B	R448A	R449A	R449B	R450A	R452A	R452B	R454A	R454B	R454C	R455A	R513A	R744 (CO_2)	R717 (NH_3)	R1234YI
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Refrigerant benefits in your HVACR application

		Refrigeration												Air Conditioning						Heat Pumps					
	Application	Domestic-Household refigeration			Light Commercial refrigeration			Commercial Racks and Condensing Units			Industrial Refrigeration			Residential A/C (including Reversible systems)			Commercial A/C			Residential and Commercial			Industrial		
	Watt	50 – 300			150 – 5000			> 5.000			> 1.000.000			1.000 - 20.000			> 20.000								
Refrigerant	Region/Year	2018	2022	2027	2018	2022	2027	2018	2022	2027	2018	2022	2027	2018	2022	2027	2018	2022	2027	2018	2022	2027	2018	2022	2027
CO_2 R744	NAM											*													
	Europe											*													
	China												*												
	ROW												*												
NH_3 (2L) R717	NAM											*													
	Europe											*													
	China												*												
	ROW												*												
HC	NAM																								
	Europe																								
	China																								
	ROW																								
HFC	NAM																								
	Europe																								
	China																								
	ROW																								
HFC/HFO below GWP 700	NAM																								
	Europe																								
	China																								
	ROW																								

Main refrigerant | Regular use | Limited use and only niche applications | Not applicable or unclear situation

** Ammonia/CO_2 cascades will dominate industrial refrigeration*

Table 1: Global trends in refrigeration and air conditioning (Status in 2017)

Seen from a global perspective, the tendency of the industry is to move increasingly toward natural refrigerant solutions when it is technologically safe & economically feasible. Synthetic refrigerants are still likely to play an important role in both the refrigeration and air conditioning industries, where the trend is also moving toward new low-GWP substances that cause a minimal environmental impact.

CO_2 (R744)

- The CO_2's GWP value equal to 1
- Lends itself well to **food retail applications**, where the impact, in case of leaks, is minimal and where its thermodynamic properties make it the ideal media for heat recovery
- Transcritical CO_2 cycles reject a large proportion of the cycle heat at high temperatures which makes it suitable for **heat pumps**
- In **industrial refrigeration**, CO_2 provides a means to reduce the charge of Ammonia, increasing the efficiency and decreasing the footprint of freezing equipment
- In **transport refrigeration**and **electronics cooling**, CO_2 provides a non-flammable, environmentally benign solution

Ammonia (NH_3 - R717)

- GWP and ODP (Ozone Depletion Potential) equal to zero, cost (per kg) considerabl lower than the cost of HFCs
- Ammonia is one of the most **energy efficient** refrigerants in applications ranging from high to low temperatures. With the increasing focus on energy consumption, ammonia is a sustainable choice for the future
- Ammonia has better **heat transfer properties** than most of chemical refrigerants and therefore plant construction and operating costs will be lower

Hydrocarbons (R290, R600)

- Provides high energy-efficiency, good volumetric capacity and large operating envelopes compared to HFCs
- The flammability limits the use to **small systems** and **chillers** (e.g. **chillers for food retail systems** or for **comfort air conditioning** installed outside the building)
- Allows for very low evaporating temperatures without overheating the compressor when used in **heat pumps** (with HFCs you need to supplement with an electrical heating element for the really cold days or more expensive vapor / liquid injection cycles) **Medium GWP HFC / HFO blends**
- A transitional solution that can be used in retrofitting high-GWP HFC systems. Medium GWP solutions, <1500, and non-flammable are particularly indicated where indoor system charge can be an issue and alternative system architecture too expensive

Mildly flammable HFC & HFO

- The low GWP and low flammability makes these refrigerants suitable for **relatively large systems**
- Especially interesting for **air conditioning** where there is a lack of non-flammable (A1) natural alternatives

Scan here for a direct access to the **Danfoss white paper**

Read more about energy efficiency and your refrigerant options at **refrigerants.danfoss.com**