ENGINEERING
TOMORROW

Save money and be ready
for the 4th refrigerant transition

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.

>25

refrigerants with GWP < 2500 qualified by Danfoss for HVACR applications

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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 (CSR).

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 information, see in Coolselector or contact Danfoss.

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Main applications and refrigerant types

In the future, GWP values are decreasing due to phase downs and energy efficiency demands (MEPS) are increasing. HVAC-R professionals will focus on using components which allow for the lowest possible charge and on technologies with the best cost/performance for a given refrigerant type.

Chillers:

Generally speaking when it comes to refrigerants, chillers are divided into two categories: low/medium (L/M) and medium/high (M/H) pressure. L/M pressure chillers can benefit from the use of pure HFOs (R1233zd and R1234ze), resulting in a GWP close to zero (Fig. 1). The flammability penalty is very low and manageable, especially for systems installed outdoors or in machine rooms. We can expect that for the short-to-medium term, this type of system will adopt ultra-low GWP refrigerants. The upper GWP limit, for large L/M chillers, will be governed by local phasedown implementation and informally by GWP level impact on fluid costs. Depending on these, they could reach 630, which corresponds to the GWP of HFO blend R513A, listed by the EPA-SNAP regulation of July 2015 while R134a will be delisted starting in 2024. For M/H pressure chillers, the medium GWP alternatives are in the 125-750 GWP range but users must be willing to accept an A2L flammability classification. This, again, should be acceptable for systems installed outdoors or in machine rooms. The market will likely move to GWP alternatives which offer the best trade-off between system costs and performance. We foresee that the high density/ pressure refrigerant choice will fall to those with a GWP around 500-750.

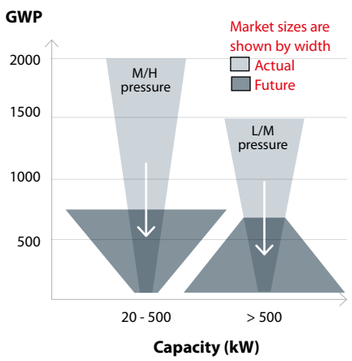


Figure 1: Market transition and GWP level per Chiller size. Most of the M/H Chillers will use refrigerants with a GWP around 750, and most L/M chillers will use ultra-low GWP refrigerants

VRF systems:

VRF systems use relatively large amounts 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 like R32 or R452B.

The use of A2L refrigerants is closely connected to safety standards like EN378 and ISO5149, where the allowable amount of A2L refrigerant has been increased considerably in the latest editions. The ASHRAE15 working group is also looking into the future need of low GWP refrigerants. However, while these safety standards are a must, they are not sufficient on their own.

Many local fire regulations have been serious barriers towards the using of A2L refrigerants. Innovative, alternative fluids for circulation are under constant development—water is an obvious choice for circulation and even CO_2 has been proposed. The recent HFC phasedown under the Montreal Protocol has put pressure on revealing opportunities and risks associated with using A2L refrigerants. The coming years will likely show a more clear direction on the refrigerants choice for VRF systems.

Industrial Refrigeration:

From a glance, Industrial Refrigeration (IR) 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 5 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 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 before slowly seeking for more, lower solutions like CO2, R290 (Hydrocarbons), or HFO blends. (Fig. 2)

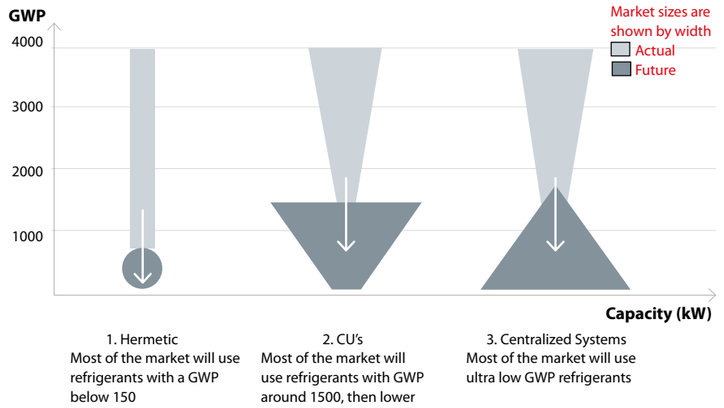
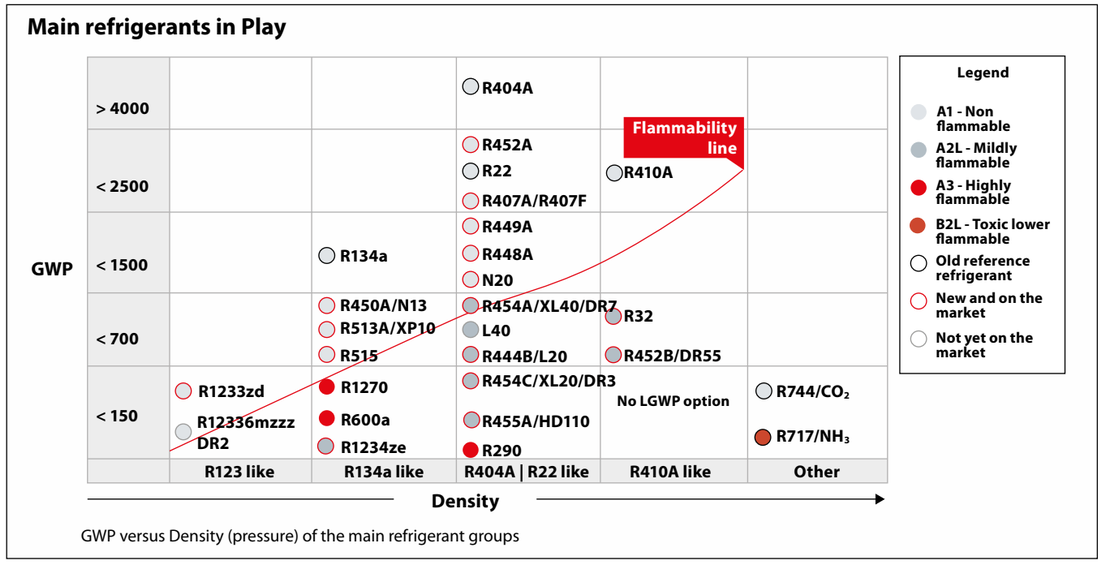


Figure 2: Market transition and GWP levels for Commercial Refrigeration applications

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 injection technologies have seriously increased CO_2 system efficiency even in very warm climates and we expect it to see a market breakthrough during the next years.



GWP versus Density (pressure) of the main refrigerant groups

Products for refrigerants with a GWP <2500

										Refrigerants																		
Product grouping	**Product**	**Product description**		**R1233zd**	**R134a**	**R450A**	**R513A**	**R1234ze**	**R290, R600a**	**R452A**	**R407A R407F**	**R407C**	**R449A**	**R449B**	**R448A**	**R454A**	**L40**	**R444B**	**R454C**	**R455A**	**R410A**	**R32**	**R452B**	**R454B**	**R422D**	**R422B**	**R744 (CO_2)**	**NH3**
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, EKD 316, EXD 316	Electronic superheat controllers			●		●	●	●	●	●	●	●		●						●	●			●		●	●
	EKC 316A, EKC 312	Electronic superheat controllers			●				●		●	●									●	●					●	●
	EKC 313	Cascade injection with CO_2		●				●	●	●	●							●				●	●				●	●
	EKC 315a	Superheat controllers		●				●	●	●	●							●				●	●				●	●
	EKC 361	Temperature controllers		●				●	●	●	●							●				●	●				●	●
	EKE 347	Liquid level controllers		●				●		●	●							●				●	●				●	●
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								●			●*		●*													
	P/T/D/N/SC/ D/U/L/P/X/S	Light Commercial AC Compressors for LBP/MBP			●		●*		●	●*			●*															
	SLV	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	PAllround electronic valves	28-52 bar		●	●	●			●	●	●	●		●										●	●	●	
	AKVA	Pulse width modulating expansion valves	42 bar				●			●	●		●		●										●			●
	AKVH	High pressure electronic exp. valves	90 bar		●	●	●			●	●	●	●		●						●				●	●	●	
	CCM	High pressure standstill capable motorized expansion valves	90 bar		●																						●	
	CCMT	High pressure standstill capable motorized expansion valves	140 bar		●																						●	
	ETS Colibri®	Electronic expansion valves	50 bar		●	●	●	●	●	●	●	●	●		●	●		●	●		●	●	●	●	●			
	ETS	Electronic expansion valves	45.5/34 bar		●			●				●									●							
Valves	ICM	Industrial motor operated valves	65 bar								●																	●
	ICMTS	High pressure industrial motorized expansion valves	140 bar								●																	
Electronic pressure & temperature regulating valves	CCM	Standstill capable electronic backpressure regulators	90 bar		●																						●	
	CCMT	Standstill capable electronic backpressure regulators	140 bar		●																						●	
	CTR	3-Way Heat Reclaim Valve	140 bar																								●	
	KVS	Electronic suction modulating valves	45.5/34 bar		●					●		●									●							
	ICM	Industrial motorized regulating valves	52 bar								●																	●
	ICMTS	High pressure industrial motorized regulating valves	140 bar							●												●						
Sensors & transmitters	AKS	Pressure sensors with 4-20 mA, volt., and ratiometric outputs	100 bar	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●
	MBS 8200	Pressure sensors with 4-20 mA, and ratiometric outputs	160 bar	●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●
	AKS Temperature	Sensors with Pt1000, Pt 1000 and thermistor elements		●	●	●	●	●	●	●	●	●	●		●	●		●	●	●	●	●	●	●	●	●	●	●
	GD	Gas detecting sensors						●	●									●					●				●	●
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

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		Refrigerants																					
				R1233zd	R134a	R450A	R513A	R1234ze	R290, R600	R452A	R407A R407F	R407C	R449A	R449B	R448A	R454A	L40	R444B	R454C	R455A	R410A	R32	R452B	R454B	R422B	R422D	R744 (CO_2)	NH3
Thermostatic expansion valves	TU	Stainless steel thermostatic expansion valves	45.5 bar		●	●	●		●	●	●		●		●						●	●					●	
	TU		34 bar		●	●	●		●	●	●		●		●						●	●					●	
	TC		45.5 bar		●	●	●		●	●	●	●	●		●						●	●					●	
	T2	Thermostatic expansion valves	34 bar		●	●	●			●	●	●	●		●													
	TD1		34 bar		●	●	●		●	●	●	●	●		●													
	TG		46 bar		●	●*		●*	●		●							●				●	●*	●*				
	TE5-TE55		28 bar		●	●*	●*			●*	●		●*		●*							●		●*				
	TEA	Industrial thermostatic exp. valves																										●
Solenoid valves	EVR [2]	Allround solenoid valves	32-45.2 bar		●	●		●	●	●	●	●	●		●			●			●	●				●		
	EVRA	Solenoid valves	42 bar								●																	●
	EVRH	High pressure solenoid valves	45.2 bar		●	●		●		●	●	●	●	●	●						●	●			●	●		
	EVU	Semi-hermetic solenoid valves	70 bar			●				●	●	●	●		●												●	
	EVUL	Fully-hermetic solenoid valves	90 bar			●			●	●	●	●	●		●												●	
	ICLX	Flexline™ solenoid valves	52 bar						●		●											●					●	●
Valve stations	ICF	Flexline™ valve stations	52 bar								●																●	●
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			●	●	●		●	●	●		●		●										●	●		
	ICS	Mechanical backpressure regulators	52 bar						●		●											●					●	●
	REG-S	Flexline™ regulating valves	52 bar								●											●					●	●
Switches	AKS 38	Electro-mechanical float switches	28 bar					●			●							●			●	●	●	●			●	●
	KP	Pressure switches	46 bar		●	●	●	●	●	●	●	●	●		●			●			●	●	●	●	●	●		●
	RT				●						●	●													●	●		●
	MP	Differential pressure switches			●	●	●		●	●	●	●	●		●							●			●	●	●	●
	RT				●						●	●													●	●	●	●
	ACB	Cartridge pressure controls	45 bar		●		●	●	●	●	●		●		●						●	●						
	CCB		165 bar																								●	
Water regulating valves	WVFX	Pressure operated water valves			●	●	●		●	●	●		●		●						●				●	●		●
	WVO				●	●	●		●	●	●		●		●										●	●		●
	WVS				●	●	●		●	●	●		●		●						●				●	●		●
Filters & driers	DCR	Receiver filter driers	28/46 bar	●	●	●	●	●		●	●		●	●	●								●					
	DMC		42 bar	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
	DCC			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
	DML	Liquid line filter driers	46 bar	●	●	●(3)	●	●(3)	●(3)	●	●	●	●	●	●	●(3)	●(3)	●(3)		●	●	●(3)	●(3)	●	●	●		
	DCL			●	●	●(3)	●	●(3)	●(3)	●	●	●	●	●	●	●(3)	●(3)	●(3)	●**	●	●	●(3)	●(3)	●	●	●	●	
	DMB	Bi-flow filter driers	46 bar	●	●	●(3)	●	●(3)	●(3)	●	●	●	●	●	●	●(3)	●(3)	●(3)		●	●	●(3)	●(3)	●	●	●		
	DCB			●	●	●(3	●	●(3)	●(3)	●	●	●	●	●	●	●(3)	●(3)	●(3)	●**	●	●	●(3)	●(3)	●	●	●	●	
	DAS	Burn-out filter driers	35 bar	●	●	●(3)	●	●(3)	●(3)	●	●	●	●	●	●	●(3)	●(3)	●(3)		●	●	●(3)	●(3)	●	●	●		
	DMT	Filter driers for transcritical applications	52/140 bar																								●	●(3)
	FIA	Flexline™ filters	65 bar								●											●					●	●
Check valves	NRV	Piston check valves	46 bar		●	●	●	●	●	●	●	●	●		●			●			❖	●(4)		●(4)			90 bar	
	NRVA		40 bar						●		●											●						●
	CHV-X	Flexline™ check valves	52 bar								●																●	●
	SCA-X	Flexline™ check & stop valves	52 bar								●																●	●
Shut-off valves	GBC	Shut-off ball valves	45 bar		●	●	●	●		●	●	●	●		●						●	●(5)					90 bar	
	BML	Shut-off diaphragm valves	28 bar		●	●	●	●	●(6)			●										●(6)						
	SVA	Flexline™ stop valves	52 bar						●		●											●						●
Sight glasses	SG	Sight glasses for low pressures	35 bar		●	●	●			●	●	●	●		●													
	SGP	Sight glasses for high pressures	52 bar		●	●	●	●	●(6)	●	●	●	●		●						●	●(6)		●(6)			●	

[2] New EVR: 45.2 bar
[3] Filter Dryers with connection sizes below 25 mm - Qualification of the filter driers mentionned for R452B and R454B in progress - Qualification of DMT/52 bar for CO_2 in progress
[4] NRV with connection sizes below 22 mm for solder version
[5] GBC with connection sizes below 25 mm
[6] only for solder version

For any refrigerants not listed and for the detailed information per product, please contact Danfoss or check in Coolselector: **coolselector.danfoss.com**

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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 Heat Pumps			Industrial Heat Pumps		
	Watt	50 - 300			150 -5000			> 5.000			> 1.000.000			1.000 - 20.000			> 20.000								
Refrigerant	Region/Year	2017	2022	2027	2017	2022	2027	2017	2022	2027	2017	2022	2027	2017	2022	2027	2017	2022	2027	2017	2022	2027	2017	2022	2027
CO_2	NAM											*													
	Europe											*													
	China												*												
	ROW												*												
NH_3 (2L)	NAM											*													
	Europe											*													
	China												*												
	ROW												*												
HC	NAM																								
	Europe																								
	China																								
	ROW																								
HFC	NAM																								
	Europe																								
	China																								
	ROW																								
HFC/HFO below GWP700	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, light commercial applications** and **electronics cooling**, CO_2 provides a non-flammable, environmentally benign solution

Ammonia (NH_3)

- 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**

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