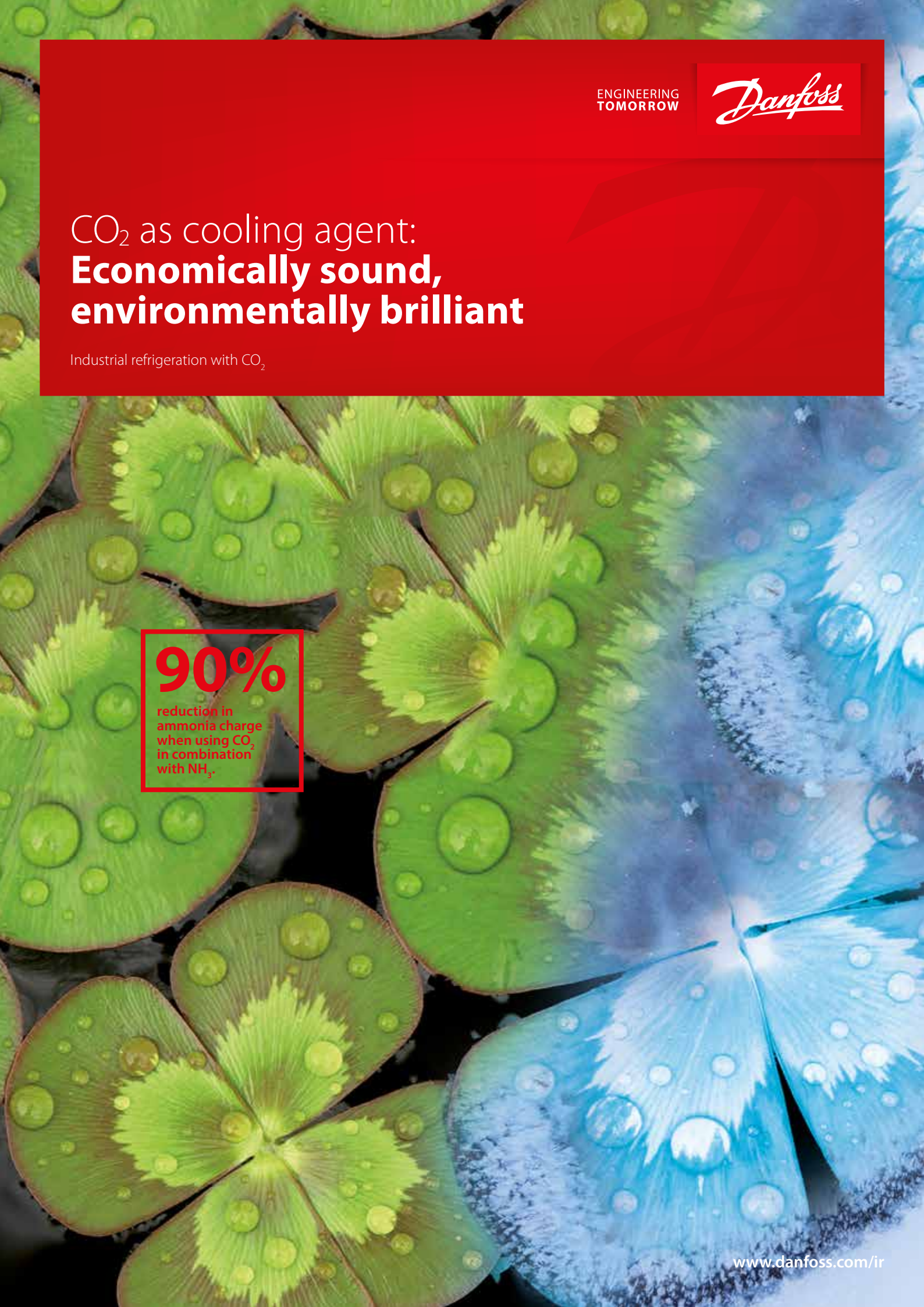
ENGINEERING
TOMORROW

CO_2 as cooling agent:
Economically sound, environmentally brilliant

Industrial refrigeration with CO_2



www.danfoss.com/ir

You can do that ? Really ?

CO_2 is an excellent choice when it comes to replacing HFCs and glycol based systems in industrial refrigeration plants. Danfoss has the expertise in applied technology as well as the experience to offer the leading components you need to build reliable, cost effective and environmentally friendly refrigeration systems using CO_2 as secondary coolant.

Additional benefits include a compact footprint of the engine room, smaller piping and pumps that consume only 10 % of the power of traditional brine systems.

Both operational and maintenance costs of process and cold storage facilities are reduced considerably in comparison with plants operating with traditional water-based brines.

Use CO_2

to save CO_2

by using CO_2 as a secondary coolant you save energy and reduce the total carbon footprint of your system. You also save money on your refrigeration plant.

Sure we can!

Industrial refrigeration with CO_2 is:

- **Reliable technology – tried and well tested**
- **A way to save up to 20 % in energy cost**
- **A more efficient way to build cooling systems**
- **Environmentally friendly**
- **Less costly to operate and service versus traditional cooling systems**

It's no surprise that CO_2 has always been attractive to be used as a secondary coolant. CO_2 is not only abundant and relatively inexpensive but it offers non-toxic and non-flammable properties.

Challenges dealing with high pressures in a cost effective way are over. The technology has achieved a maturity stage where standard 52 bar components are available making CO_2 secondary coolant systems financially and environmentally advantageous.

Danfoss has been and continues to be at the forefront offering solutions designed to operate under the conditions required by CO_2 based systems. Danfoss also offers expertise and know-how in this field.

CO_2 - you just got to love it

- **Superior thermophysical properties**
- **Non-corrosive**
- **Non-toxic**
- **Non-flammable**
- **ODP = 0***
  GWP = 1**
- **Low viscosity means smaller pipe dimensions**
- **Allows for downsizing to lower efficiency pumps**
- **Works as cooling agent even with lower energy consumption**

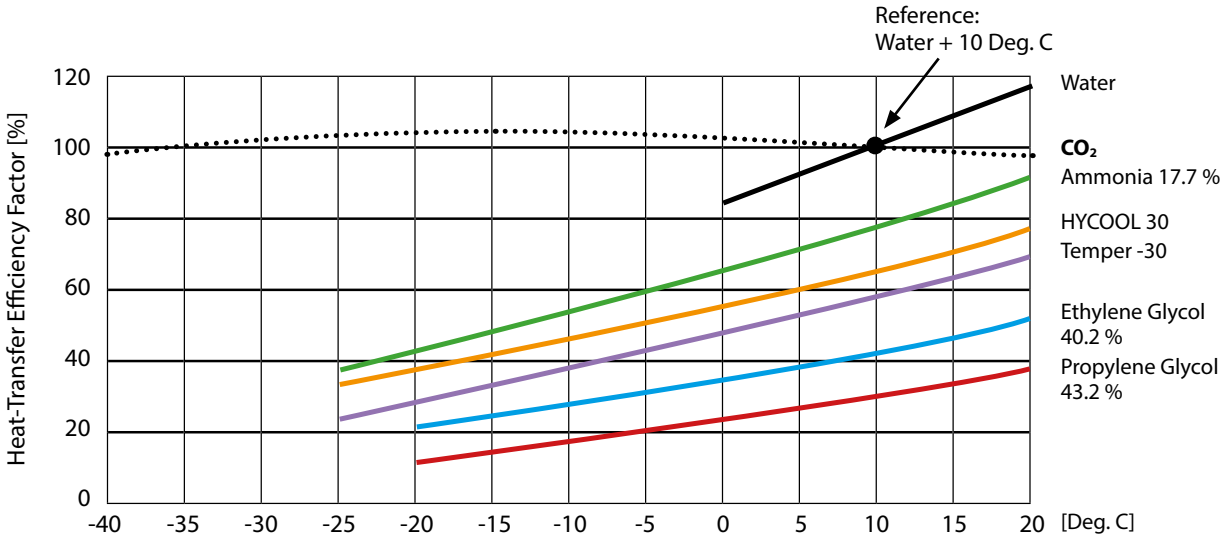
* ODP stands for Ozone Depletion Potential.
** GWP stands for Global Warming Potential.

CO_2 as cooling agent

CO_2 has a very high heat transfer efficiency coefficient. This, along with its constant evaporation temperature, makes it possible to operate with a lower temperature difference in the evaporators and heat exchangers. The benefit is much lower energy consumption.

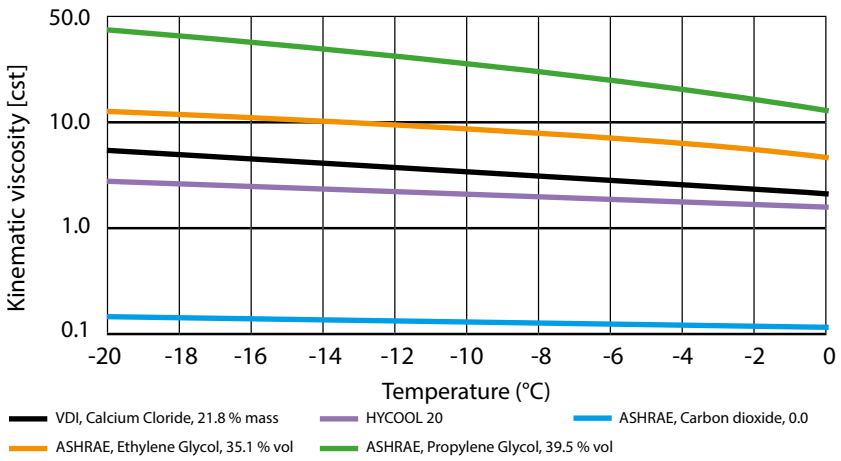
Since CO_2 is significantly less viscous throughout the temperature range, smaller pipe dimensions and pump sizes are required, adding to the cost savings of the system.

High Heat-Transfer Efficiency Factor



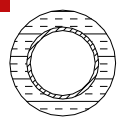
The Heat-Transfer Efficiency Factor expresses the relation between the heat-transfer coefficient and the cooler temperature.

Low viscosity



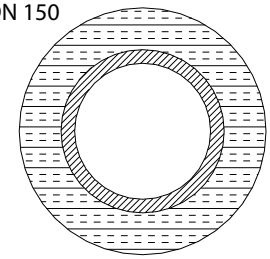
CO_2

DN 65



Glycol

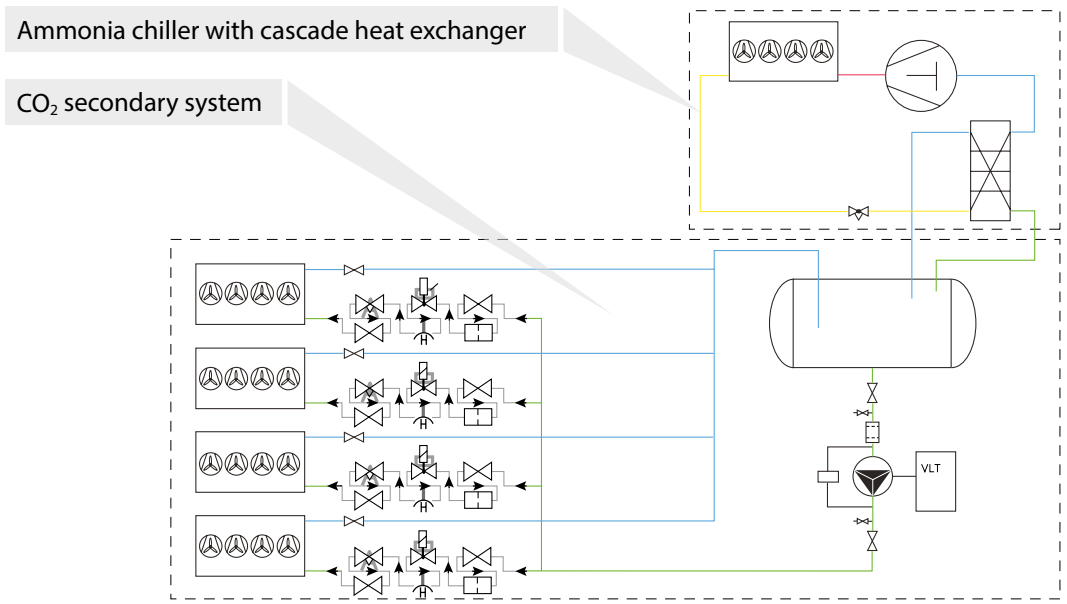
DN 150



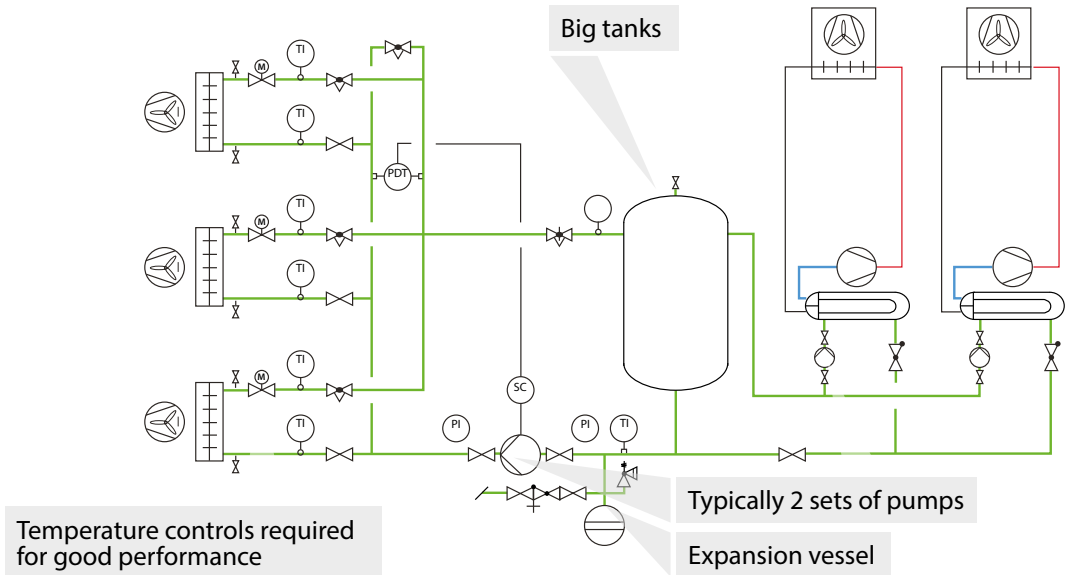
Low installation costs

Systems using CO_2 as a cooling agent are relatively less complex compared to more conventional cooling systems. Combined with smaller dimensions for piping and for pumps this means that a refrigeration system with CO_2 can be up to 12 % less expensive to install than systems using water brine and glycol. You can estimate your potential savings by using our simple calculation tool at www.danfoss.com/COtoo.

CO_2 brine system



Water brine systems



Using CO_2 to save money

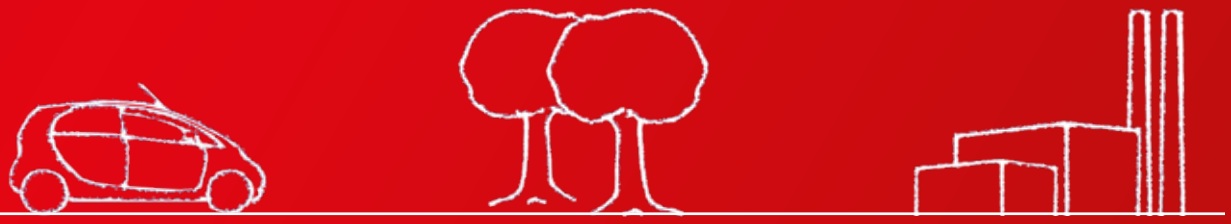
CO_2 cooling technology has made significant gains in recent years. Combined NH_3 / CO_2 cooling installations are no longer more costly to install. Even in such cases where refrigeration systems require higher installation costs, experience shows that the average additional 10 % installation cost is quickly recovered through considerably lower energy costs. In the diagram below is a comparison in energy expenditure in two systems – one using propylene glycol, the other using CO_2.

CO_2 brine efficiency calculator	CO_2	Propylene Glycol	Units
Air temperature, t_{air}	*0*		°C
Cooling power, Q_o	*500*		kW
Circulation rate, n	*1.1*		-
Temp. dif. in evap., dt_{evap}	*5.0*	*7.0*	K
Temp. dif. in PHE, dt_{PHE}	*3.0*	*4.0*	K
Brine temp. dif., t_{out} - t_{in}		*4.0*	K
Evaporating temp., t_o	*-8.0*	*-11.0*	°C
Additional heat gains, k_q	*5 %*	*7 %*	%
Additional heat gains, Q_{add}	*25*	*34*	kW
Frequency controllers used?	*NO*	*NO*	
Pump head pressure, H_{pump}	*2.5*	*2.5*	Bar
Pump power cons., P_{pump}	*0.7*	*11.0*	kW
Adjusted cooling power, $Q_{o,ad}$	*525.7*	*543.6*	kW
Compr. power cons., P_{comp}	*131.0*	*150.5*	kW
Working hours, daily	*18.0*		h
Total install energy cons.	**132**	**161**	**kW**
Total daily energy cons.	**2,375**	**2,971**	**kW*h**
Energy savings	**20 %**		**%**

Savings calculation			
kW*h price	*0.1*		EURO
Life time of the installation	*4*		years
Discount rate	*14 %*		%
First cost	*550,000*	*500,000*	EURO
Energy cost, life time	347,468	434,646	EURO
Total energy savings	**87,177**		**EURO**
Annual energy savings	**21,794**		**EURO**
NPV	**19,645**		**EURO**

Using CO_2 to save CO_2

Whenever CO_2 is used to supplant conventional gases such as HFCs, the environment will draw benefits from it. CO_2 itself is a greenhouse gas - however, studies show that the impact of HFCs on global warming is up to 6,000 times higher than CO_2. Governments worldwide are taking action to reduce the use of HFCs. Therefore the use of CO_2 as your choice for a cooling agent does not only mean that you help to reduce your carbon footprint through lower energy expenditure and the use of a cooling gas with negligible environmental impact compared to conventional gases. It also means safeguarding your cooling plant from future restrictions. The example above converts to the following environmental benefits:



4,383,642 km saved

6,255 trees saved

565 tons CO_2 saved

Minimum energy expenditure, maximum freshness

Danfoss is an experienced and reliable partner in CO_2-based secondary cooling systems. You can benefit from our experience with more than 1,000 transcritical systems installed across the world and a decade of field tests. Our experience in CO_2 systems design covers all aspects from the design of components such as controls, valves and compressors to support and monitoring.

Country	Size (kW)	Note
CANADA	490	NH_3 - CO_2 LT and MT brine system
FINLAND	400	CO_2 system for the VahterusRing Ski Tunnel
RUSSIA	4,300	Very large CO_2 installation in Moscow
USA	3,600	US Cold storage warehouse in Pennsylvania
CHINA	3,000	NH_3-CO_2 Production and cold store in Dalian

HOLLAND

In Rotterdam, close to the harbor, sits the sophisticated De Jong Coldstores fruit distribution center, where thousands of tons of fresh fruit are being stored and distributed to consumers all over Europe. Keeping fruit fresh and cool can be a bit of a headache, especially as the cooling chain must never be broken.

In the facility, 12,500 pallets in 15 individually temperature controlled compartments are handled by fully automated cranes and conveyors, removing the need for human handling.

Realizing the need to replace ammonia with a NH_3/CO_2 solution, the De Jong company and their Dutch contractor Cofely designed a unique cooling system using 100 evaporators with Danfoss ICF valves which provide a refrigeration capacity of 3,000 kW.

The demands for working pressure were high, as always when dealing with CO_2-cooled systems, so maximum working pressure was fixed at 52 bar. This means that the installation process was somewhat complex, mostly because little experience was available. The expertise needed was provided by Danfoss and now allows De Jong Coldstores to keep the fruit fresh at optimum temperatures, to save money on daily operation and to contribute to a cleaner environment.

Key Figures:

- 100,000 m^3 storage space
- Capacity 10 – 15,000 pallets
- Refrigeration capacity 3,000 kW
- Maximum working pressure 52 bar
- Estimated energy savings compared to conventional systems: 19 %

Danfoss Industrial Refrigeration

A world of expertise at the click of a button

Turn to Danfoss if you want to combine quality components with expert knowhow and support. Try out these free tools, designed to make your work much easier.

Coolselector® 2 – New calculation software for Industrial Refrigeration
Coolselector®2 is your brand new Danfoss calculation and selection software designed to make selection processes for all industrial refrigeration projects easier and less time consuming. Coolselector® 2 is a unique calculation and support tool for contractors and system designers, offering complete pressure drop calculations, analysis of pipe and valve design and the ability to generate performance reports. It replaces the well-known DIRcalc™ software and offers several new functionalities.

Danfoss IR app
The free IR App gives you a spare parts tool, which makes it easy for you to find the spare part number for a given Danfoss industrial refrigeration valve. It also presents all the products and benefits of the SVL Flexline™ range – with a fun game thrown in as well.

Download 3D CAD symbols
From our online product catalogue on our website, you can download 3D CAD symbols and illustrations to help you when designing refrigeration plants.

IR application tool
With this interactive PowerPoint slideshow, you can explore all the details of a two-stage ammonia plant. You will find detailed cut-away drawings and information on the valves in the installation along with links to videos, literature and product animations.

Application handbook
The Application Handbook is designed to help you every step of the way when working with industrial refrigeration systems. Among many other things, it contains examples of how to select control methods for different refrigeration systems, their design and which components to choose.

Visit **www.danfoss.com/IR-tools** and find all the tools you need.

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Produced by Danfoss® RC-MC/DBS 2015-03