ENGINEERING
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Danfoss

Brochure | Oil-free technology for Heat Pumps

Meet decarbonization goals in commercial buildings and district heating

Decarbonization and the reduction of greenhouse gas emissions require electrification and the related move from fossil fuel source to electric-driven heating equipment. Commercial heat pumps constitute one of the most important types of technologies in decarbonizing future heating supply. And with heating electrification, Danfoss oil-free technology will bring decisive operating cost and emissions reduction advantages to commercial building owners and district heating utilities.

From
60%
lower CO_2 emissions with electric heat pumps featuring oil-free technology

heatpumpsolutions.danfoss.com

Heat pumps are the key to meeting efficiency operating cost and **carbon emissions goals**

Many organizations today are working to identify ways to meet decarbonization goals, reducing their dependence on carbon-rich fossil fuels such as coal, natural gas, oil, and propane. Their goal: to dramatically reduce emissions of the greenhouse gases implicated in climate change, while also decreasing their energy costs at the same time.

The drive to ditch fossil fuels

Heating buildings consumes the largest amount of energy and produces the highest CO_2 emissions. So, the focus is on planning for a resilient and efficient system that can provide affordable and low-carbon heat for all. To minimize investments, energy demand must be reduced by applying energy efficiency measures to buildings and optimizing the performance of technical building systems.

There is also a need to establish efficient, decarbonized heating supply systems that put a focus on supply-side renewable energy. The nature of renewable primary energy supply will force the demand and supply sides to become much more integrated. This will in turn call for new applications and technologies like demand-side flexibility and thermal or electrical energy storage. As an example of the potential, in the Heat Roadmap Europe (HRE) studies 1 and 2, it has been shown that increasing district heating to cover 50 percent of the total heat demand, together with 40 GW heat pump capacity, can address up to 15 percent of total heat demand. In periods with a surplus of renewable electricity, heat pumps are supposed to continue operating and using thermal storage to capture excess heat during periods when the low cost compressor heat capacity would otherwise go unutilized.

With maximized renewable power generation integration, heat pumps can be introduced effectively on a mass scale as centralized or decentralized zero carbon heat suppliers. Smaller heat pumps can boost flow temperatures for offices or multi-apartment buildings, while large heat pumps can supply heat to the grid via seawater or a ground source.

Traditionally, fossil fuel-based heating has been popular due to its lower equivalent unit cost compared to electricity. For example, the cost of a kW of electricity can average two and half times that of natural gas in the US and Europe. But the efficiency comparison ratio—including the significant heat pump part load efficiency advantage—is higher, reducing the operating cost of electric against gas by 35%.

Warming to district heating systems

One method of comfort heat production that is proving increasingly popular—particularly in Europe where it accounts for 20% of overall production—is district heating.

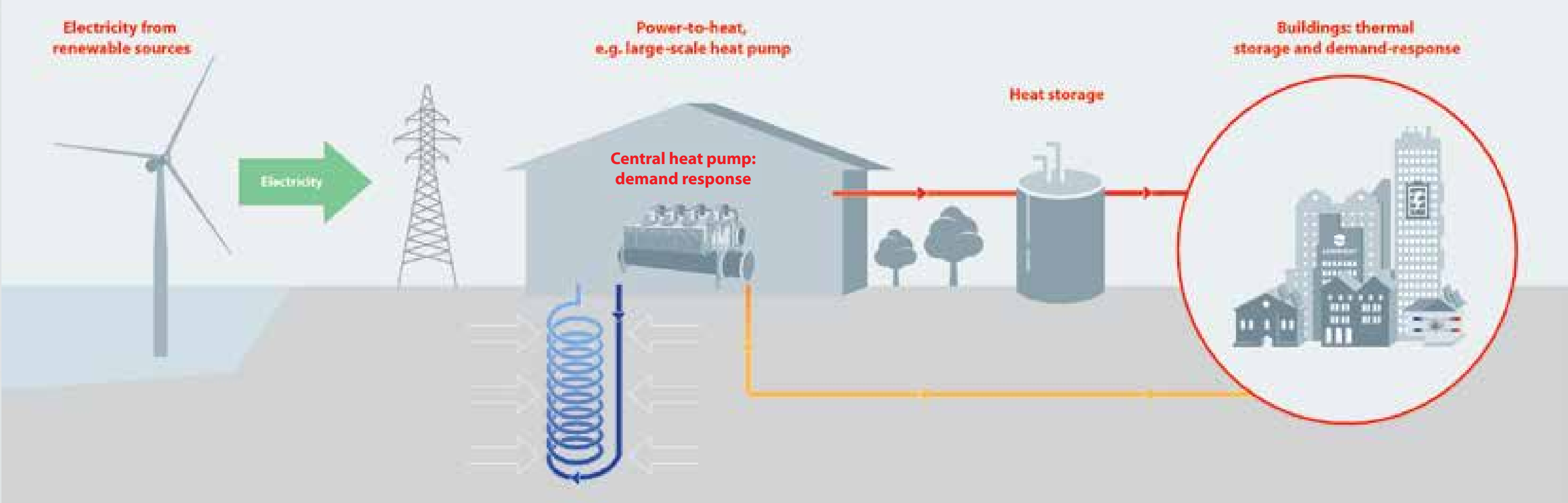
District heating is a system designed to distribute heat that's produced in a central and/or distributed location. Using a network of insulated pipes, heat is transferred to buildings for comfort space and water heating.

District heating is already having a significant impact, transforming both heating and cooling efficiency, helping reduce harmful emissions—increasing resiliency of electrified heating while eliminating the individual residence heat pump equipment and electrical infrastructure investment for it—and helping reduce energy bills.

And while fossil fuels have been the predominant source of district heating, electric heat pumps are an increasingly popular replacement.

The higher the recovered temperature, the more efficient the heat pump. That's why many opt for distributed heat recovery heat pump systems over centralized systems where the temperature range is far higher and there are more possibilities.

For example, moving from a centralized location—using seawater as the heat source at the same location as the former fossil fuel-fired heat plant—to a new data center where the heat pump is cooling the data storage while recovering the heat to district heating, increases the recovered temperature by 20K or more. This results in a 20%–30% increase in the heat pump efficiency.



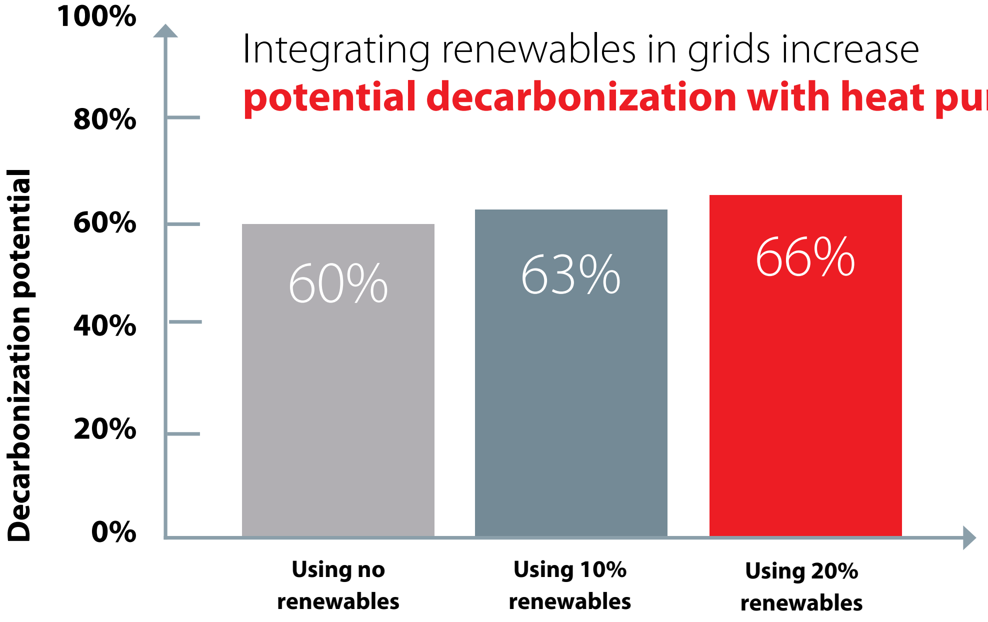
A virtuous process: using renewables boosts growth, sustainability, and resilience in conjunction with district energy heat pumps

The more renewables used and the larger the scale, the more sustainable and resilient the electrification of heating.

Electrification of heating boosts renewables benefits
The transition from fossil fuels to electric heat pumps delivers more benefits from renewables used in power grids.

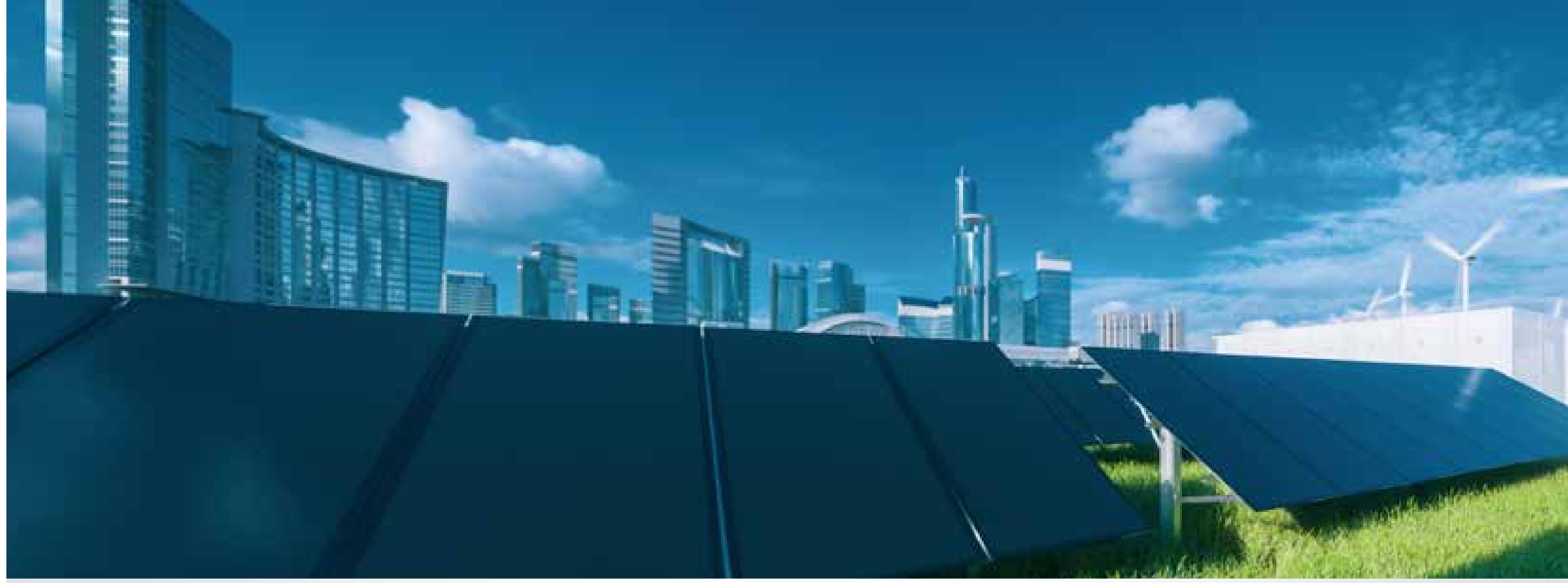
Variable speed equipment and district energy promises resilience
Demand response-optimized solutions in micro-grids and district energy provide resilience for ultimate efficiency and minimized downtime.

Optimized compression for a variety of requirements
Heat pumps driving higher lift-optimized and higher maximum temperature capable compressors to meet more challenging heat pump operating temperature requirements efficiently. Plus, various optimized and staged versions of variable speed oil-free compressors provide optimal part-load efficiency and resilience solutions in district systems.



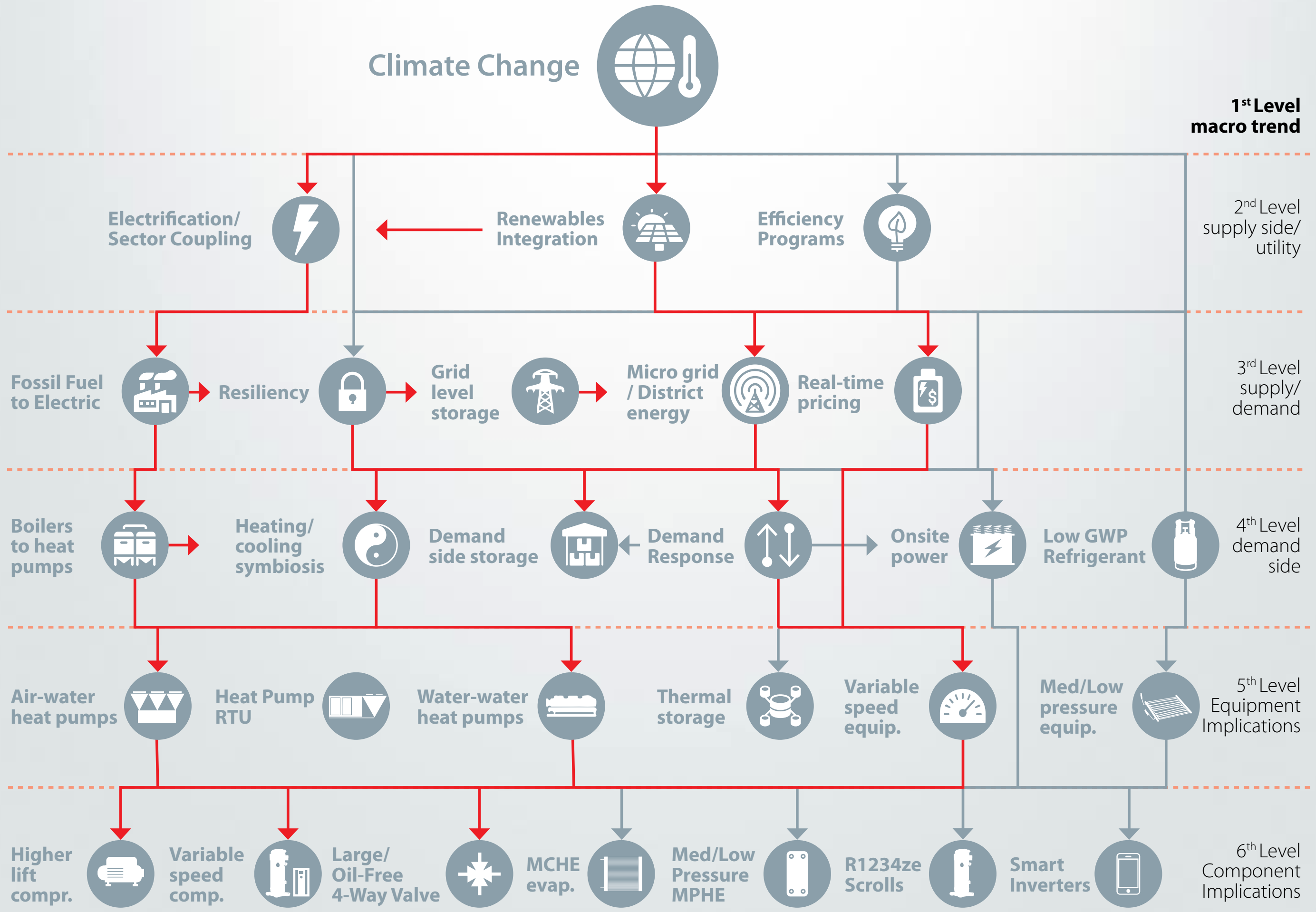
For every 10% of increase in percent of power coming from renewables, there is a corresponding 3% increase in emissions reduction* resulting from heat pump installation.

*Starting from the ~60% decarbonization baseline



From megatrends down to product implications: the levels driving system innovations

The interlinking of megatrends and their implications leads to the ultimate solution: **district heating integration of oil-free heat pumps.**



The potential of Danfoss **oil-free Technology**

– Making heat pumps **more efficient**

With more than 45,000 systems installed worldwide, Danfoss Turbocor® oil-free compressors have been successfully implemented for decades. The pioneering technology boasts many system benefits while delivering the lowest lifetime cost of ownership—and new innovations have the potential to bring oil-free benefits in heat pumps.

Cutting-edge development has brought the Danfoss Turbocor® TTH and TGH compressors to the market, leveraging oil-free technology with a high potential for satisfying the drivers of heating decarbonization. Featuring expanded operating maps optimized and with expanded maximum temperature for use in high lift applications—such as district heating networks or commercial building heat pumps–TTH and TGH compressors, as with all Danfoss Turbocor® compressors, feature built-in variable speed operation for maximum efficiency.

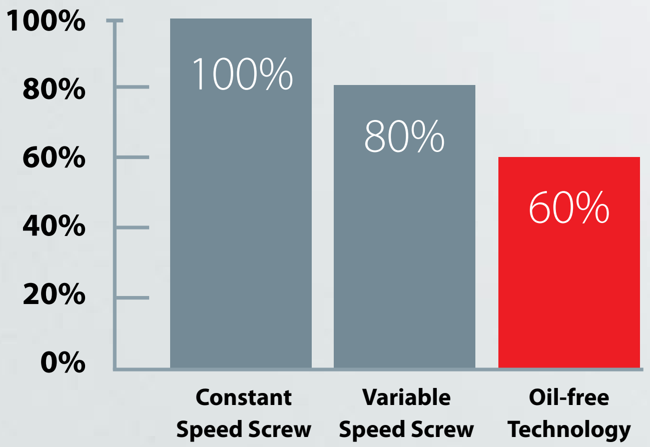
Modeling suggests that, when used in electric heat pump applications, Danfoss Turbocor® oil-free, magnetic bearing centrifugal compressors can provide significant energy use, operating cost savings and substantial reduction in carbon footprint vs both variable and constant speed screw compressor technologies.

And, when replacing or as an alternative to a high efficiency condensing boiler, the operating costs and primary energy use/emissions reduction is as shown below. This estimated reduction in CO2 emissions increases as renewables are integrated into the power grid.

These comparative improvements can further increase over time because oil-free, magnetic bearing centrifugal compressors maintain performance over the long term.

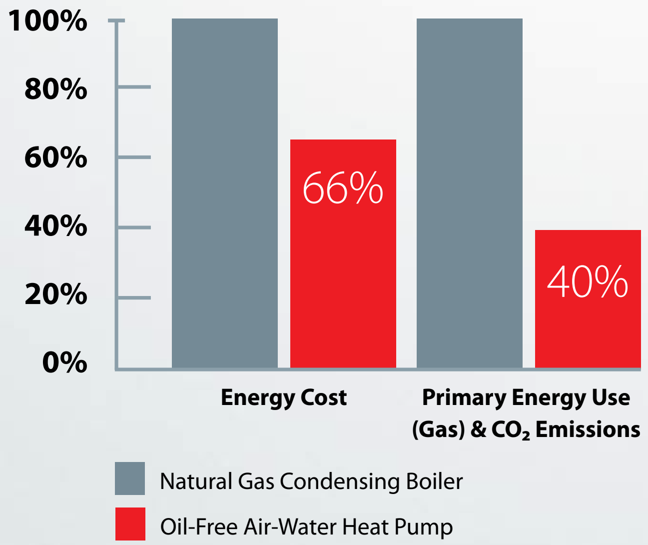
Oil-Free Air-Water Heat Pump:
Energy Use, Cost & CO_2 Emissions

vs. Alternative Compressor Technologies



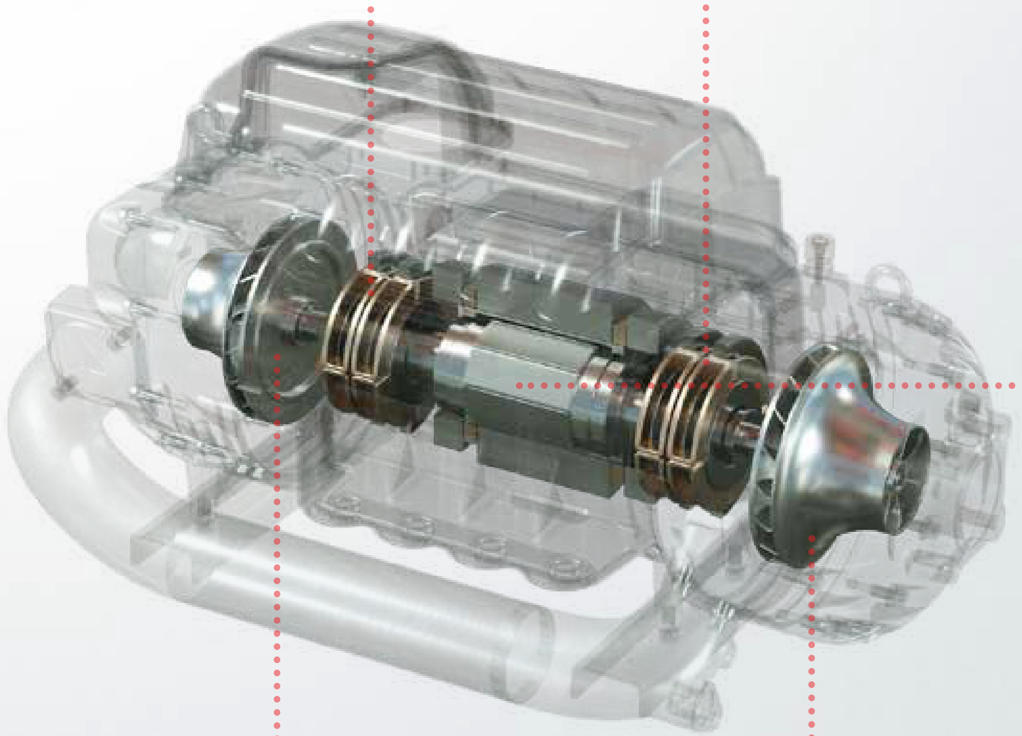
Source Danfoss. Modeled for Warm Climate conditions; Rating points at EN 14825

vs. Condensing boiler



Oil-free, magnetic bearing compressor technology eliminates complex oil and refrigerant lubrication management systems resulting in a simplified chiller design, increased reliability and reduced maintenance.

Oil-free, magnetic bearings and integrated variable speed drive delivers industry leading efficiency with no performance degradation over the life of the compressor.



Permanent magnet synchronous motor provides high efficiency and enables compact design.

Two stage back-to-back compression design provides flexibility to use for Water-water and air-water heat pump applications.

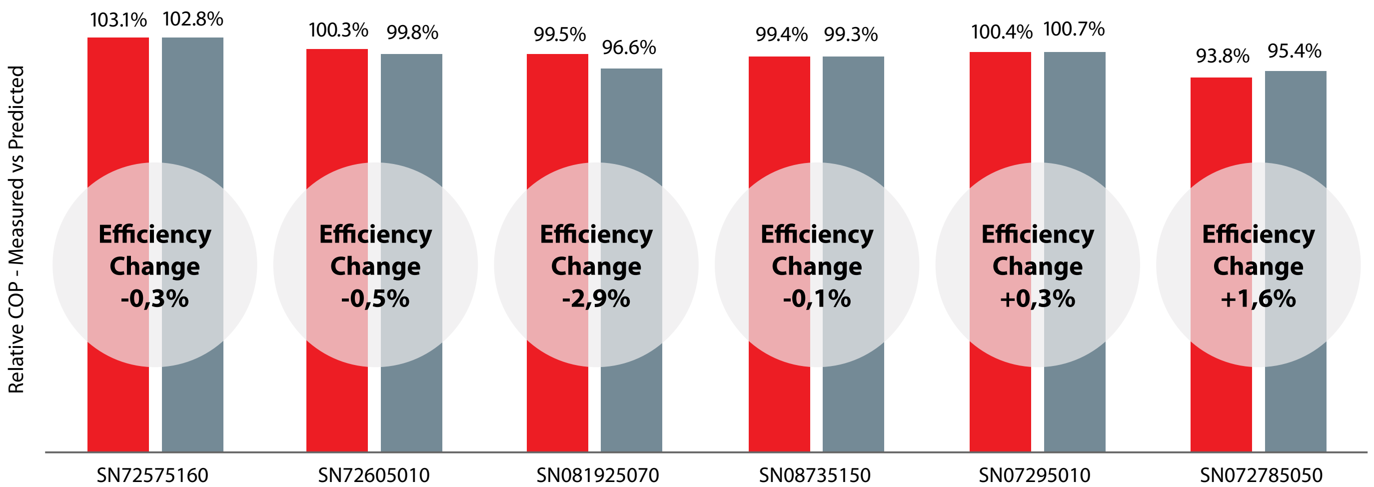
The potential of Danfoss oil-free technology minimizing heat pump **lifecycle costs**

Zero Performance Degradation

Without oil in the system, there is no performance degradation due to oil contamination or mechanical wear. This, along with the contact-free operation enabled by magnetic bearings, means the performance remains consistent over the life of the compressor—proven through testing of 10+ year-old compressors in our factory compared to the original testing from the time of production.

Oil-free compressor performance after more than 10 years of operation

- No variation above any measurement uncertainty
- Turbocor® Magnetic bearing compressors means no wear in and no wear out



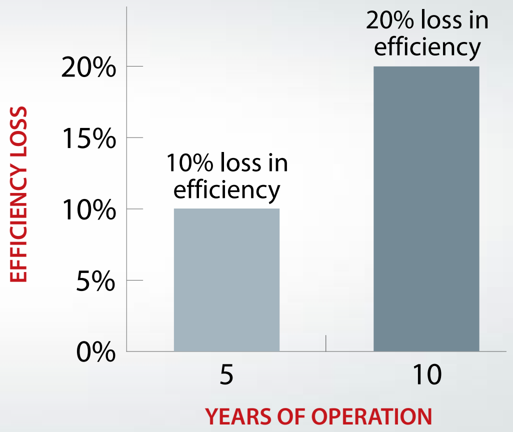
Original Retest after 10+Yrs

Source: Danfoss tests in laboratories

Measurement uncertainty error typically +/- 3%

Performance degradation over time with **oiled compressors**

Source: Tsinghua University Study 2014



A simplified design with **Reduced Maintenance**

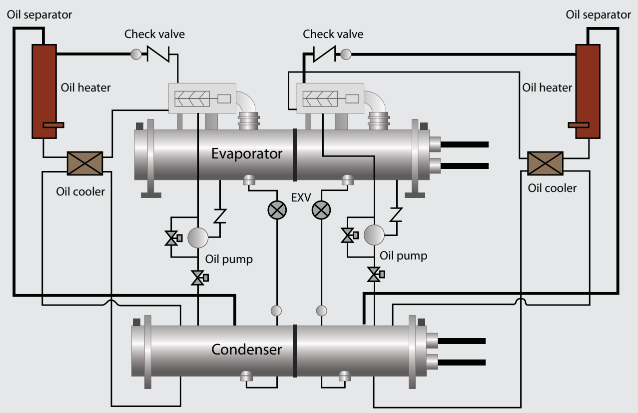
While long-term performance is a key advantage for oil-free compressor technology, there are additional benefits in terms of design and maintenance. Removing oil from the system results in a more simplified design that eliminates frequent maintenance tasks required on traditional oiled systems.

A heat pump with a typical oil management system includes components such as an oil separator (separates the oil from the refrigerant), oil cooler (reduces the temp of the oil because hot oil loses some of its lubrication properties), oil heater (boils off refrigerant from the oil to prevent dilution) and an oil pump (circulates the oil through the system). A heat pump using oil-free technology eliminates these components and provides a design with significantly fewer mechanical parts and reduced complexity.

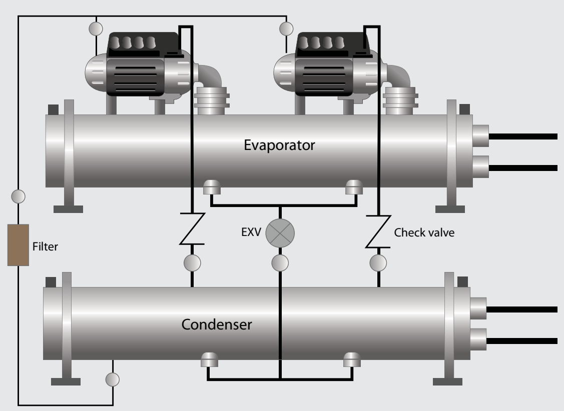
Eliminating the oil management system means common maintenance tasks associated with oil are no longer necessary, resulting in annual savings of $3,650 or lifetime savings of $83,950 in maintenance costs assuming a 23-year heat pump life.

Design

Oil management system



Oil-free heat pump



Maintenance

Required tasks for oiled systems:

Check oil level daily	
Change oil annually	$1,600
Replace oil filter Bi-annually	$2,000
Inspect / maintain key components - oil pump, sump heater weekly	
Oil analysis annually	$50

The above five maintenance tasks are no longer required for oil-free systems.

Oil-free compressor benefits:

- Energy and cost savings
- Zero performance degradation
- Low sound and vibration
- Less complexity
- High reliability
- Reduced maintenance
- Compact and light weight
- Low-GWP refrigerants (R513A, HFO1234ze(E) and R515B)

The **optimization and low-GWP edge** …

A range for **various applications**

Staged compression optimized for varying requirements

Combined with a portfolio of tested oil-free technology, standard, medium, and high-lift* oil-free compressors optimize system efficiency with high reliability and fit various applications.

For district heating applications, the most efficient heat pump system almost always incorporates more than one optimized compressor lift design.

***Lift: Temperature difference between Saturated Suction (SST) and Saturated Discharge (SDT)**

Standard

Up to ~50 °C ~32 K design (~57 °F)

Down to ~4 °C ~42 K max (~76 °F)

Applications
Water-cooled chiller
Evap-cooled chiller

Compressors
TTS400, TTS700
TGS390, TGS520
VTT1200
VTX1600

Medium

Up to ~63 °C ~42 K design (~76 °F)

Down to ~-10 °C ~57 K max (~103 °F)

Applications
Air-cooled chiller
Water-cooled chiller
Evap-cooled chiller
W-W heat pump
High-temp process

Compressors
TTS300, TTS350
TGS230, TGS310
TGS490

High

Up to ~69 °C ~55 K design (~99 °F)

Down to ~-18 °C ~65 K max (~117 °F)

Applications
Air-cooled chiller
W-W heat pump
A-W heat pump
Med-temp process
Thermal storage

Compressors
TTH375
TGH285

… with **Danfoss Turbocor® oil-free** compressors

Including **higher lift applications**

The Danfoss Turbocor® TTH/TGH oil-free centrifugal compressor is specifically designed for high lift applications such as air-cooled chillers in hot ambient climates, heat recovery, heat pumps, low-temp process, or thermal storage.

The TTH/ TGH compressor provides a high-performance alternative to the traditional oiled screw compressor that is more efficient, quieter and with a smaller physical footprint.

Choose the refrigerant that suits **your local regulations**

Danfoss Turbocor® compressors are available with R134a, low-GWP refrigerants R513A and R515B, and ultra-low GWP R1234ze.

TTH375 Nominal capacity of 376 kW / 107 tons using R134a or R513A.

TGH285 Nominal capacity of 288 kW / 82 tons using R1234ze or R515B.

Both feature

- Large Operating Range and High-Lift up to 6.2PR covering both Air-Cooled and Water-Cooled capability
- Low, medium and high temp applications
- 380, 400, 460V and 575V

Flexibility and symbiosis efficiency edge ...

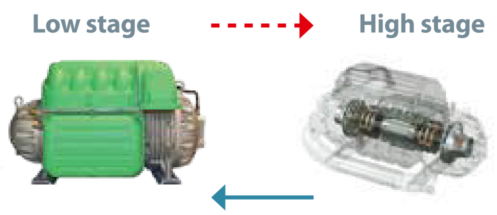
... with **Danfoss Turbocor®** **oil-free** compressors

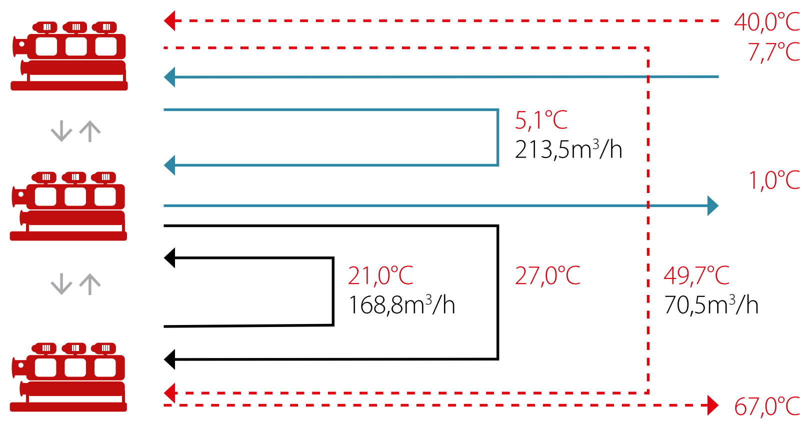
Pairing compressor with **4th and 5th Generation District Heating** system designs

In 4th Generation District Heating, medium- and high-lift compressor models are used.

4th Generation District Heating Symbiosis with TGS and TGH Compressors

- Series-Series Counterflow/Stage **= optimal performance**
- Low stage TGS medium lift
- High stage TGH high lift

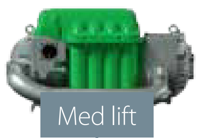


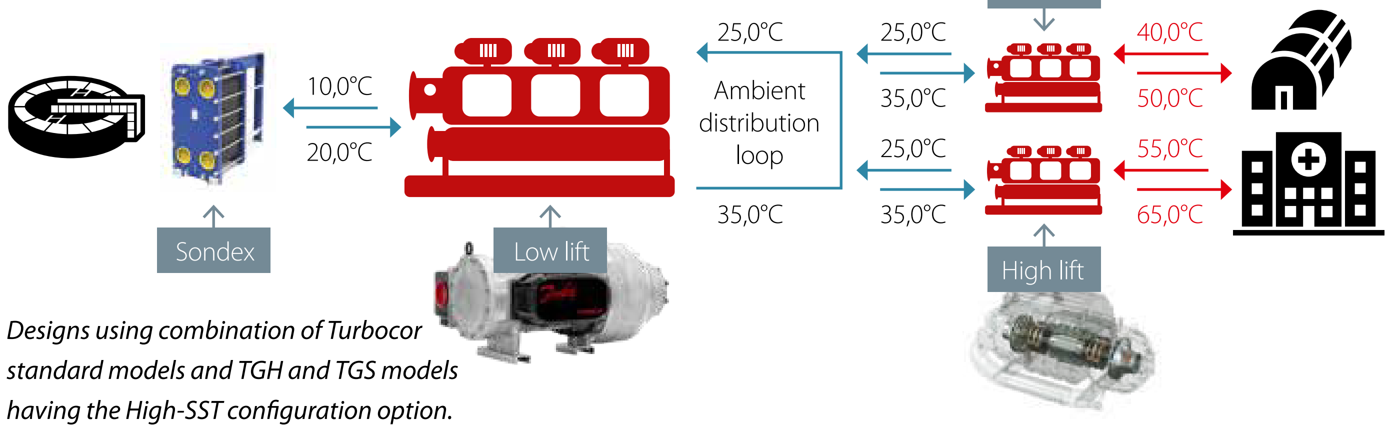


In 5th Generation District Heating, standard compressors combined with a high-lift are used.

5th Generation District Heating with VTX and TGH/TGS Compressors

- 5th generation systems growing in newer heating networks/regions - Minimize distribution losses.
- Design for individual loads:
  – Distributed heat pumps at individual facilities per requirements
  – All three compressor optimizations incorporated
- Wastewater heat source – Sondex semi-welded HX isolates heat pump





Designs using combination of Turbocor standard models and TGH and TGS models having the High-SST configuration option.

Water–water heat pump design parameters

Critical factors

- Source & supply water temperature both critical to heat pump system efficiency
- Higher source water and/or lower supply water = more efficient system
- Enables lowest resulting heat price/quickest payback
- Heat pump system ~ 1-1.5 % efficiency increase with 1K reduction in system lift

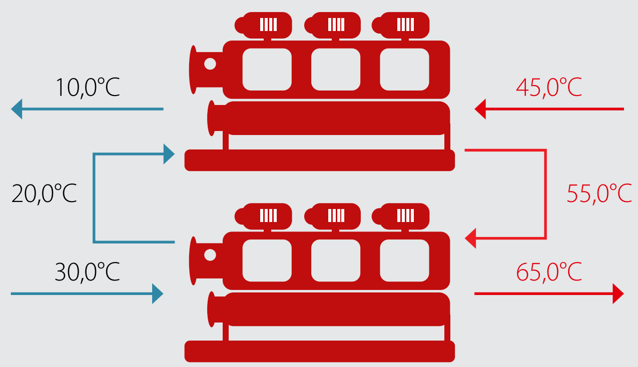
Architecture guidelines

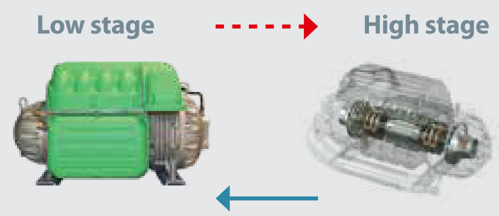
- Source & supply flows and differentials drive parallel vs series arrangements
- Cascade arrangement driven by lower source and/or higher supply temperature

Compressor implications

- Max 65K compressor differential & system capacity/turn-down drive architecture
- 3 main compressor optimizations - All utilized in heat pump systems

-1 K system lift = +1,5 % system efficiency

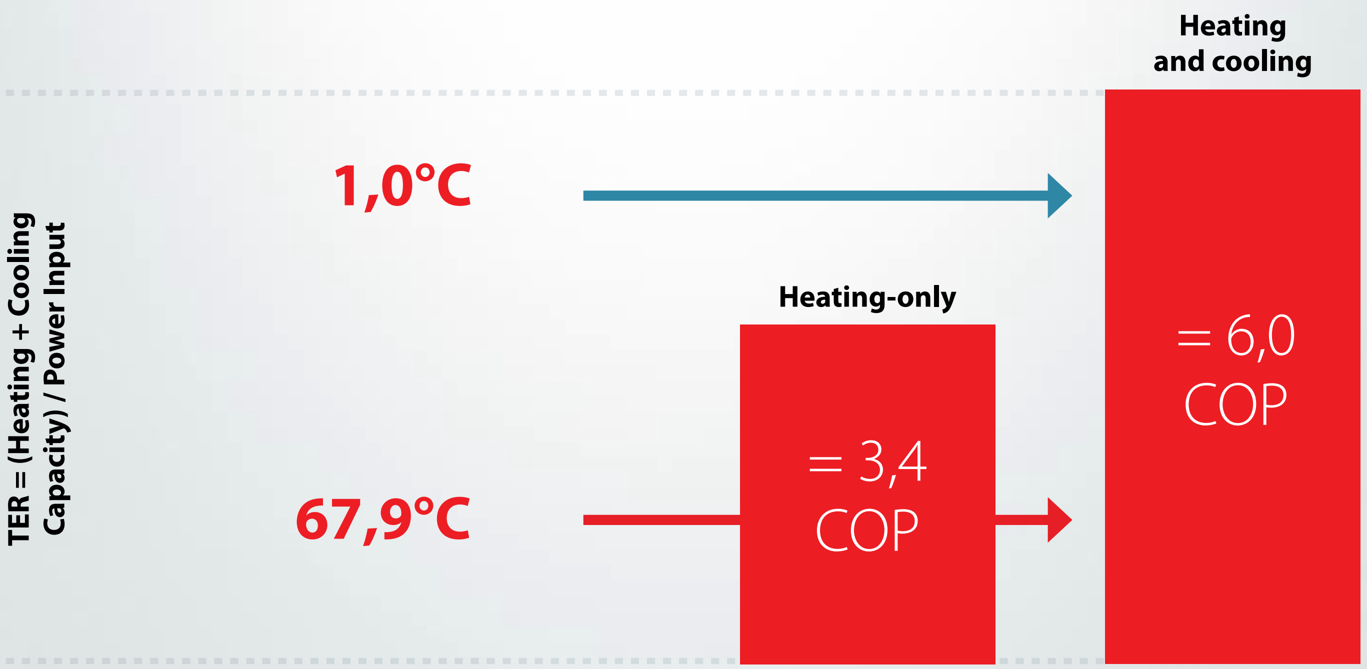




Utilizing both **cooling and heating** for unmatched **efficiency ratio**

Turbocor® TGS and TGH compressors provide symbiosis in district heating by simultaneously utilizing both the cooling and heating provided by the water-water heat pumps—achieving an unmatched Total Efficiency Ratio.

- **Distributed application benefit**
  1. Chiller cooling
  2. Heat pump heating
- **Change from cooling or heating to "moving heat"**
- **Former heat recovery capacity limitations eliminated in district heating**



$$\text{TER} = \frac{\text{1572kW Cooling + 2201kW Heating}}{\text{629kW power draw}} = 6{,}0\ \text{COP}$$

Case study | Ringsted DHC

97% Renewable Ringsted DHC's heat recovery kickstarts a new era of **greener district heating**

Ringsted District Heating Company (DHC)—a large district heating utility in Denmark—has reduced its reliance on fossil fuels by 97% after Unicool installed an innovative heat recovery system using Geoclima heat pumps built with Danfoss Turbocor® oil-free compressor technology.

With increasingly strict environmental regulations and growing costs, district heat plants are moving away from fossil fuels and turning to renewable energy—and innovative technology such as electric heat pumps and heat recovery—to reduce their environmental impact and maintain affordable heating.

Read more on the following pages >>

Keeping Ringsted warm—and hitting decarbonization goals

In the past, Ringsted DHC—a centralized heating station delivering heat to the equivalent of 7,000 single-family homes across a 124km district heating network—generated 75% of its heat from renewable sources using two straw-fuelled biomass boilers, a gas-powered Combined Heating and Power (CHP) plant, and a heat accumulator.

However, the DHC had two major challenges to address:

- A commitment to 95% CO_2-free heat production by 2020
- A need to remove 97% of harmful sulphur dioxide (SO2) emitted by exhaust gas

Three new heat pumps—and two exciting ways to use Turbocor®

In 2020, the DHC introduced four new electric heat pumps—three of which use Turbocor® oil-free technology—and a new scrubber to remove SO_2 from the straw boilers' flue gas.

The new pumps help capture what would otherwise be wasted heat and put it to good use, increasing COP, maximizing heat capacity, and further reducing its environmental impact.

Plus, the heat pumps perform two important duties resulting in cost-effective efficiency:

- Heat pump **HP01** recovers heat from the outside air to redistribute via the district heating network

- Two Turbocor®-powered Geoclima heat pumps **HP02** and **HP03** cool the flue gas to ensure the new scrubber's efficiency—and eliminate the need to provide the scrubber with an expensive external water supply. These heat pumps also cool the variable speed drives powering HP01 and the mechanical equipment room, recovering the heat from cooling these sources to the district heating system.

By making smart use of heat pumps, Ringsted DHC has met its decarbonization goals while keeping consumer prices low.

To learn more about Oil-free Heat Pumps watch our Q&A video here

Higher heat recovery temperature and lower heat supply temperature result in **higher heat capacity and efficiency**

To achieve the highest heat pump efficiency while lowering the price of heating, Ringsted DHC recovers heat at the highest possible temperature.

- The **HP02** heat pumps operate at a high heat recovery temperature—51°C> 28°C surplus heat from the straw boiler scrubber—resulting in a high heat capacity of 962kW and a COP of 7.1.
- **HP03**—which uses wasted heat from **HP01,** the CHP, and cooling the heat plant room—also runs at a high heat recovery temperature resulting in a heat capacity of 310kW and a COP of 6.2.
- The final supply heat temperature is 58°C—low enough to enable the high efficiency of all three units.

The heat recovery methodology behind the Geoclima heat pumps using Turbocor® compressor technology improves the heat plant COP by up to 21% and the plant's heat capacity by up to 31%.

Plus, the consistently balanced temperature and heat recovery technology has made the DHC's equipment more reliable.

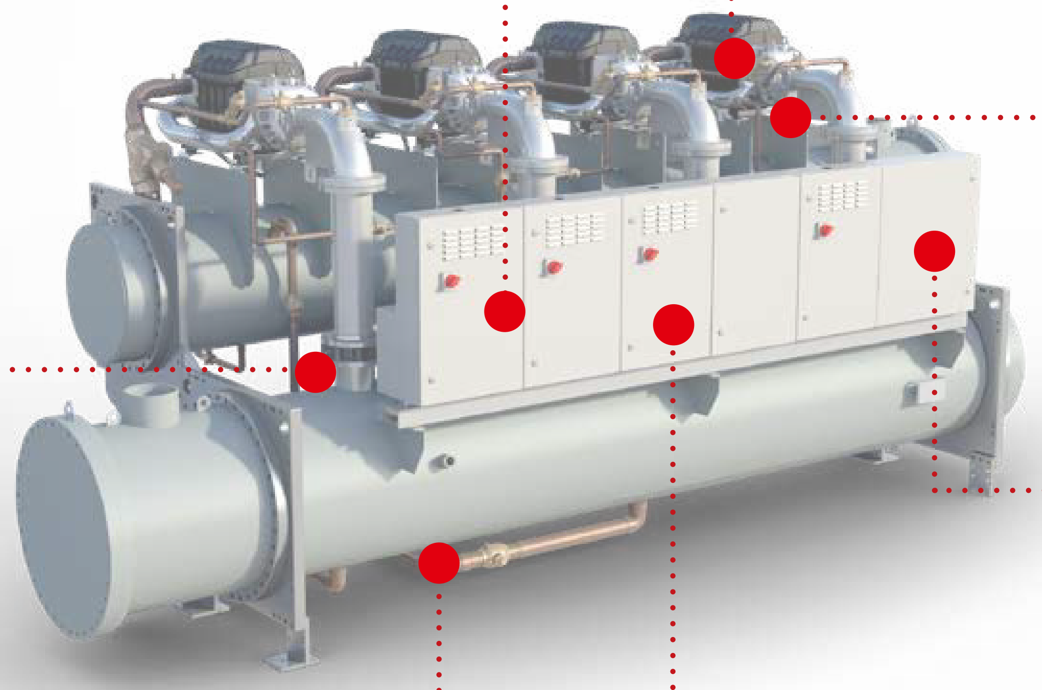
The oil-free portfolio
for heat pumps

Compressors
High efficiency Turbocor® oil-free
compressors – standard and high lift
TGS
TTS
TTH/TGH

Remote monitoring and service tools
Reliable and efficient operation
and service productivity
Danfoss Turbocor® Cloud Services

System protectors
Filter driers, sight glasses,
check and ball valves for
safe operations

Heat Exchangers
Micro Plate and Micro Channel
heat exchangers for low
refrigerant charges and high
efficiency
MPHE
MCHE



Electronics and sensors
Subsystem, unit level controllers and valve
drivers, liquid and temperature sensors
MCX15 and 20 B2 Programmable controllers
EKE Superheat controllers
EKF Stepper motor valve drivers
DST P110
AKS 4100

Valves
Expansion valves
Main, economizer, staging, load
balance valves qualified for oil-free
ETS / KVS
ICM
ETS C and ETS P
Liquid line, shut off, oil-free and
medium pressure refrigerant qualified
EVR

AC Drives
Integrated to compressor and
standalone for fans and pumps

ENGINEERING TOMORROW

Worldwide **industry recognition**

The Danfoss Turbocor® compressors were the recipient of numerous awards including the product of the year at the: **AHR Expo, China Ref and the Mostra Convegno.**

Sign up for more information about Turbocor® technologies.

Tools, services, and support 24/7

- Product selection: **coolselector.danfoss.com**
- Estimate your Return-on-Investment (ROI): **ChillerROI.danfoss.com**
- Use the Refrigerant Slider tool for simplify calculations: **RefTools.danfoss.com**
- Discover all there is to learn: **learning.danfoss.com**

heatpumpsolutions.danfoss.com