ENGINEERING
TOMORROW

Danfoss

2nd EDITION REFRIGERATION CONFERENCE 2018

Bahrain 25. April 2018

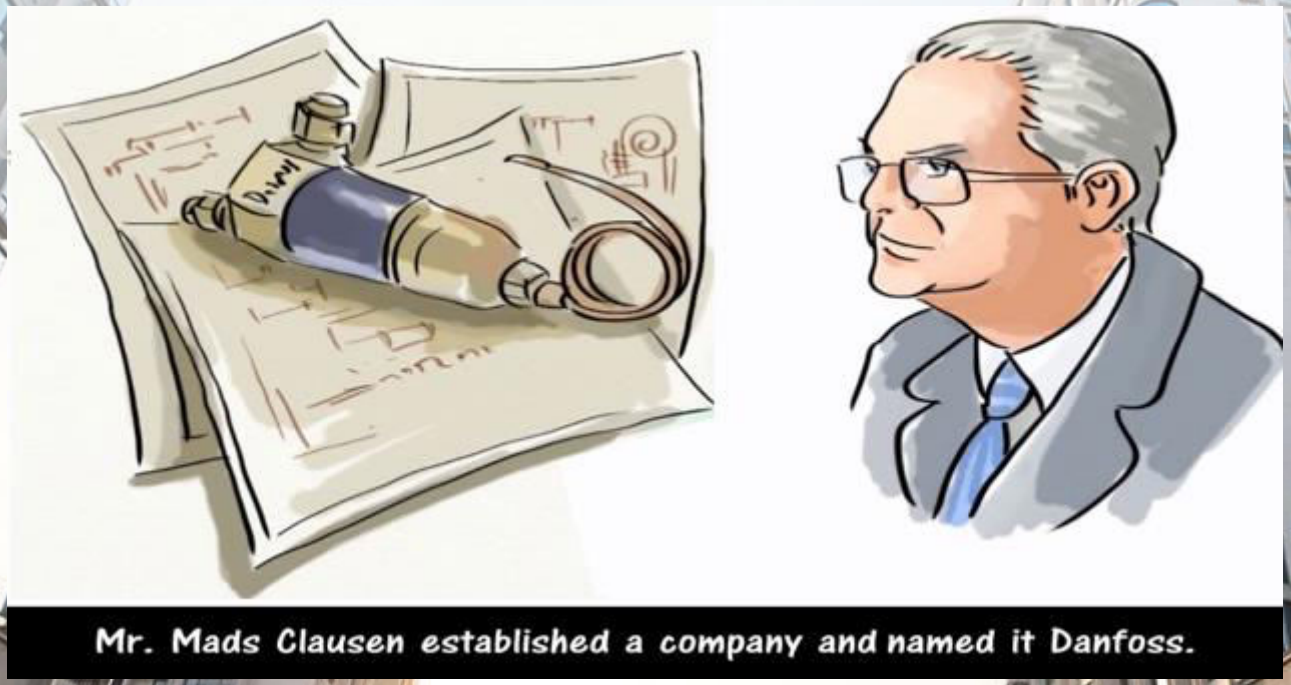
Carsten Dahlgaard

Carsten Dahlgaard

Danfoss A/S. Denmark

- **Main areas of work:**
  - Senior Director Sales
    Europe, Middle East and Africa
- **Education:**
  - Masters degree (Marine Engineering)
  - Primary Education Engineering Materials
- **Work experience:**
  - 18 years in Danfoss out of 27 years within Refrigeration
  - Branch Manager for IR Contractor
  - Senior Director Sales Asia
  - Global Marketing Director
  - Sale Manager for Industrial Refrigeration (IR) and Original Equipment Manufacturers (OEM)
  - Sales Engineer
  - Technical Service Support
  - Installation Manager for Refrigeration Contractor
  - Marine Engineer

Danfoss engineers technologies that enable the world of tomorrow to **do more with less**. We meet the growing need for **infrastructure**, **food** supply, **energy** efficiency and **climate**-friendly solutions



Key facts

26,645
Employees

USA, CHINA AND GERMANY
Top three markets

WORLDWIDE SALES
in more than **100** countries

PRIVATELY HELD
Ownership

72 FACTORIES
in more than **20** countries

NORDBORG, DENMARK
Headquarters

Sales 2017 7 bn USD
All 4 segments

Danfoss A/S

Business segments

DANFOSS POWER SOLUTIONS

#2 Market position

32%
of Group net sales

- **6,815 employees**
- **22 factories** in 11 countries
- **2.3**bn USD

DANFOSS COOLING

#1 Market position

27%
of Group net sales

- **6,396 employees**
- **13 factories** in 10 countries
- **1.9**bn USD

DANFOSS DRIVES

#2 Market position

24%
of Group net sales

- **4,652 employees**
- **11 factories** in 7 countries
- **1.7**bn USD

DANFOSS HEATING

#1 Market position

17%
of Group net sales

- **5,339 employees**
- **26 factories** in 12 countries
- **1.2**bn USD

Industrial Refrigeration

FROZEN FOOD

DAIRY PROCESSING

MARINE

MEAT PROCESSING

COLD STORAGE

BREWERIES

CHEMICAL PROCESSING

INDUSTRIAL HEATPUMPS

ICE RINKS

SOIL FREEZING

Innovation highlights 2004-2018

2004 — ICV 20 to 65

2006 — ICF 20-25

2011 — AKS 4100

2012 — SVL Flexline

2013 — EKE 347

2014 — ICLX 32 to 150, ICF 15, SVL SS Flexline

2016 — ICF 50 and 65, ICF SS 20 and 25

2017 — ICF Defrost Module

2018 — New Pilots, ICSH 26 to 65, Next Generation GD, SW Heat Exchanger

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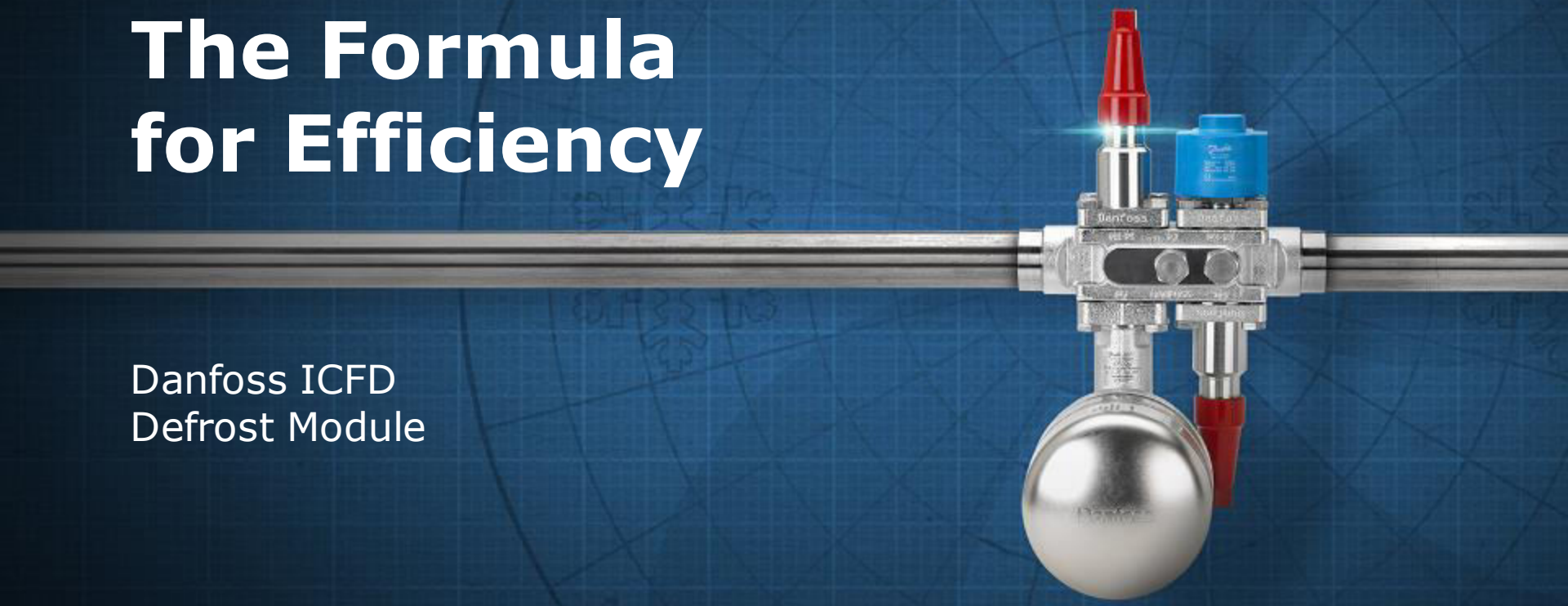
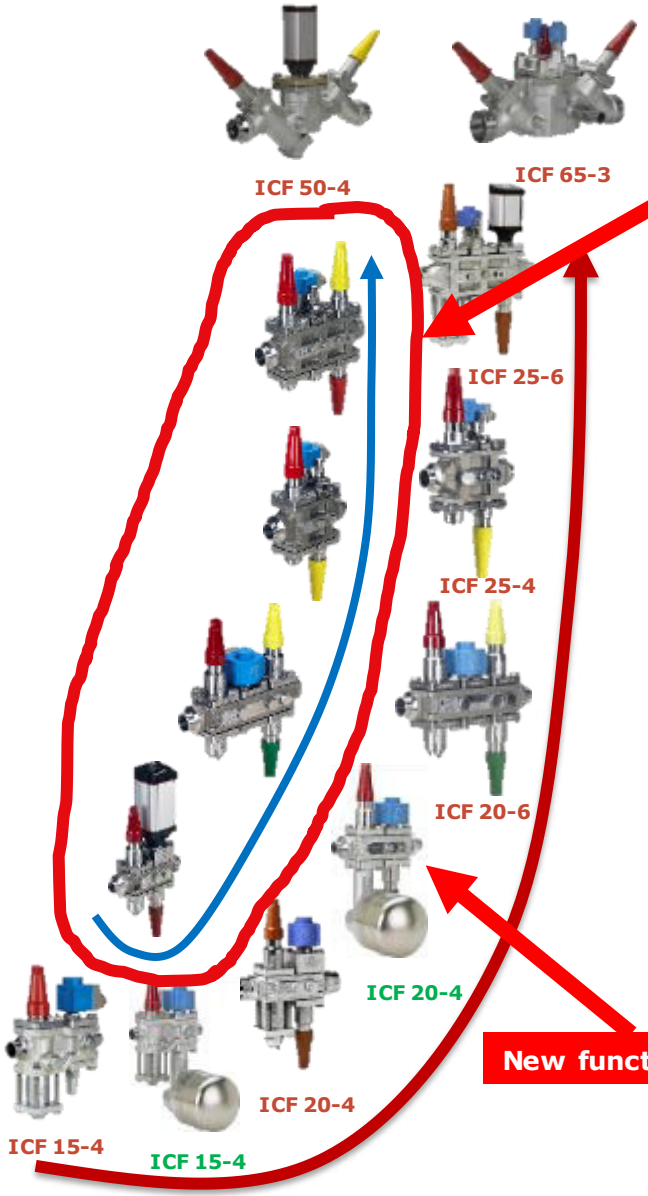
The Formula for Efficiency

Danfoss ICFD
Defrost Module

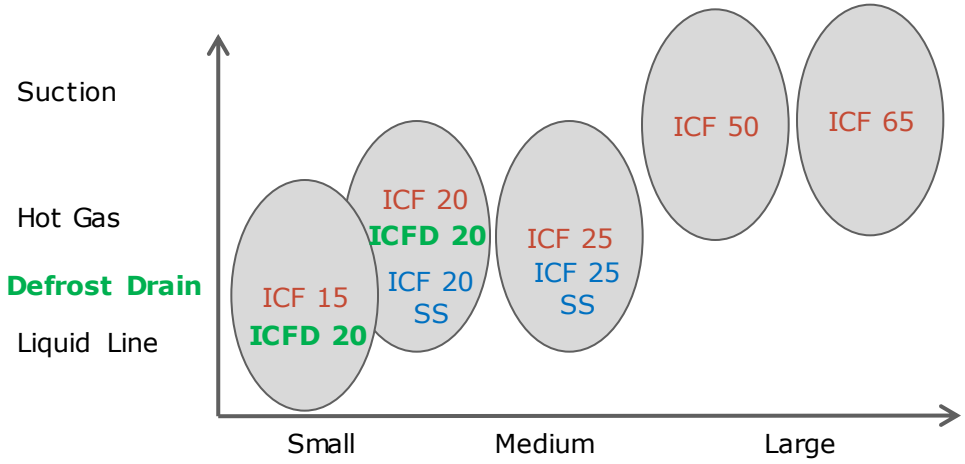




The ICF Portfolio

Focus is to continually develop our offering to meet customer and market needs and continue the journey from conventional valves and transfer to ICF valve stations.

Stainless Steel



New opportunities

SVA-FIA-ICS-NRVA-REG-SVA

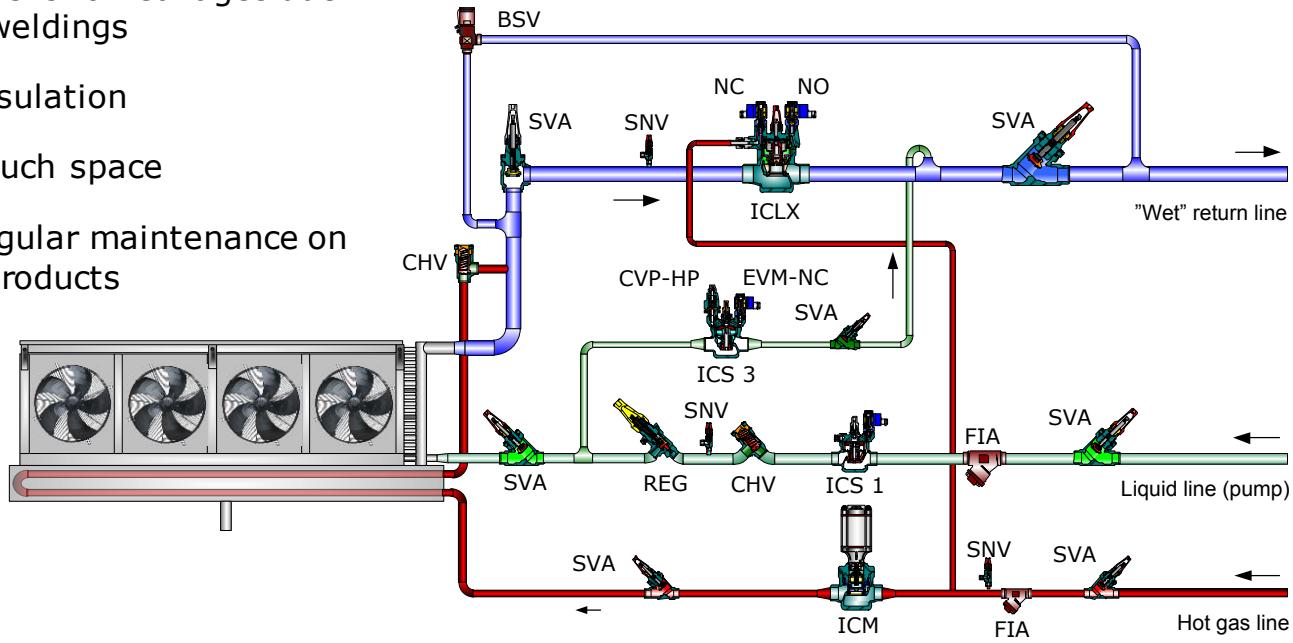
ICF

Hot gas defrost by pressure control

Air cooler **without** the ICF Valve Station

A conventional system with numerous individual valves:

- Installation requires disassembly and re-assembly prior to welding
- Increased risks for leakages due to several weldings
- Complex insulation
- Occupies much space
- Need for regular maintenance on individual products

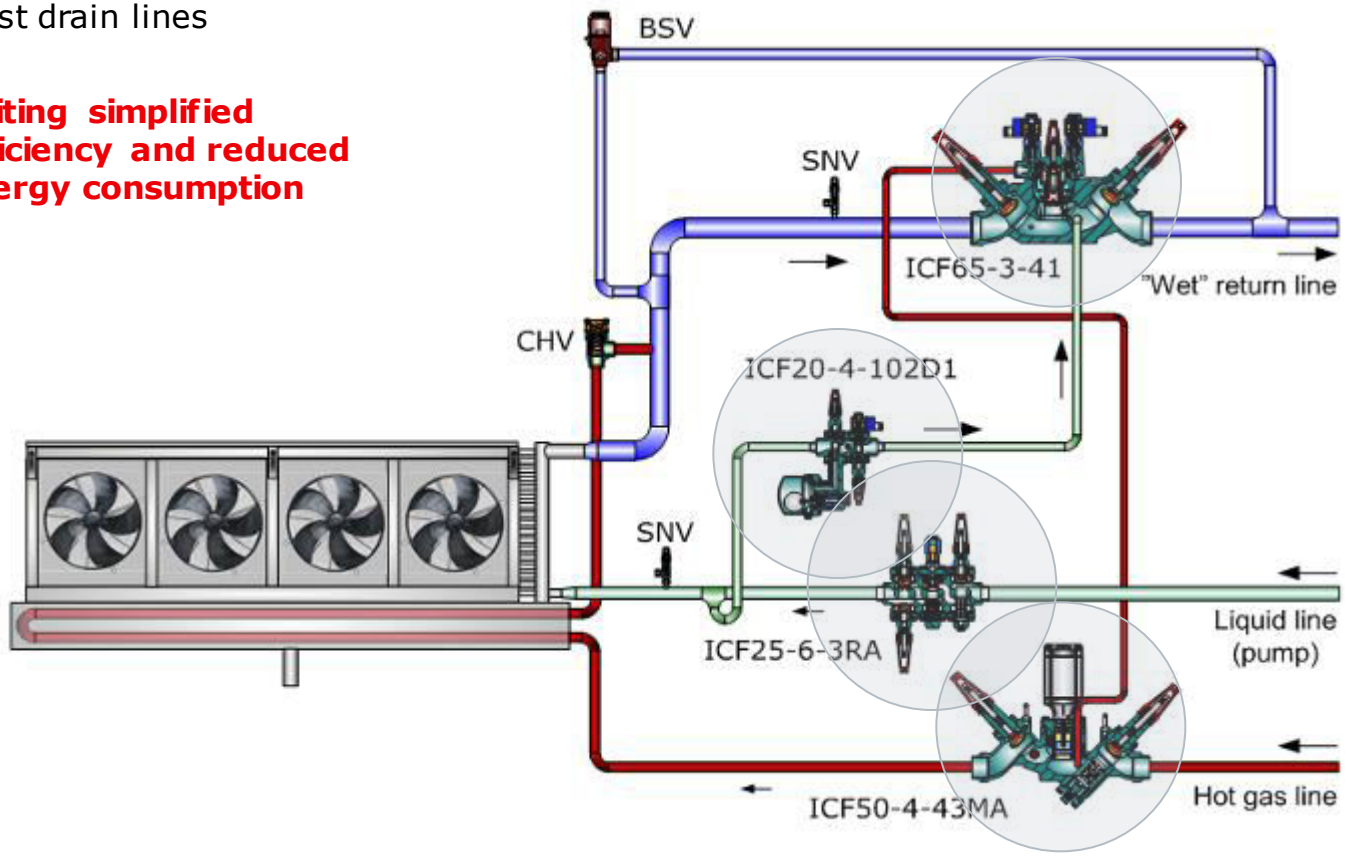


Hot gas defrost by liquid drain

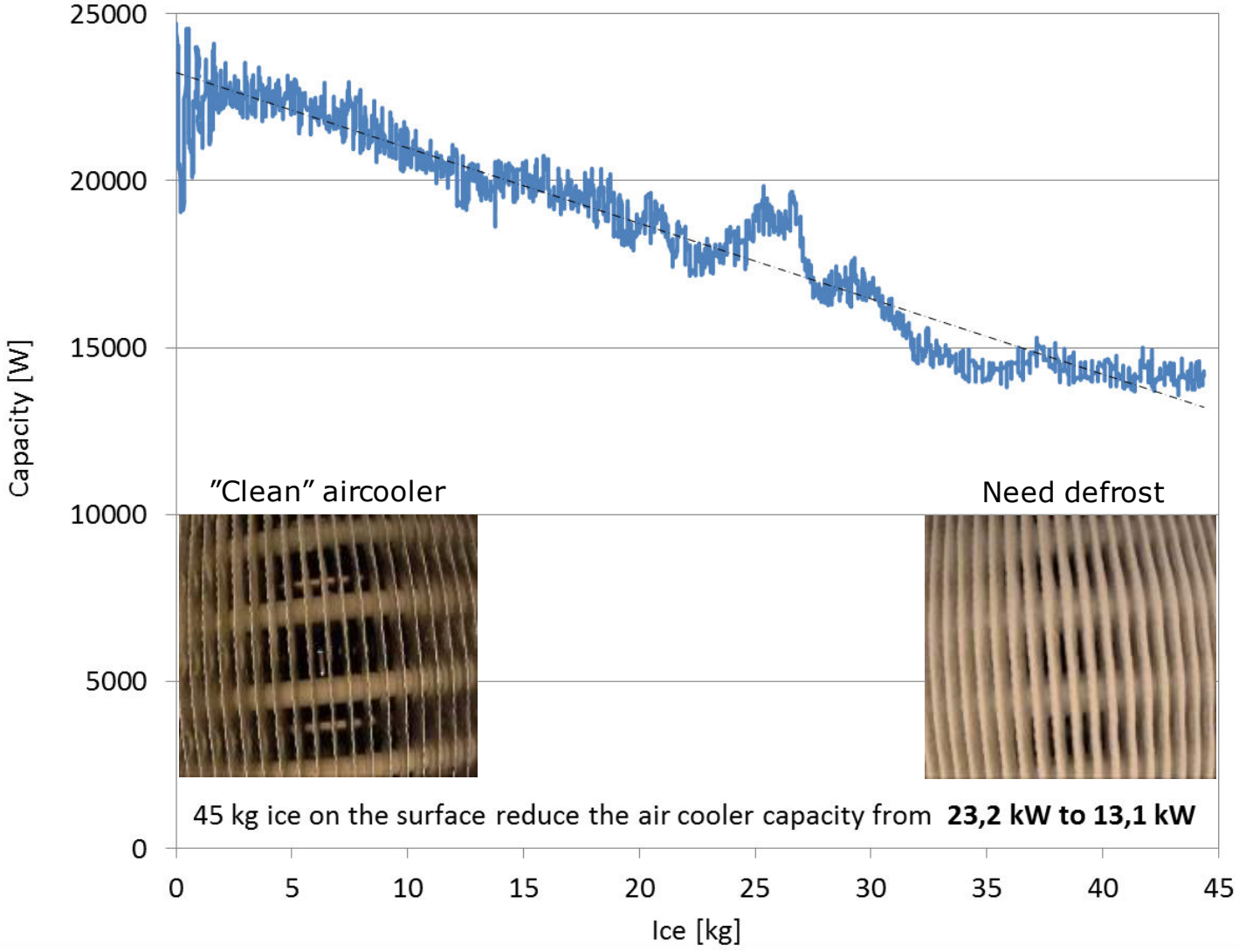
Air cooler **with** the ICF Valve Station

ICF Valve Stations across the wet suction, liquid, hot gas, and defrost drain lines

Uniting simplified efficiency and reduced energy consumption

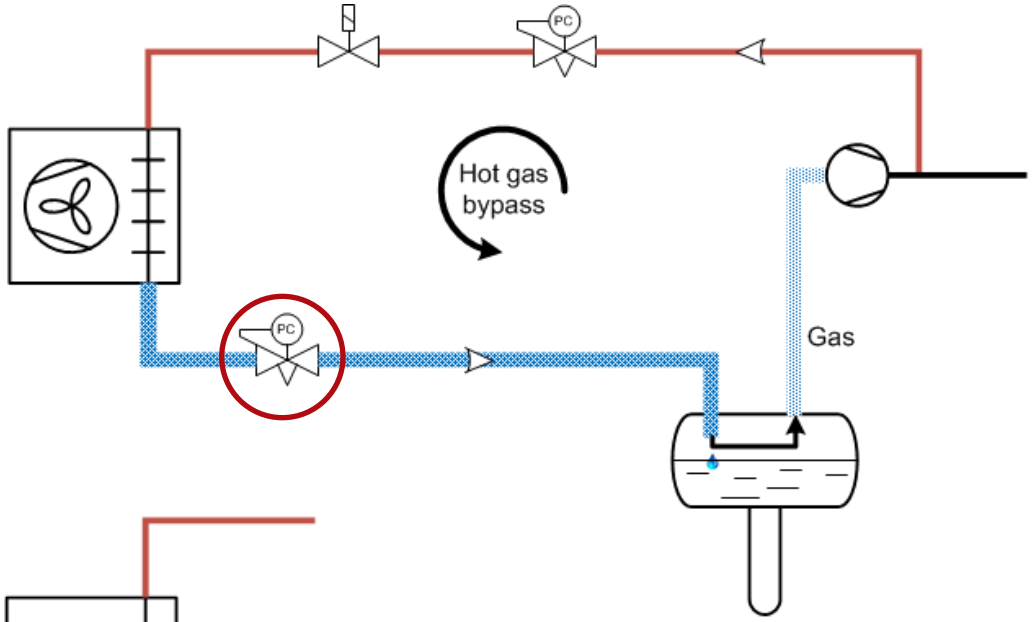


Air cooler performance vs. ice build-up on surface

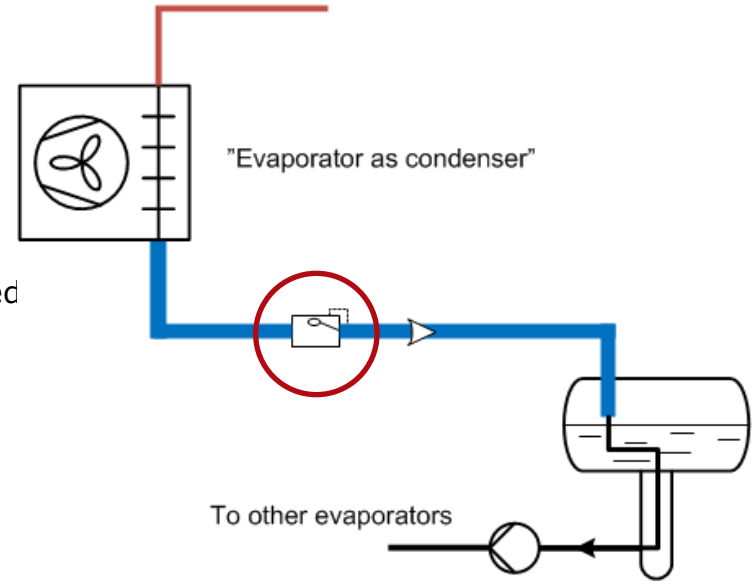


Pressure Controlled vs Liquid Drain

- **Pressure Controlled**
  - Increasing amount of gas is bypassed as defrost progresses

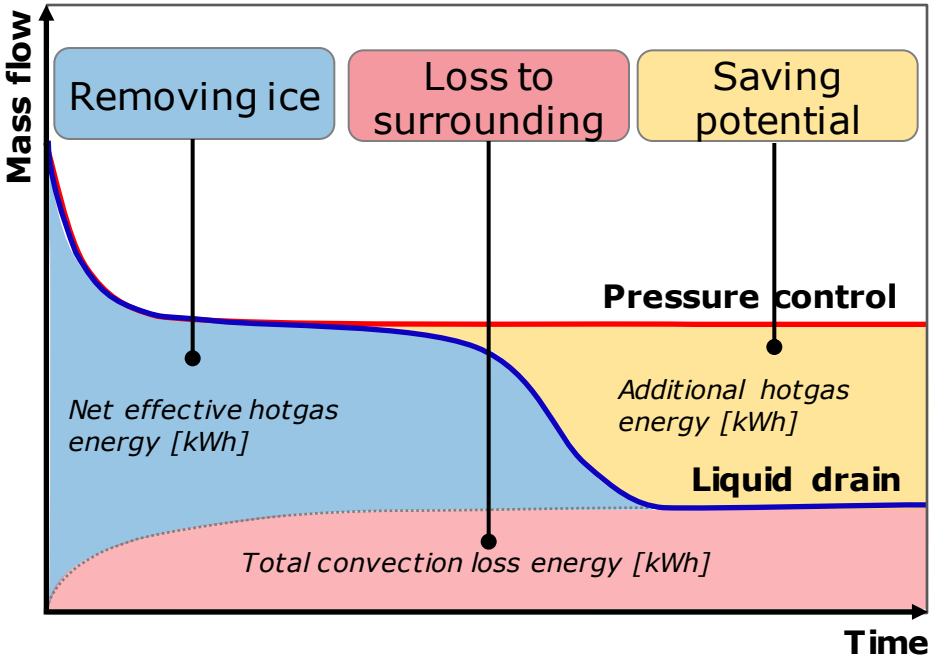


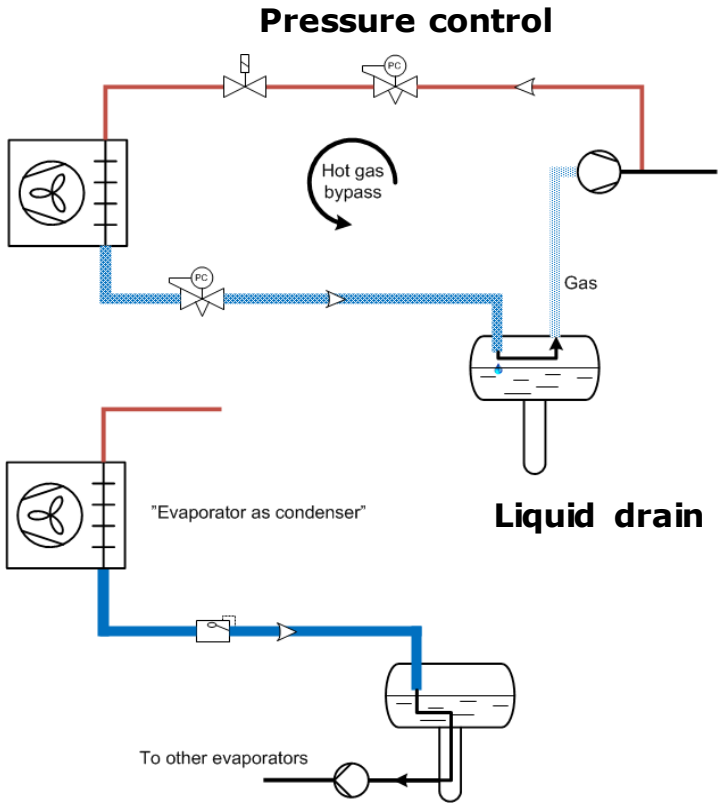
- **Liquid Drain**
  - Float valve just returns liquid to separator
  - …minor gas bypass necessary though bleed



Mass flow

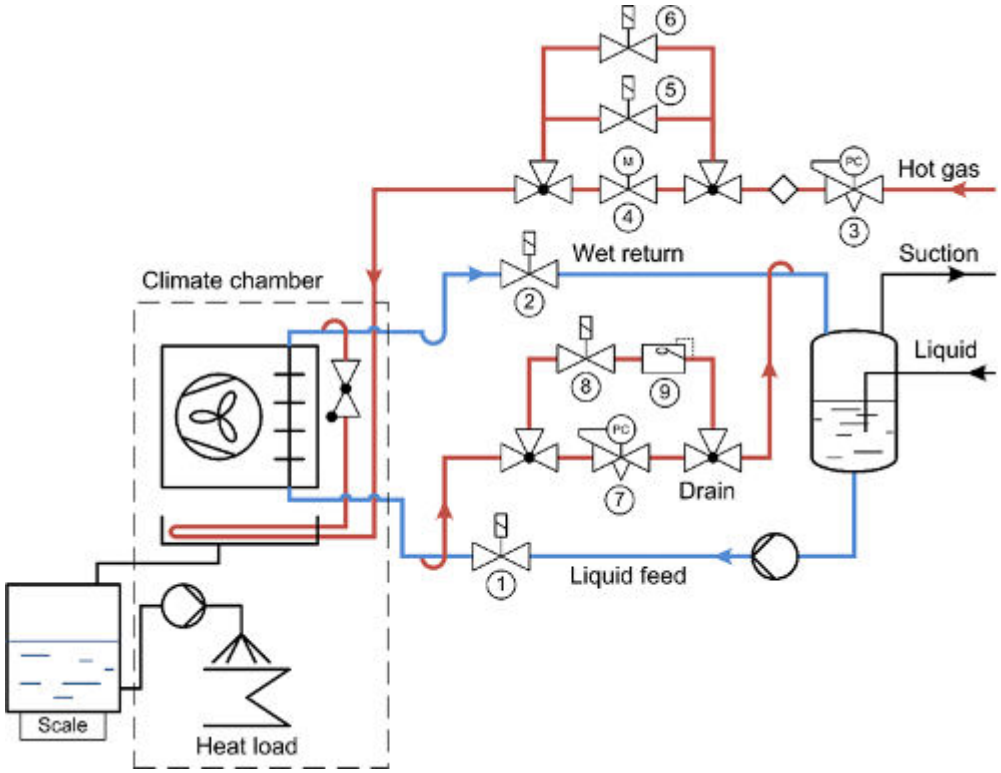
Liquid drain method vs. Pressure control method

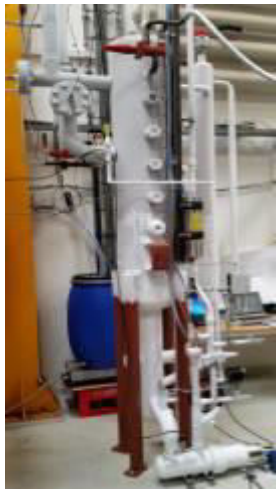




Defrost test

- Laboratory tests / measurements at DTI
- Defrost simulation tool
- Test on Industry applications
- Literature study





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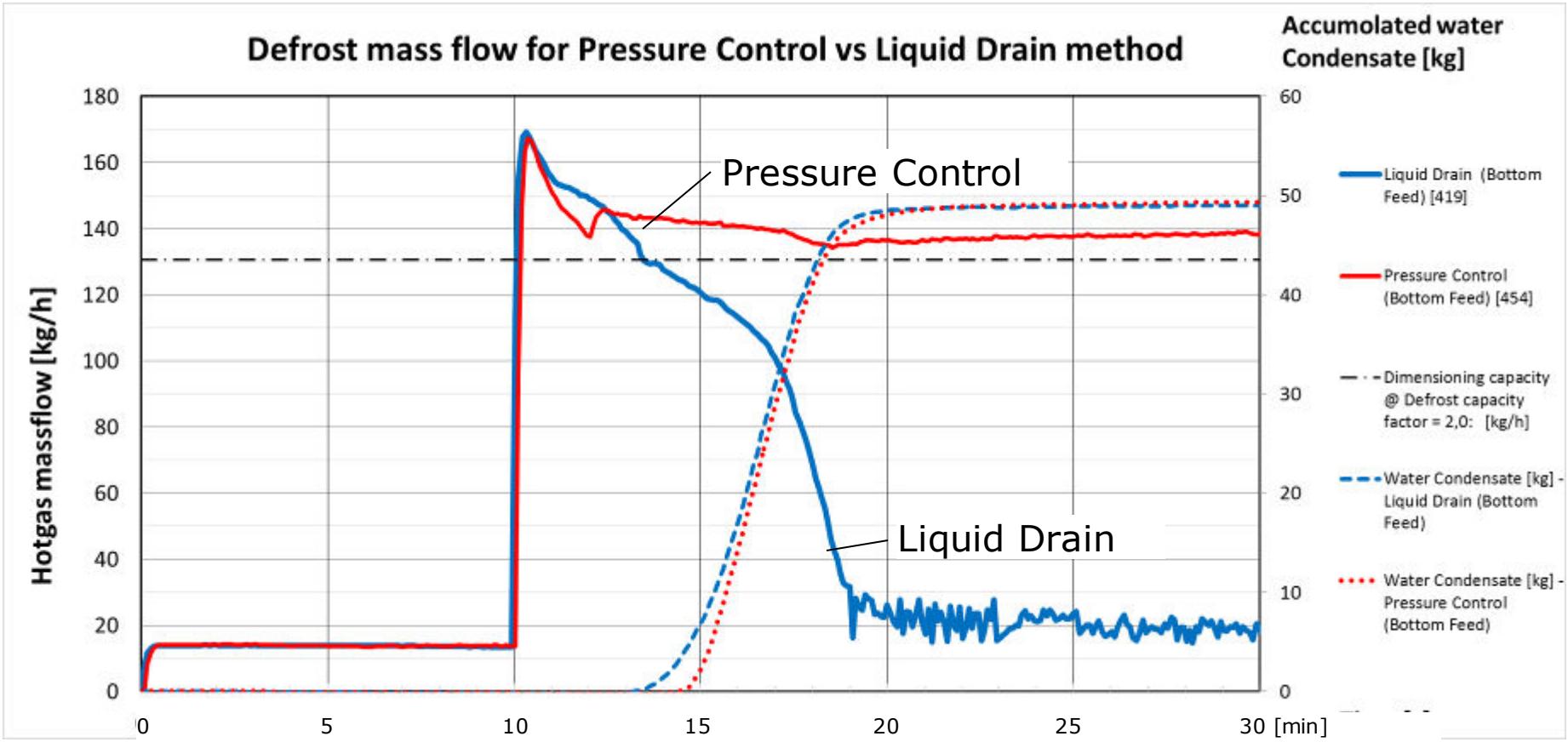
Laboratory defrost test



Laboratory defrost test shows significant saving potential on a new "modern" air-cooler, with Liquid Drain defrost vs. Pressure Controlled defrost

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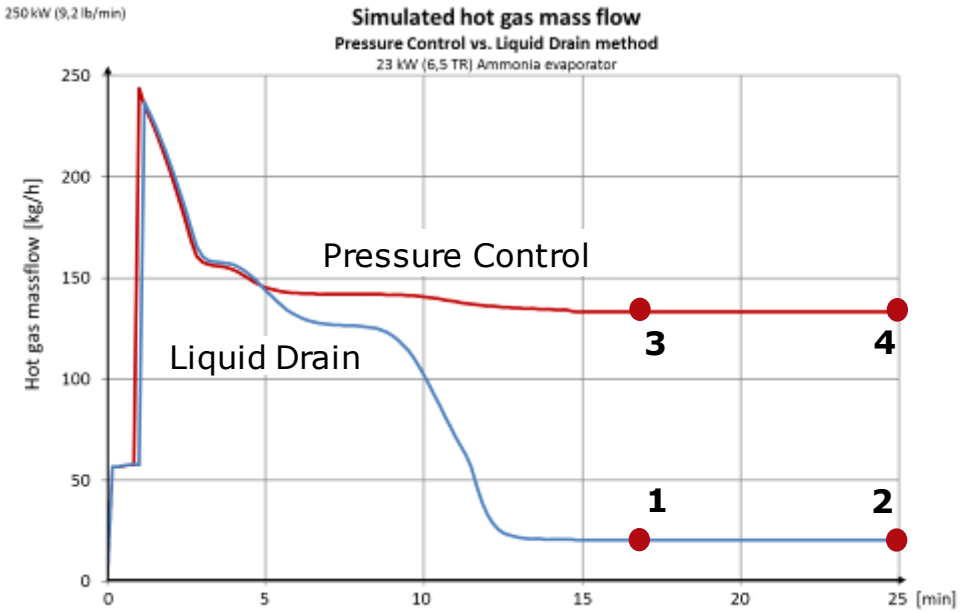
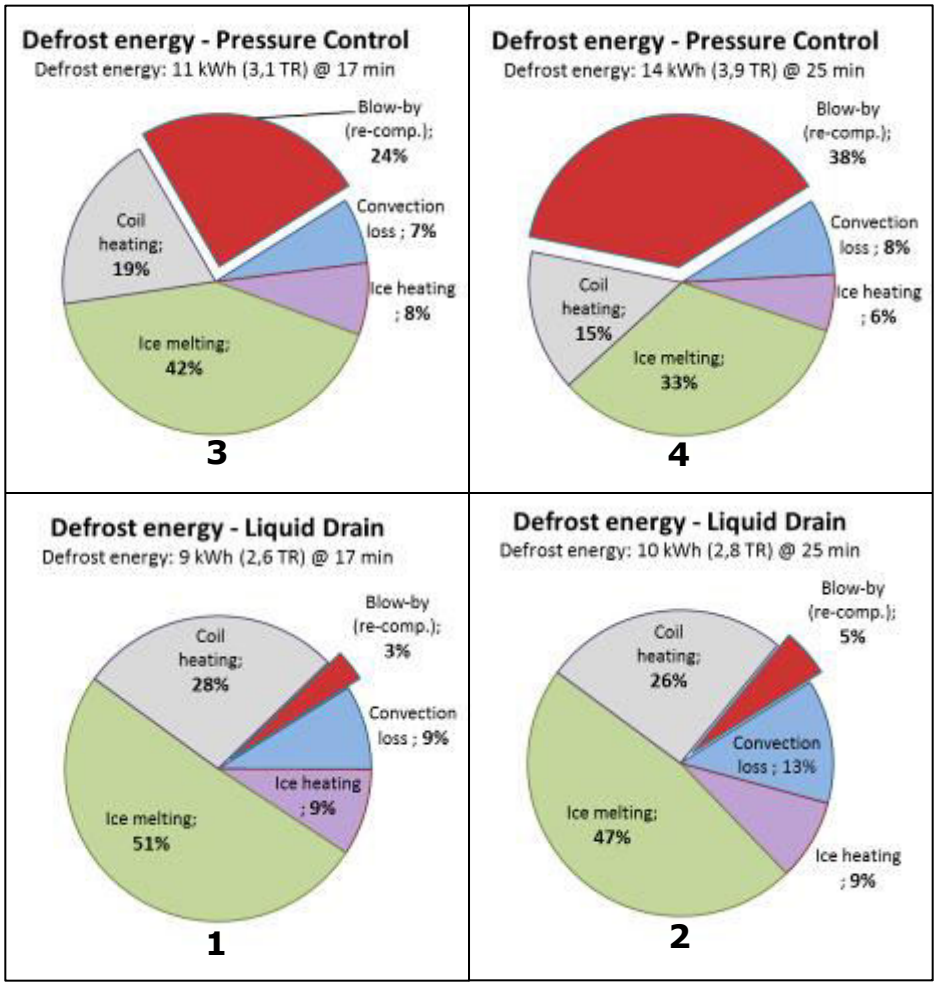
Defrost energy – Pressure Control vs. Liquid Drain



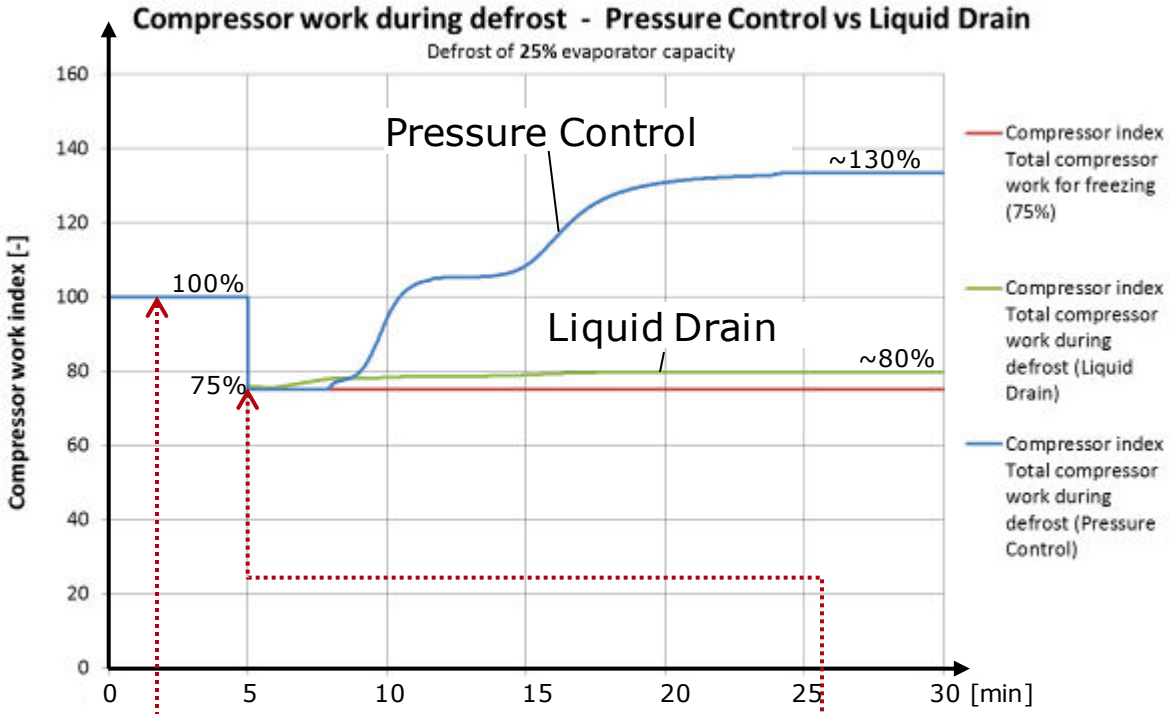
Time: 17 min

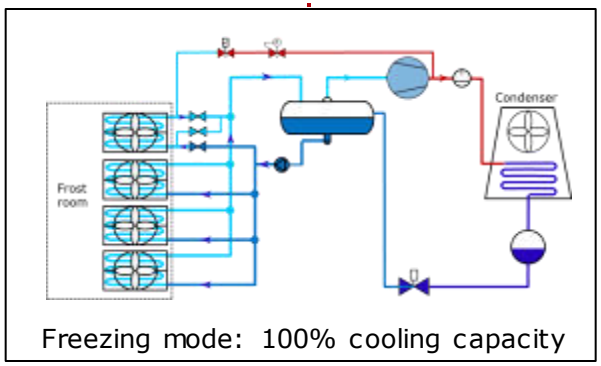
Time: 25 min



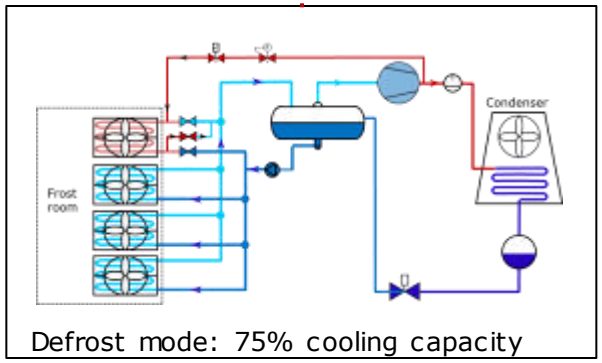
Compressor work during defrost - Pressure Control vs Liquid Drain

Defrost of 25% evaporator capacity



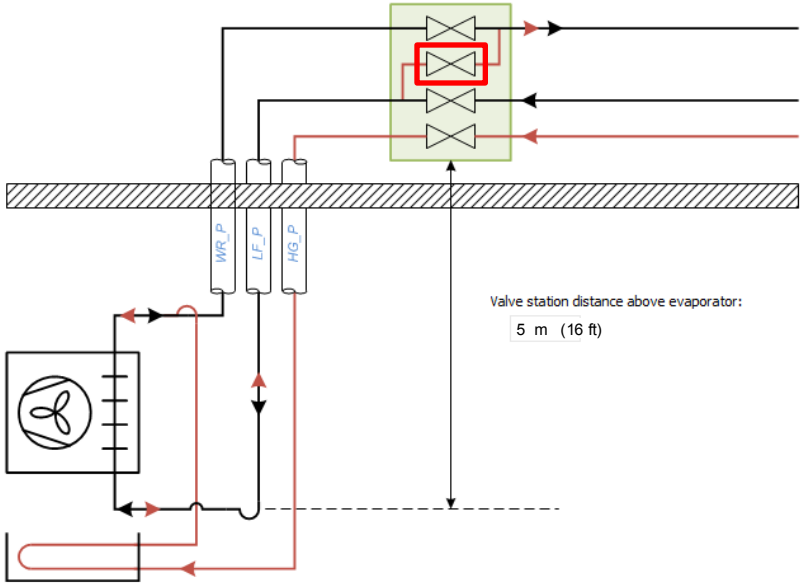


Freezing mode: 100% cooling capacity



Defrost mode: 75% cooling capacity

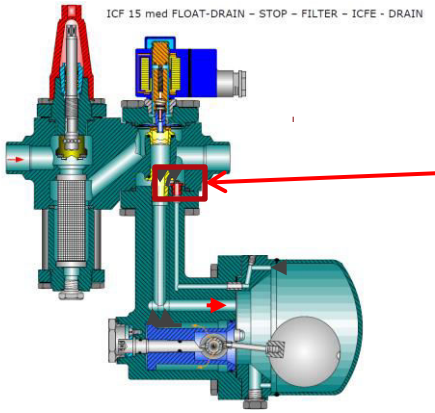
Roof mounted valve station (Liquid Drain -ICF)
Gas by-pass orifice

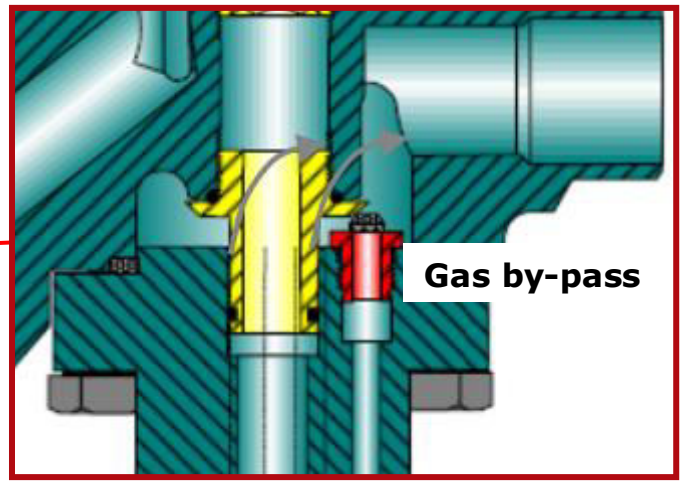


Gas by-pass orifice

A gas by-pass orifice with a flow coefficient of approximately 5-7 % of the Kv-value of the expansion device (float valve), is normally sufficient.

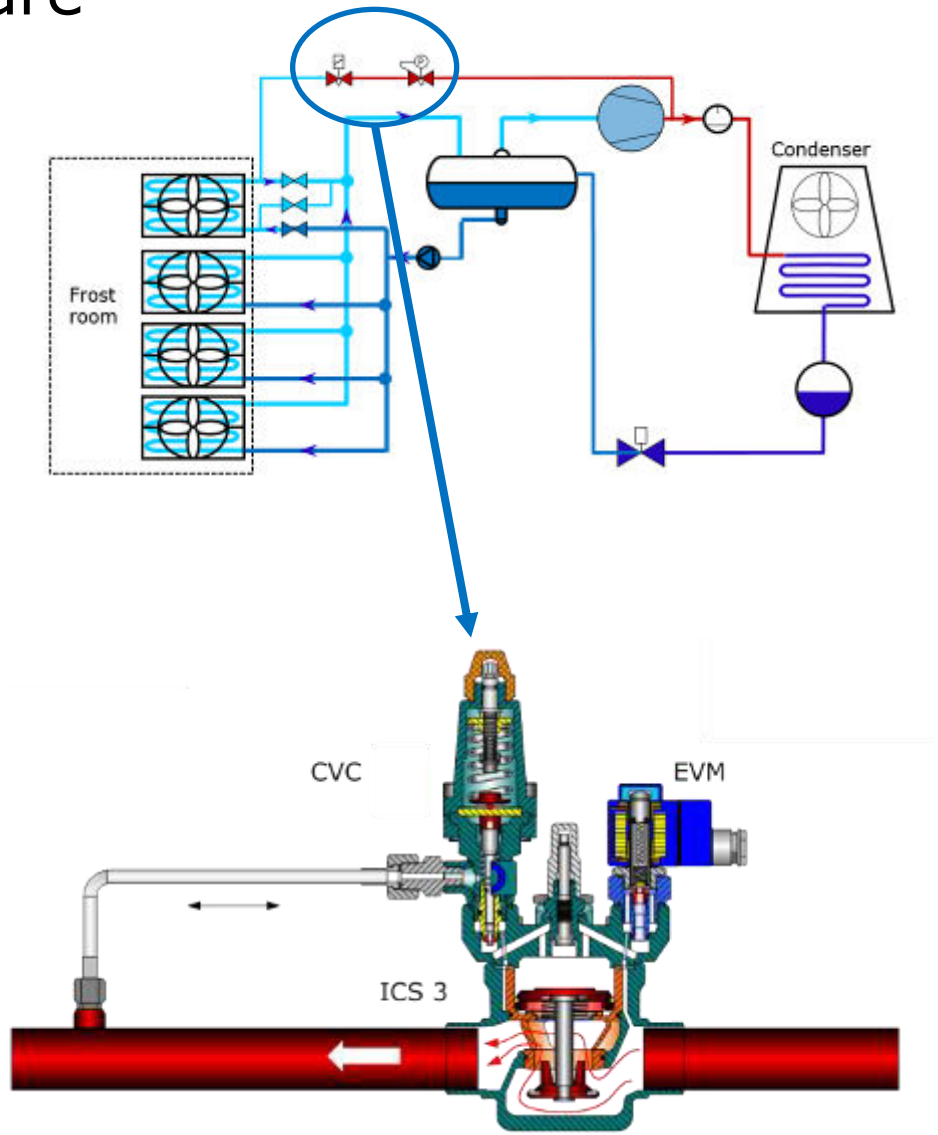
The gas by-pass is a loss, but the mass flow for gas is typically around 1/10 of the liquid mass flow => Loss ≈ 0,5%





Regulated hot gas pressure

- Defrost temperature **~ 10 C (50 F)** is generally an efficient defrost temperature.
- Hotgas supply pressure depends on the pressure drop in the supply system, but a "rule of thumb" state **~1 bar(15 psi)** across the hotgas solenoid.
- "Regulated" hot gas is recommended (pressure my increase in evaporator to higher level than for Pressure Control method); regulated by a back pressure control valve.
- "Regulated" hot gas is good design practice, and support high safety level.



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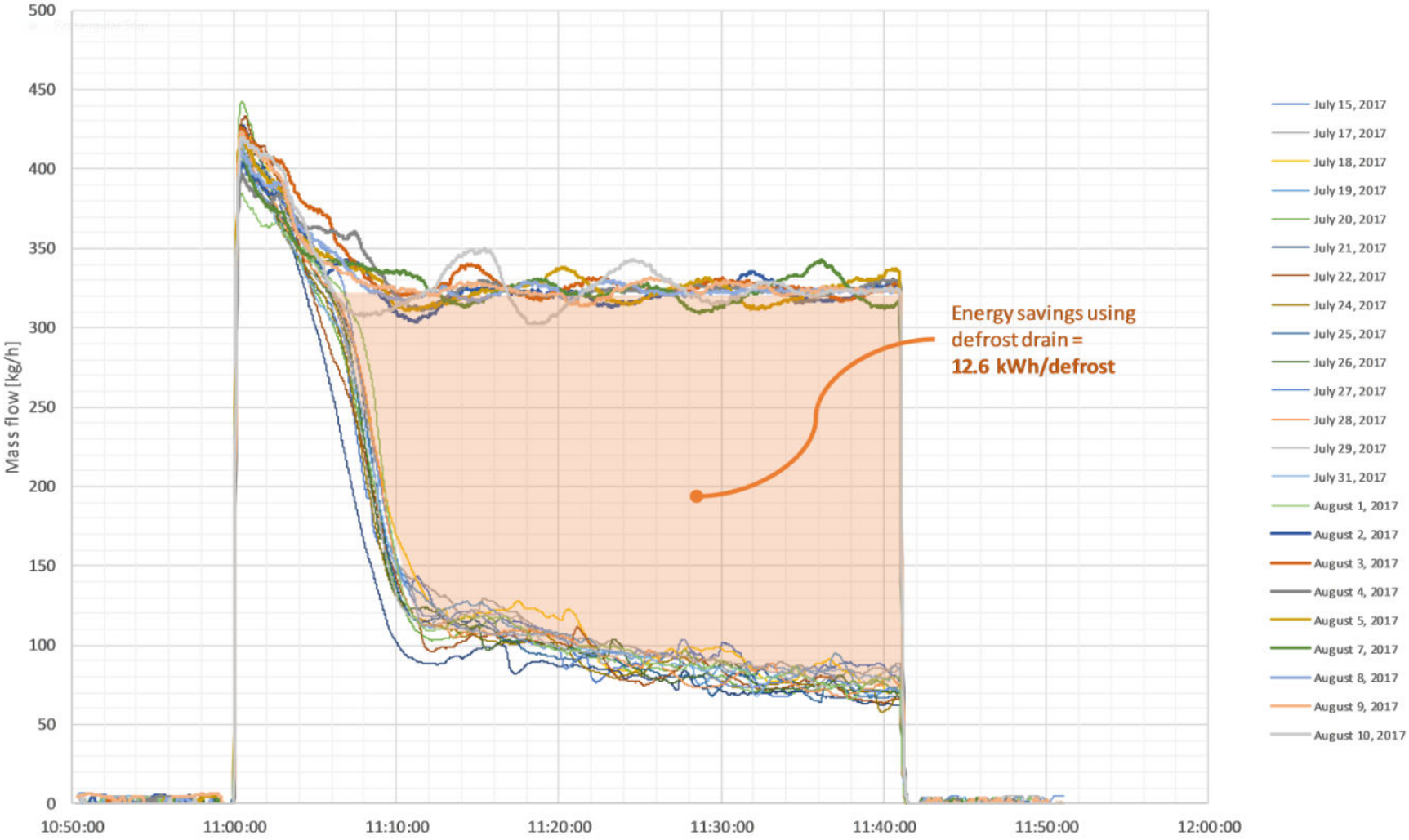
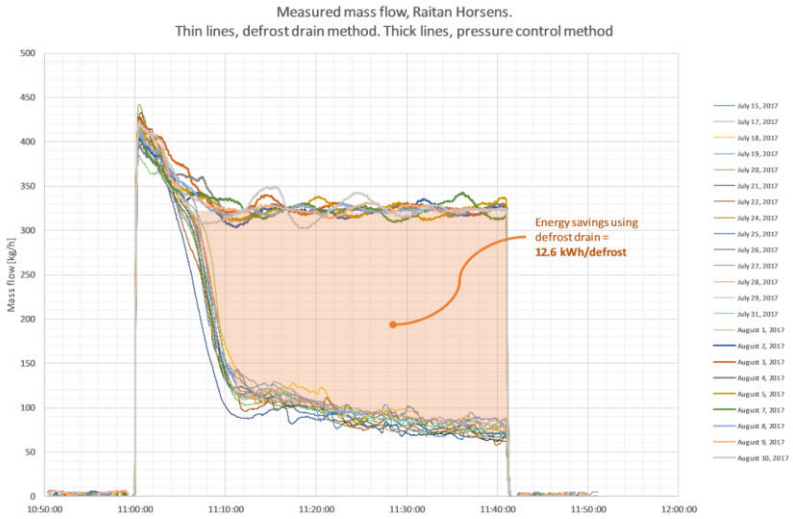
Application case stories

Making an **impact from day one**

Measured mass flow, Raitan Horsens.
Thin lines, defrost drain method. Thick lines, pressure control method



Compressor energy savings



Customer Benefit (end-user)

- Reduction of blow-by gas by up to 90%
- Eliminates need to re-compress blow-by gas
- Less loading of compressors
- Reduce hot gas consumption

Customer Value (end-user)

- Reduced energy consumsion

Value Quantification

Assumptions:

Evaporator: 41 kW @ -25C (12 TR, @ -13□F)

Defrost 40 min. Once a day

Savings:12.6 kWh pr defrost

Industry current rate: EU 28 countries 2017:0.17 USD

Danish Energy Ministry: https://ens.dk/service/statistik-data-noegletal-og-kort/priser-paa-el-og-gas

Calculation:

Evaporator/year: 12.6 x 0.17 x360

782 USD

Per Evaporator/Year

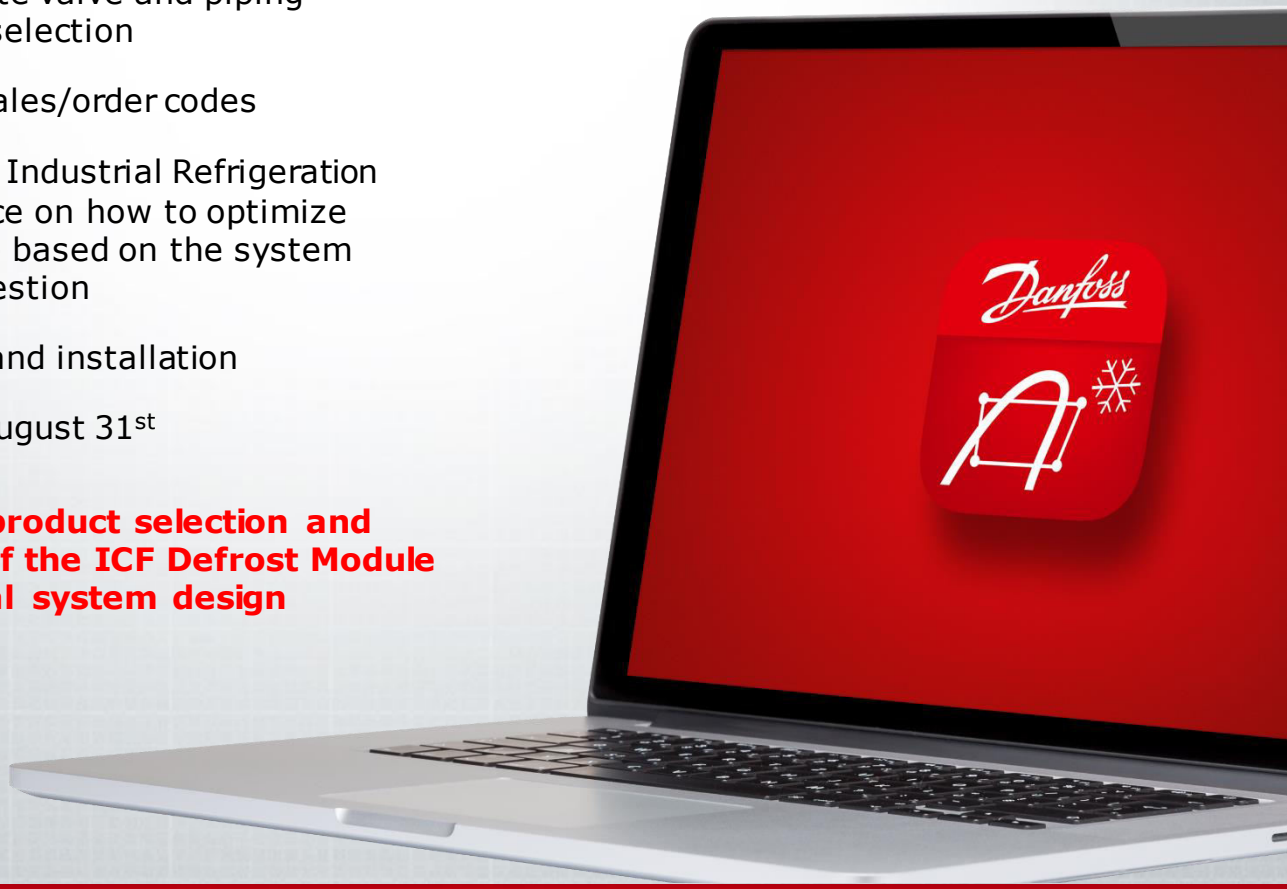
(650 EUR)

Customer Value $

Danfoss IRF
Coolselector®2

- Provides complete valve and piping calculation and selection
- Offers specific sales/order codes
- Consult Danfoss Industrial Refrigeration experts for advice on how to optimize the defrost cycle based on the system conditions in question
- Easy download and installation
- ICFD released August 31st

Optimizes product selection and operation of the ICF Defrost Module with optimal system design



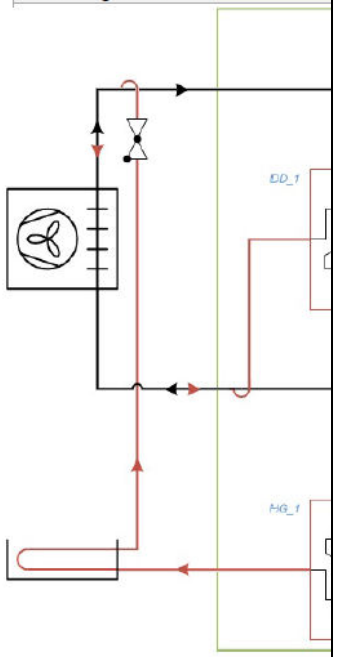
Coolselector2

Project information

Project name:	
Comments:	
Created by:	Niels Vestergaard
Coolselector2 version:	2.1.2. Database: 22.2
Printed:	29. November 2017
Preferences used:	Industrial applications

Evaporator valve station 1

Valve configuration

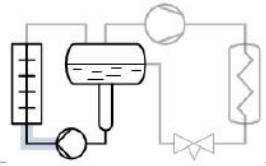


Coolselector2

Evaporator valve station 1 - Liquid feed line

Operating conditions (synchronized across application)

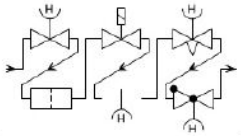
Refrigerant:	R717	Cooling capacity:	
Mass flow in line:	833,9 kg/h	Heating capacity:	
Evaporating temperature:	-10,0 °C	Condensing temperature:	
Evaporating pressure:	2,914 bar	Condensing pressure:	
Superheat before compressor:	0 K	Subcooling:	
Circulation rate:	3,00 -	Additional subcooling:	
DP pump:	2,000 bar	Discharge temperature:	
System and line:	*Pump - Liquid feed line*		
Initial line connection type and size:	*Size: DIN-EN Butt weld / DIN-EN 20 (3/4")*		



Line total

Pressure drop	0,628	bar
Saturation temperature drop	3,7	K

Position 1. ICF-20-6-20D DIN-EN Butt weld DN 20



Type code:	ICF-20-6-20DSXFXEXOXRANX62XX
Type string:	ICF 20-6-2RA
Code number:	027L3009
Pressure drop	0,628
Saturation temperature drop	3,7
Connection	OK

Position 1. House in

Pressure drop	0,005	bar
Saturation temperature drop	0,0	K
Velocity, in	0,91	m/s

Position 1. Stop valve: ICFS 20_m

Pressure drop	0,008	bar
Saturation temperature drop	0,0	K
Velocity, in	0,91	m/s
Velocity, out	0,91	m/s

Coolselector®2

Version 2.1.2 | Database 22.22.1.9.5

Project name:	
Comments:	
Created by:	Niels Vestergaard
Printed:	29. November 2017
Preferences used:	Industrial applications

Quantity	Product Description	Code number	Type Code	Sales Price
	Evaporator valve station 1			
	Liquid feed line			
1	ICF-20-6-20D DIN-EN Butt w eld DN 20. M1: Stop. M2: Filter. M3: Solenoid. M4: Manual. M5: Control. M6: Check	027L3009	ICF-20-6-20DSXFXEXOXRANX62XX	
	Wet return line			
1	ICF-50-4-50D DIN-EN Butt w eld DN 50. M1: Stop. M2: Blank. M3: Solenoid. M4: Stop	027L5023	ICF-50-4-50DSXBXIXSXXXXX2JXX	
1	Welding connection for ICF side port			
	Hot gas defrost line			
1	ICF-25-4-32D DIN-EN Butt w eld DN 32. M1: Stop. M2: Filter. M3: Solenoid. M4: Stop	027L4067	ICF-25-4-32DSXFXEHSXXXXX49XX	
	Defrost drain line			
1	ICF-15-4-20D DIN-EN Butt w eld DN 20. M1: Stop. M2: Filter. M3: Solenoid. M4: Float EV	027L4589	ICF-15-4-20DSYFYEXD1XXXX24AX	

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TREND IN TECHNOLOGIES WITHIN INDUSTRIAL REFRIGERATION

2nd EDITION REFRIGERATION CONFERENCE 2018

Bahrain 25. April 2018

Carsten Dahlgaard

Driving forces of Large Refrigeration System

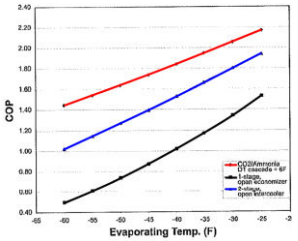
Safety

Environment Friendly

Total Cost Of Ownership

Industrial Refrigeration

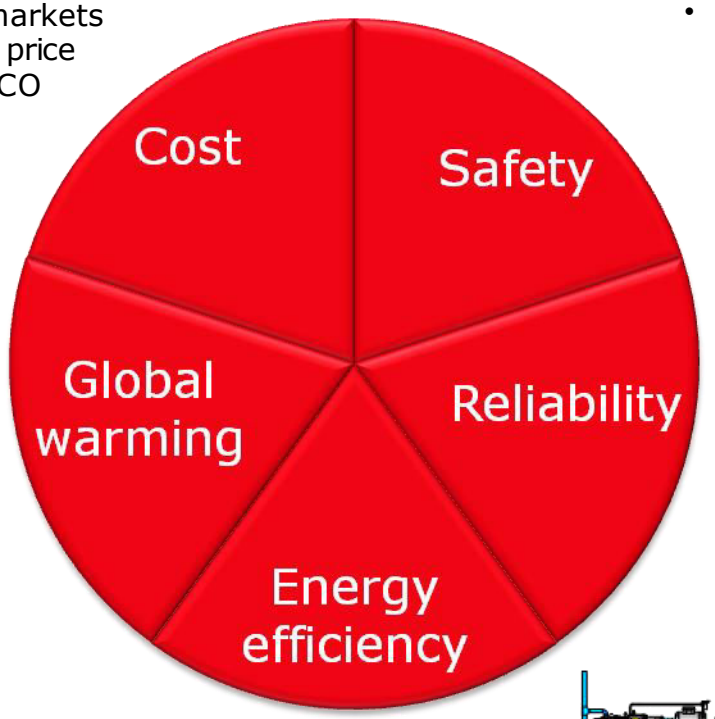
Industry Drivers



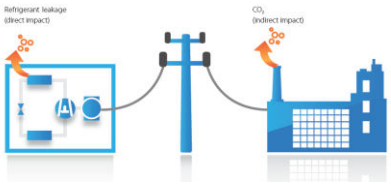
Cost
- primary growth in emerging markets with higher price pressure, TCO awareness

Safety
- products and system design

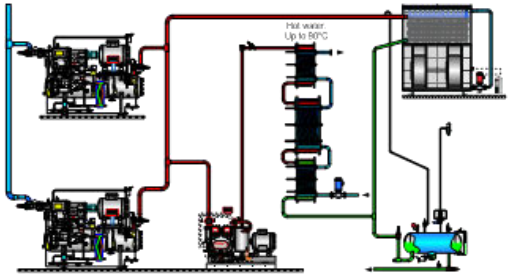
Reliability
- Automatic running



Global warming
- refrigerants focus, plays along with NH3 and CO2



Energy efficiency
- new and retrofit systems
- Industriel heat pumps



Global warming

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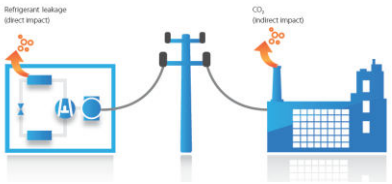
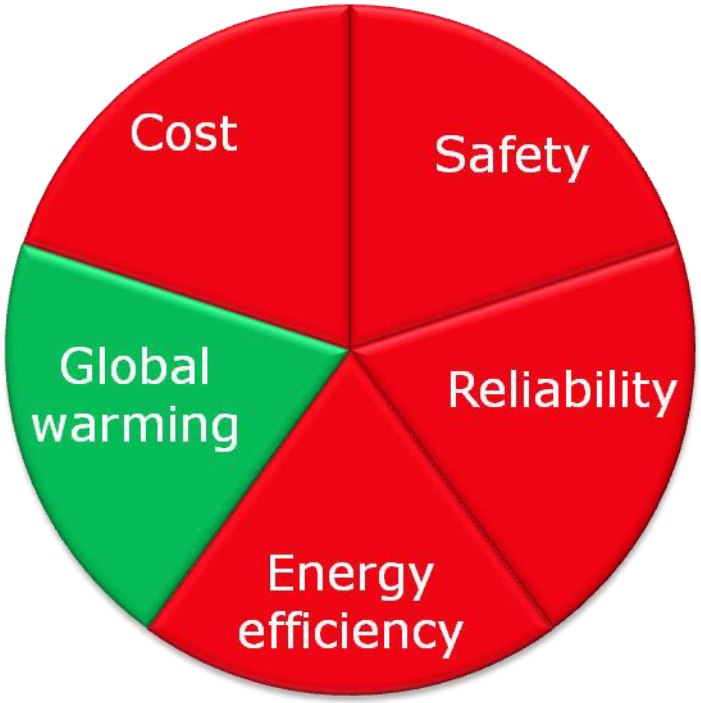
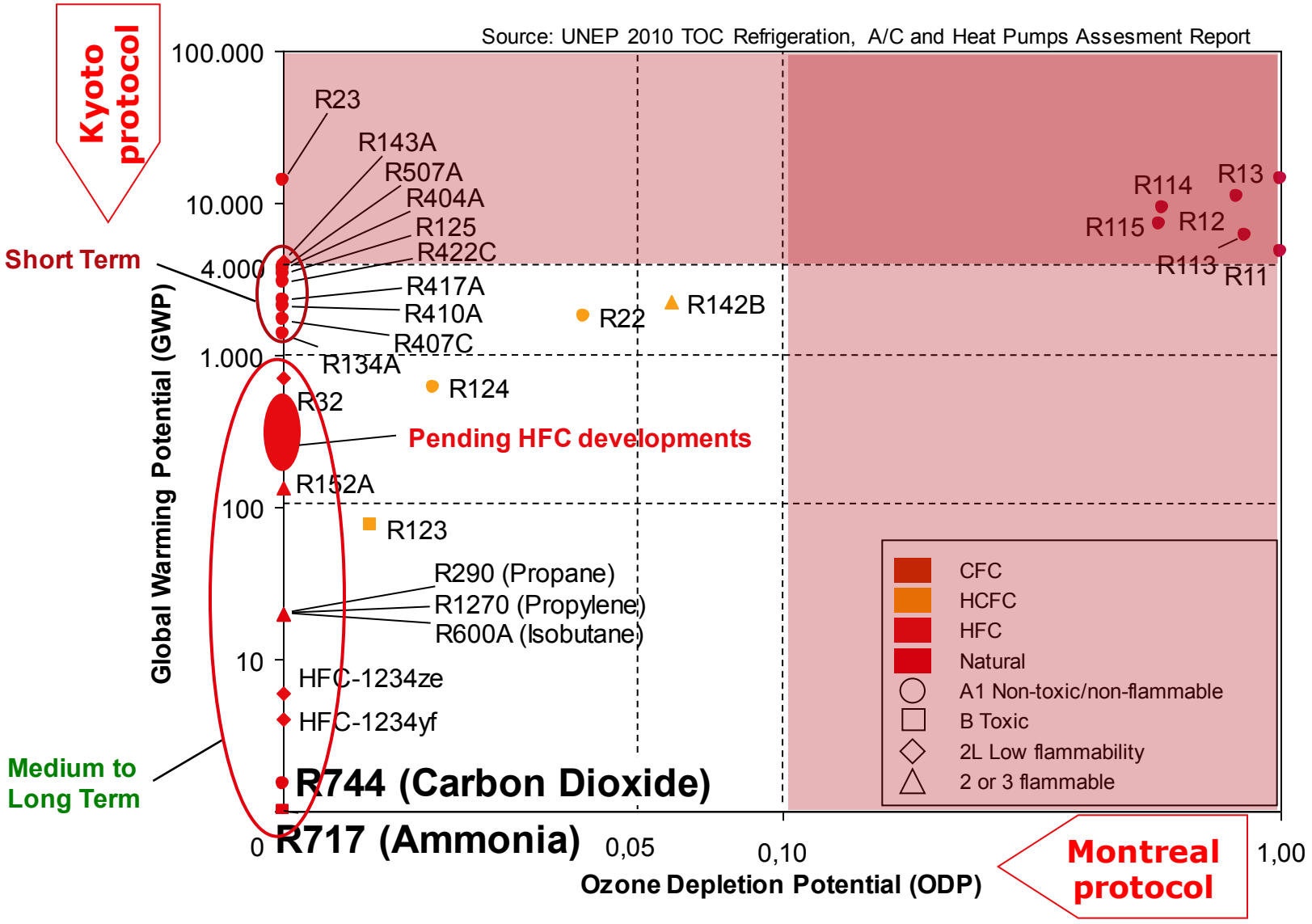




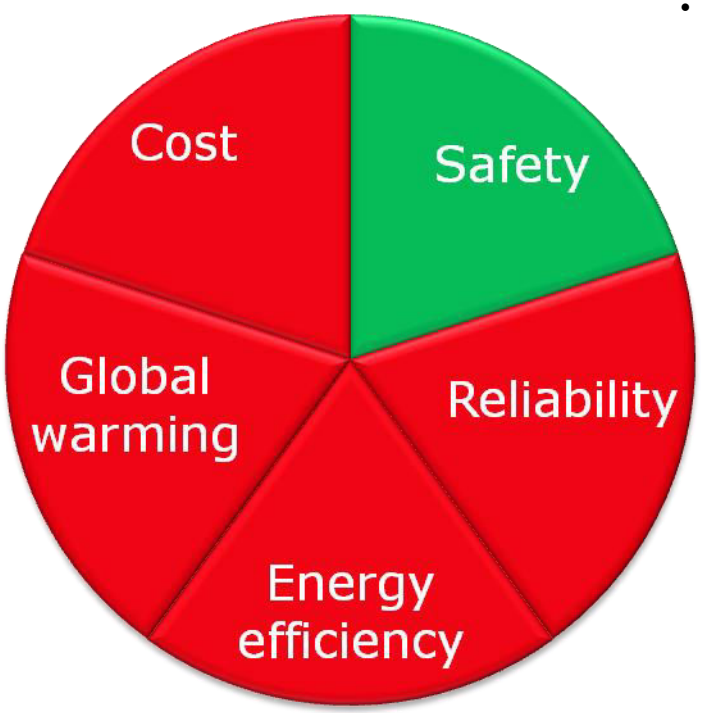
Refrigerant Map - outlook



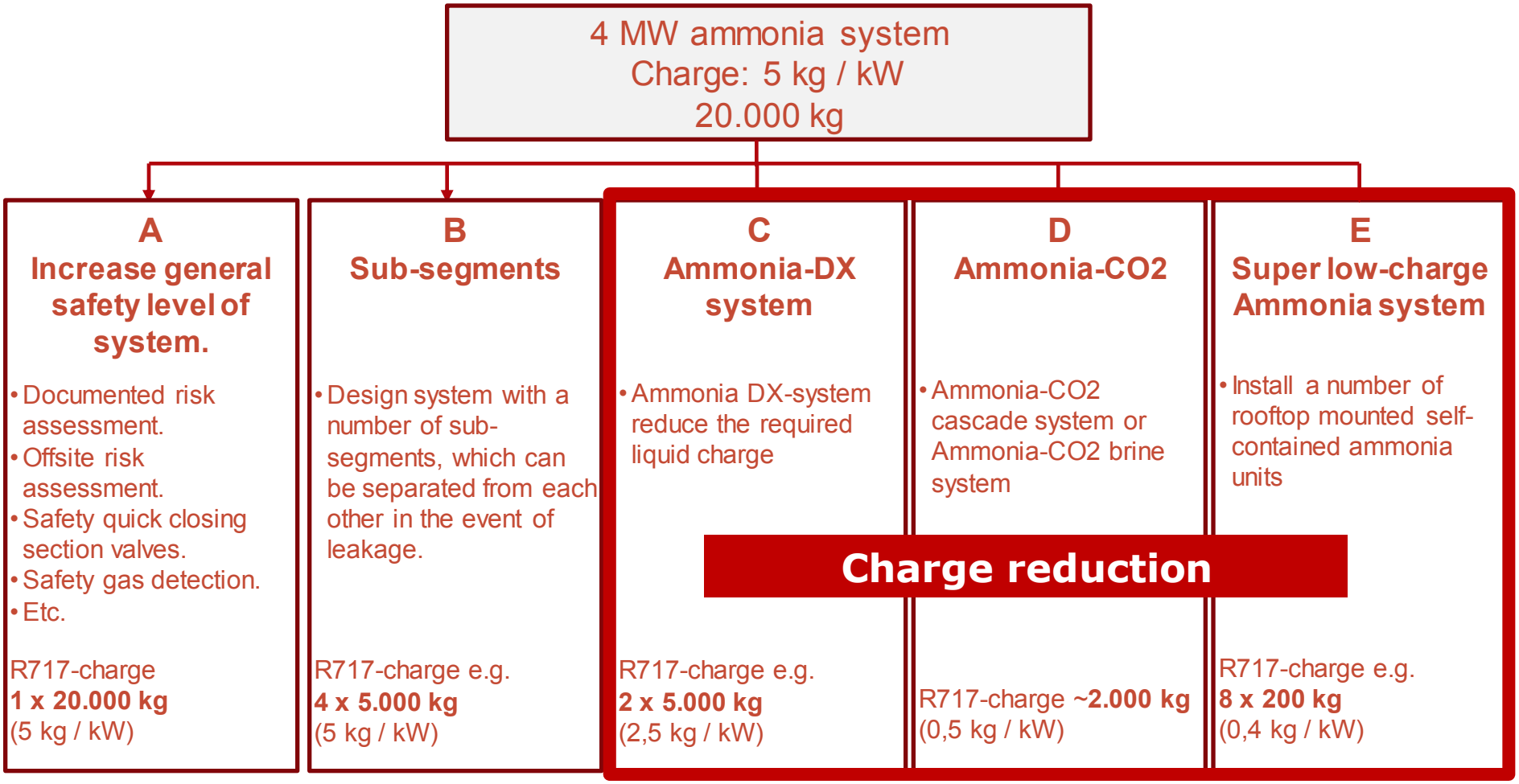
Industrial Refrigeration

Industry Drivers

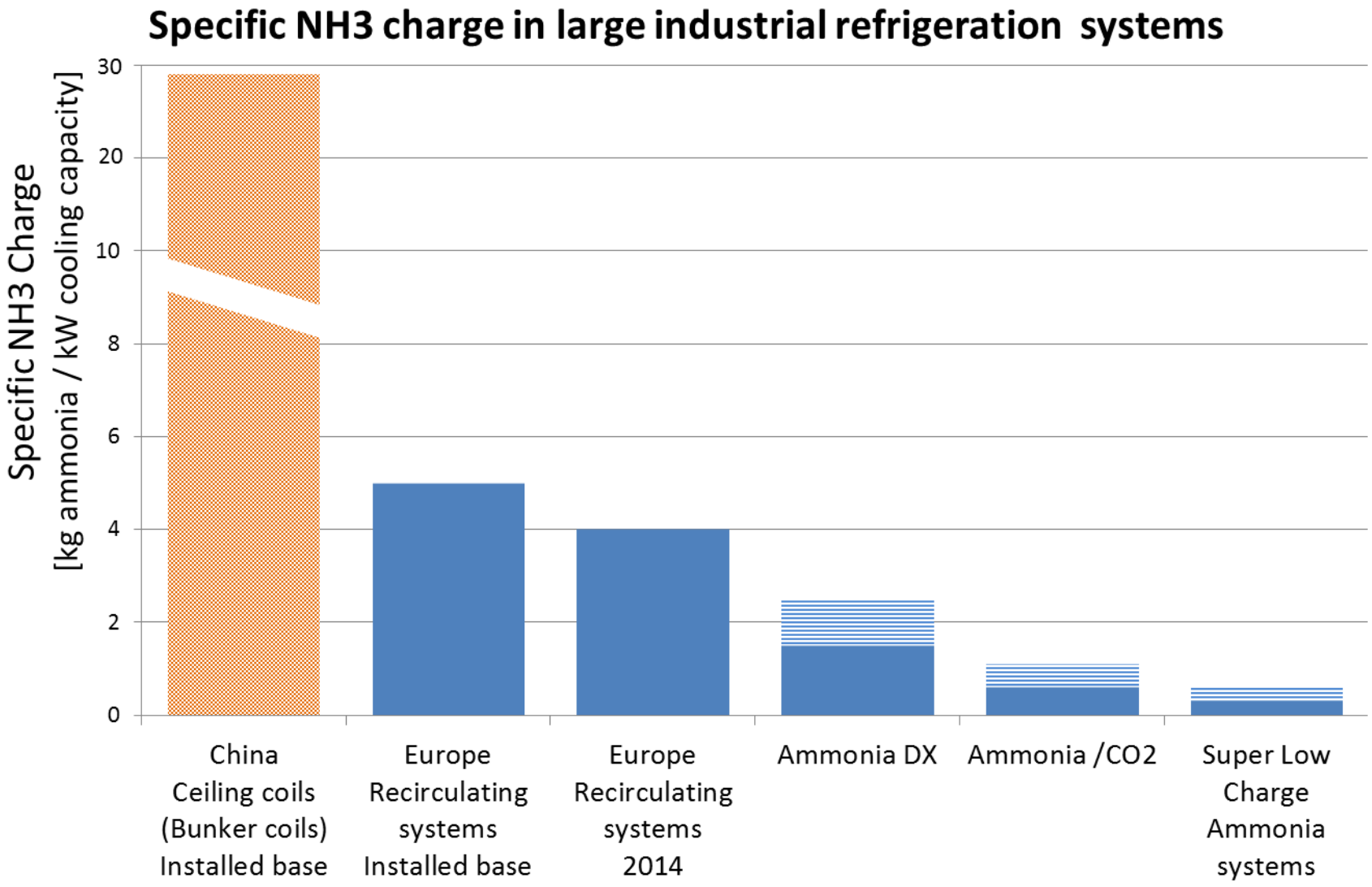
Safety
- products and system design



Offsite risk mitigation by charge reduction / segmentation



Ammonia charge in large industrial refrigeration systems

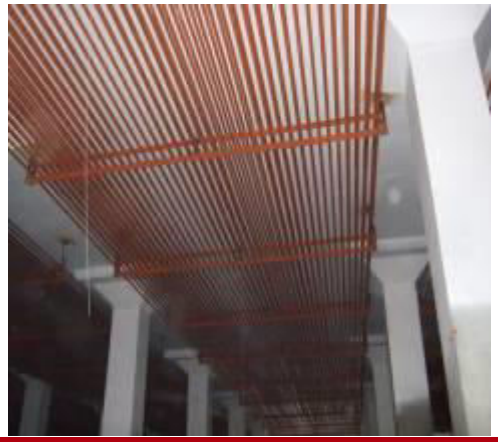


Reduced charge = Reduced Risk

Example: Cold Store 2300 kW

Ammonia Ceiling Coil system ⇔ Ammonia DX system with Aluminum Air Coolers

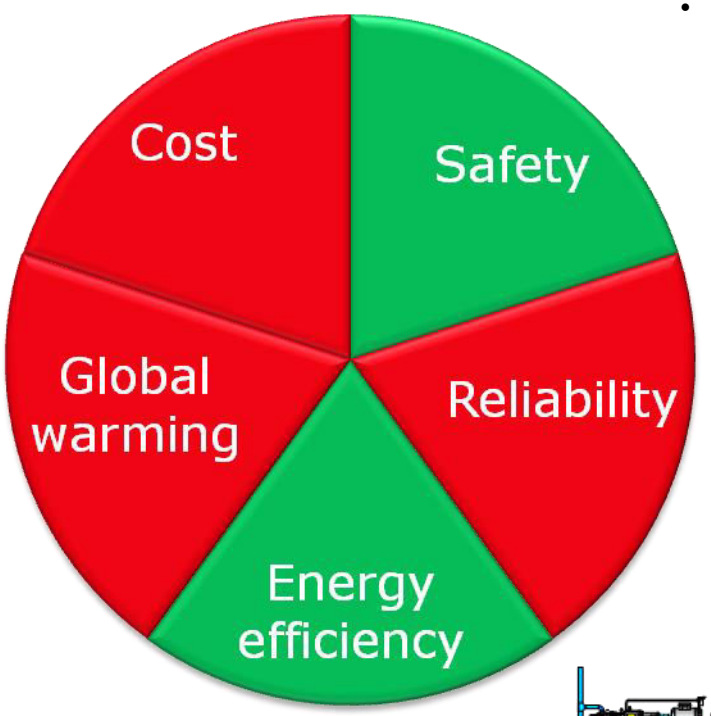
Type of evaporators	Ammonia charge (kg)	Ammonia charge (kg /kW)	Charge reduction (%)
U bend ceiling coil (OD,38mm; ID, 32mm)	59869	26	94%
Aluminum DX Air coolers	3680	1.6	



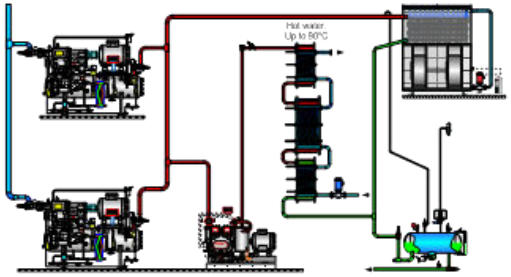
Industrial Refrigeration

Industry Drivers

Safety
- products and system design



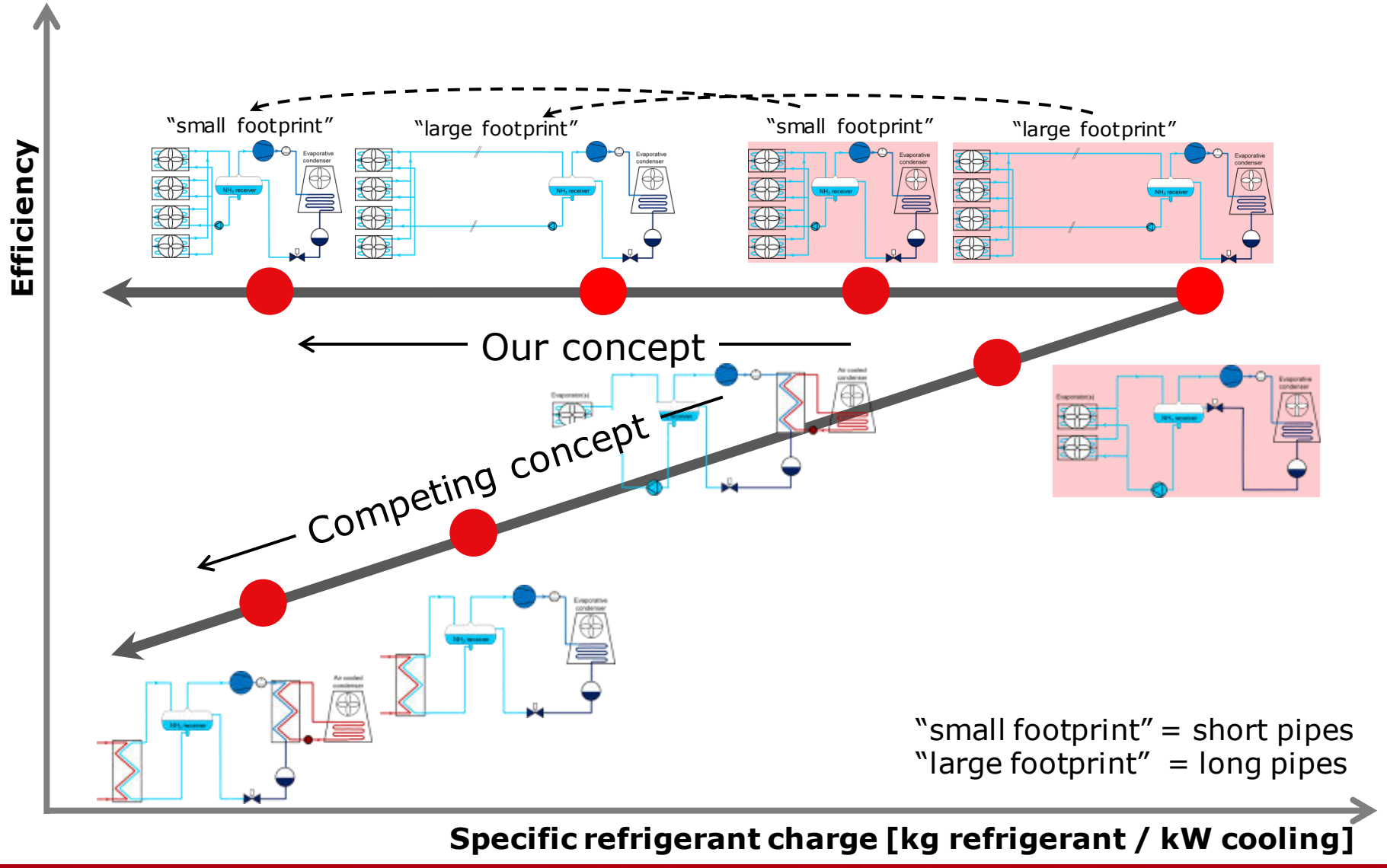
Energy efficiency
- new and retrofit systems
- Industriel heat pumps



New upcoming “Low Charge” solutions

Charge reduction without compromising efficiency

Impact on efficiency by concepts



Super low charged ammonia system for cold storages

Mitigating risks

Though not entirely new, advancements in evaporator design and liquid feed control open the door to NH3 systems offering

- No need for an engine room
- Roof-top based design
- "VLC" very low NH3 charge
- **Claimed to have up to 98% less ammonia** than regular systems (lowest charge < 100 g / kW)
- Fully automated self-contained NH3 system
- Very fast installation

1)

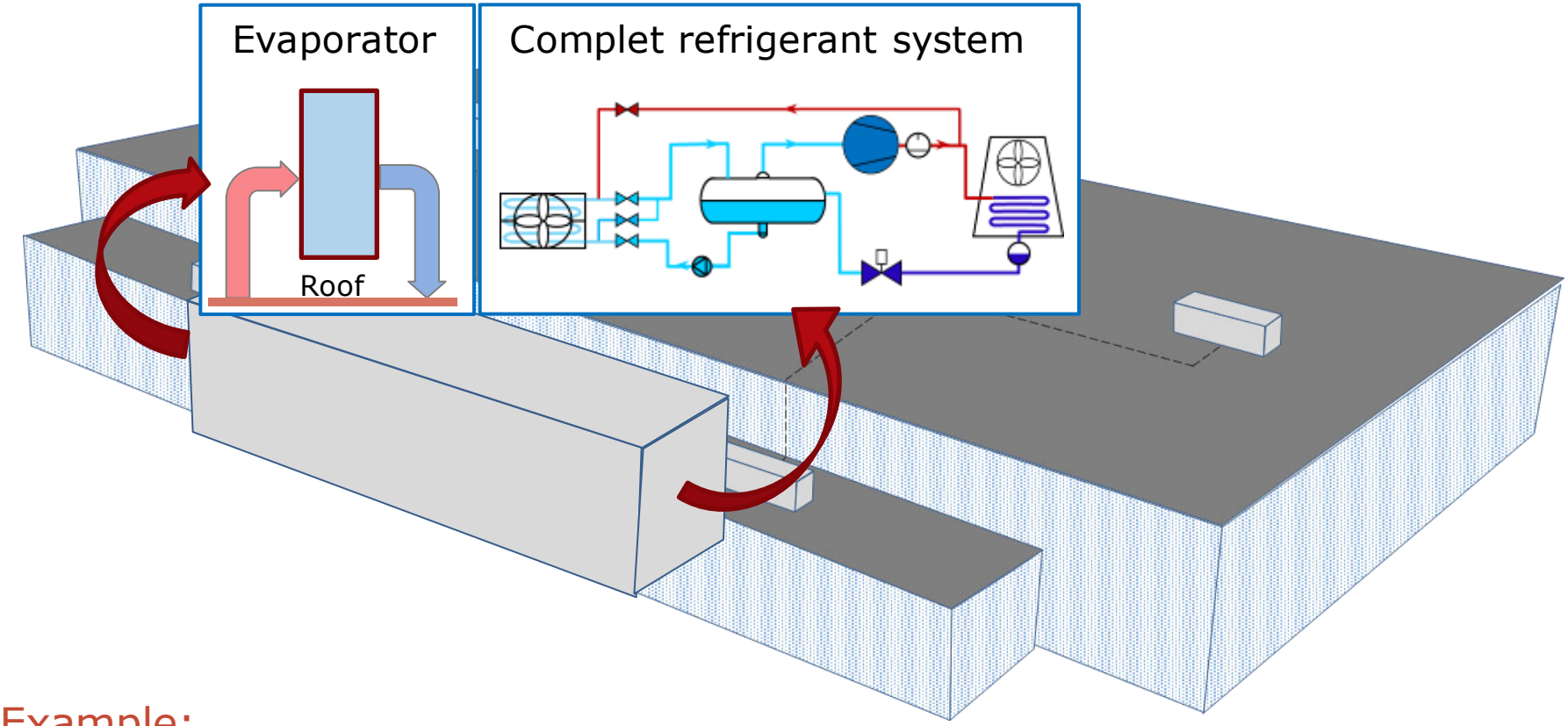
2)

3)

Source: 1) http://www.foodengineeringmag.com/articles/92191-making-ammonia-safer-and-more-efficient-in-refrigeration-applications
2) http://www.ammonia21.com/web/assets/companybrochure/file/533_azanefreezer_uk.pdf
3) http://hvacpproducts.com/2015/03/evapco-introduces-evapcold-packaged-refrigeration-system/

Super low charged ammonia system for cold storages

New upcoming trend in USA



Example:

Cold storages with 6 self-contained

NH3 “penthouse units”

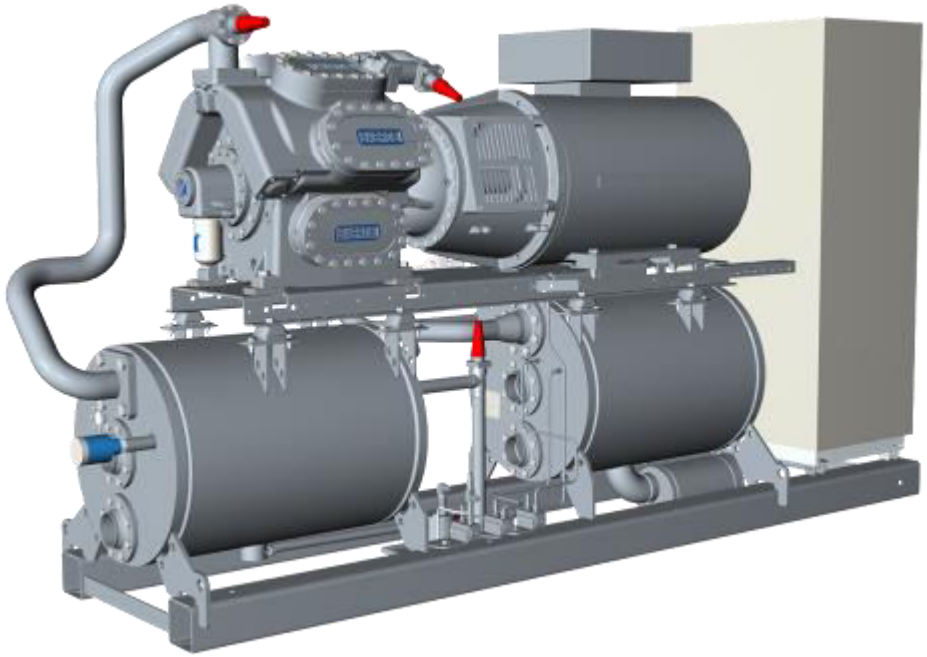
6 x 100 kg ammonia

6 x 250 kW cooling capacity

ChillPAC MK3

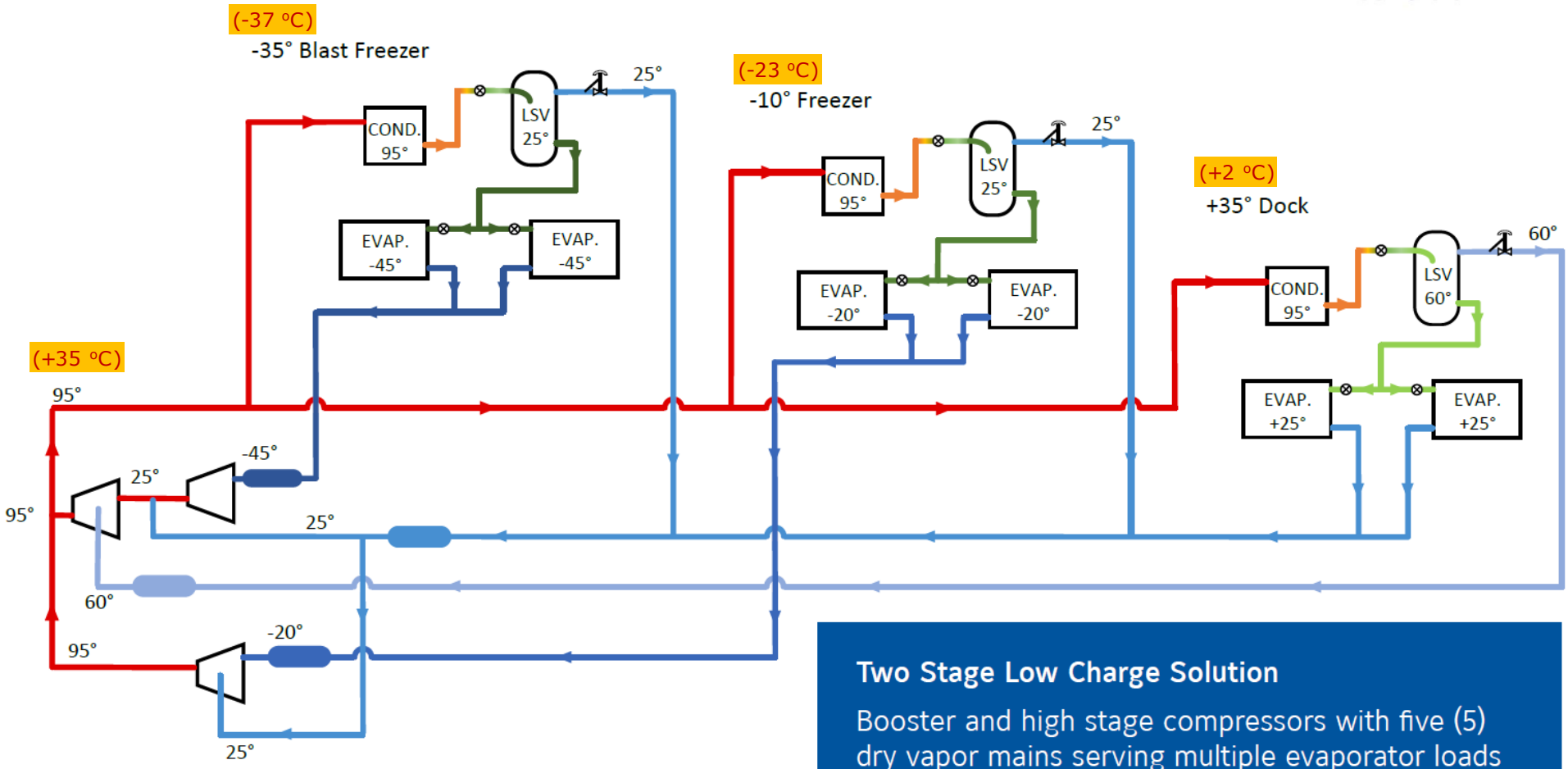
Better performance, less vibration, less charge, easy service

- Compact design, small footprint, door size
- Capacity: 150 – 1400 kW (Water inlet 12°C, water outlet: 7°C
- Flooded evaporator with integrated liquid separator
- Low refrigerant (ammonia) charge: 40 kg / 1000 kW cooling
- HP-side design pressure: 28 bar (suitable as lukevarm heat pump)



Frick® | Low Charge Central System

Johnson Controls



- No liquid refrigerant in engine room
- No liquid ”distribution lines”
- All ”distribution lines” – dry gas
- Specific charge: 1.5-3 lbm/TR (0,5-1 kg/kW)

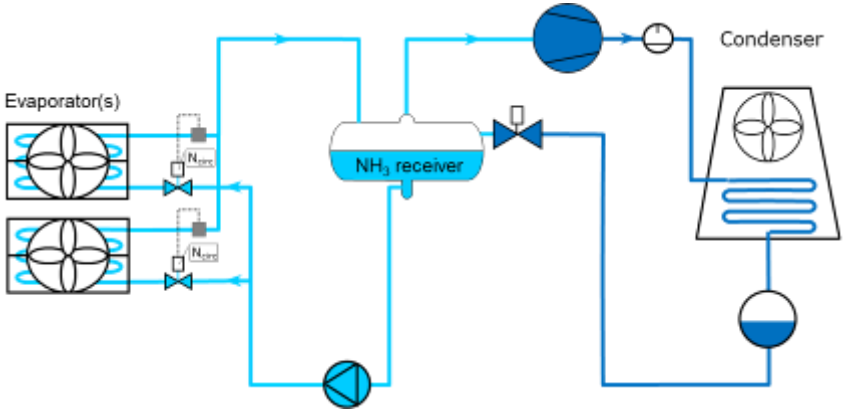
Two Stage Low Charge Solution

Booster and high stage compressors with five (5) dry vapor mains serving multiple evaporator loads at differing suction conditions.

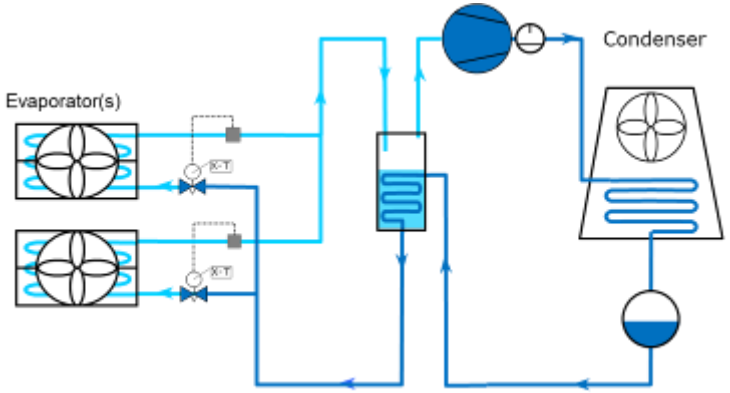
No liquid refrigerant is in the engine room. Ideal for blast freezing.

Ammonia low charge systems

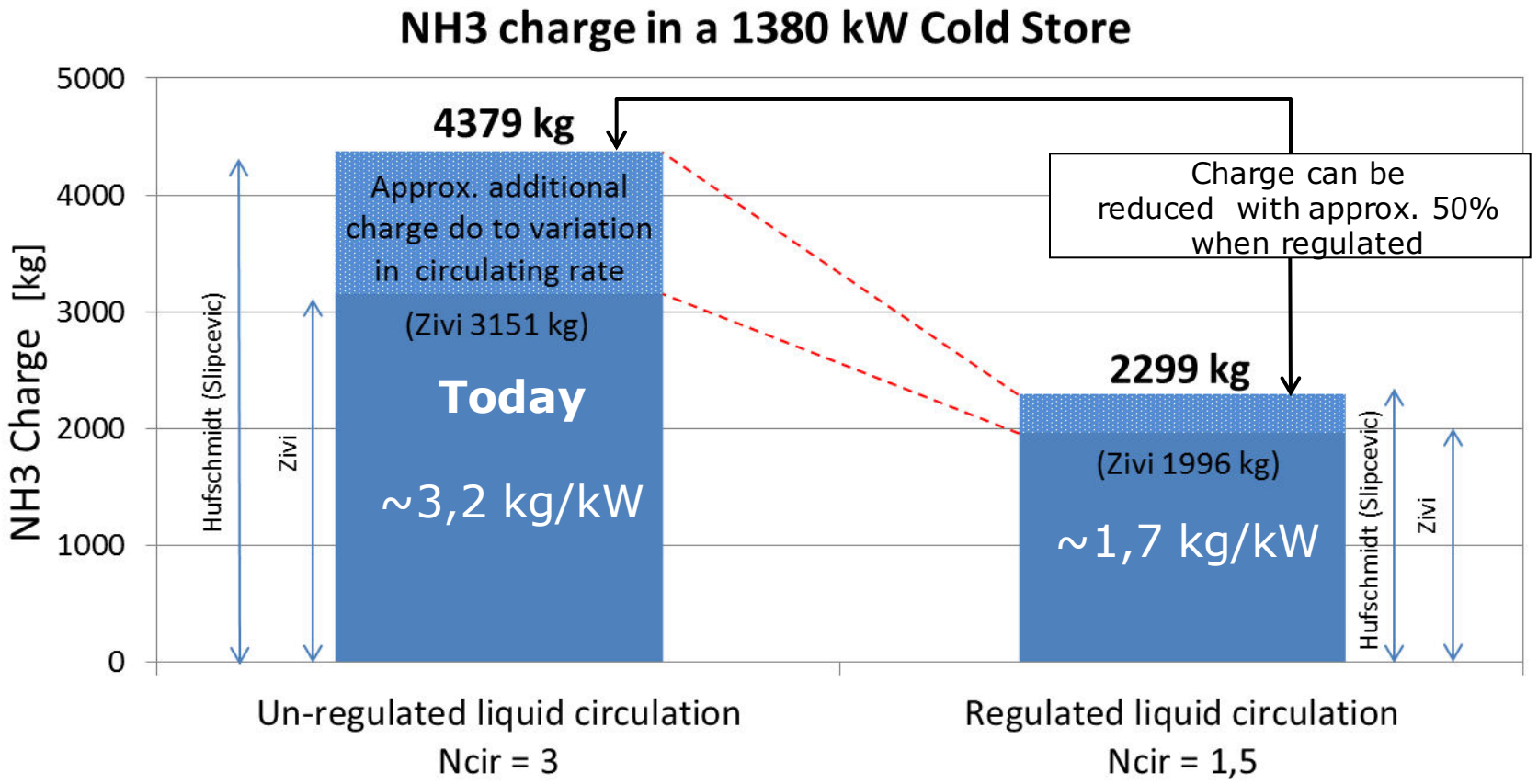
Ammonia pump circulating system with **regulated circulation rate**



Ammonia **"DX"-system** with hot gas defrost & suction accumulator

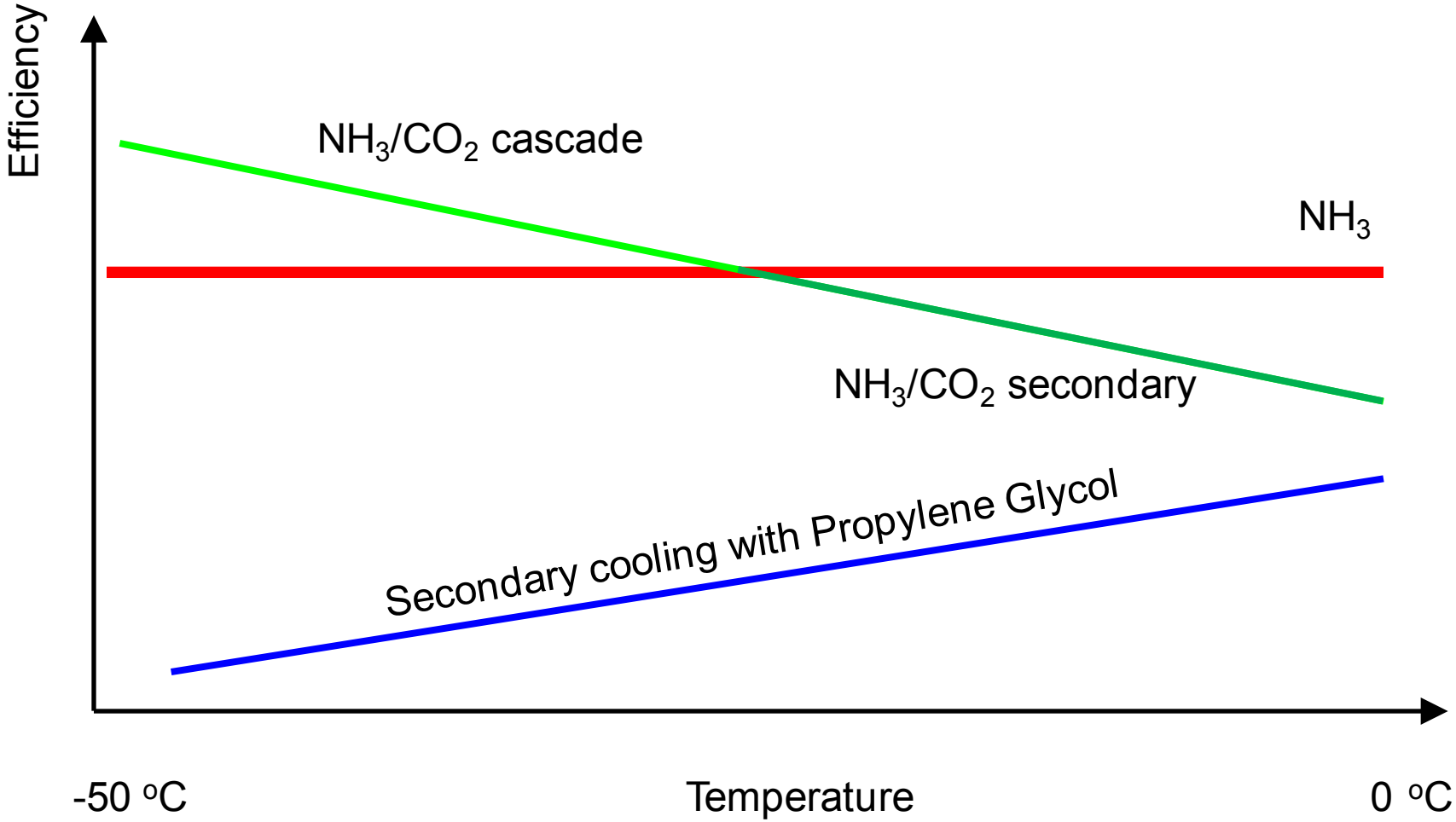


Potential: Charge reduction by regulated liquid circulation



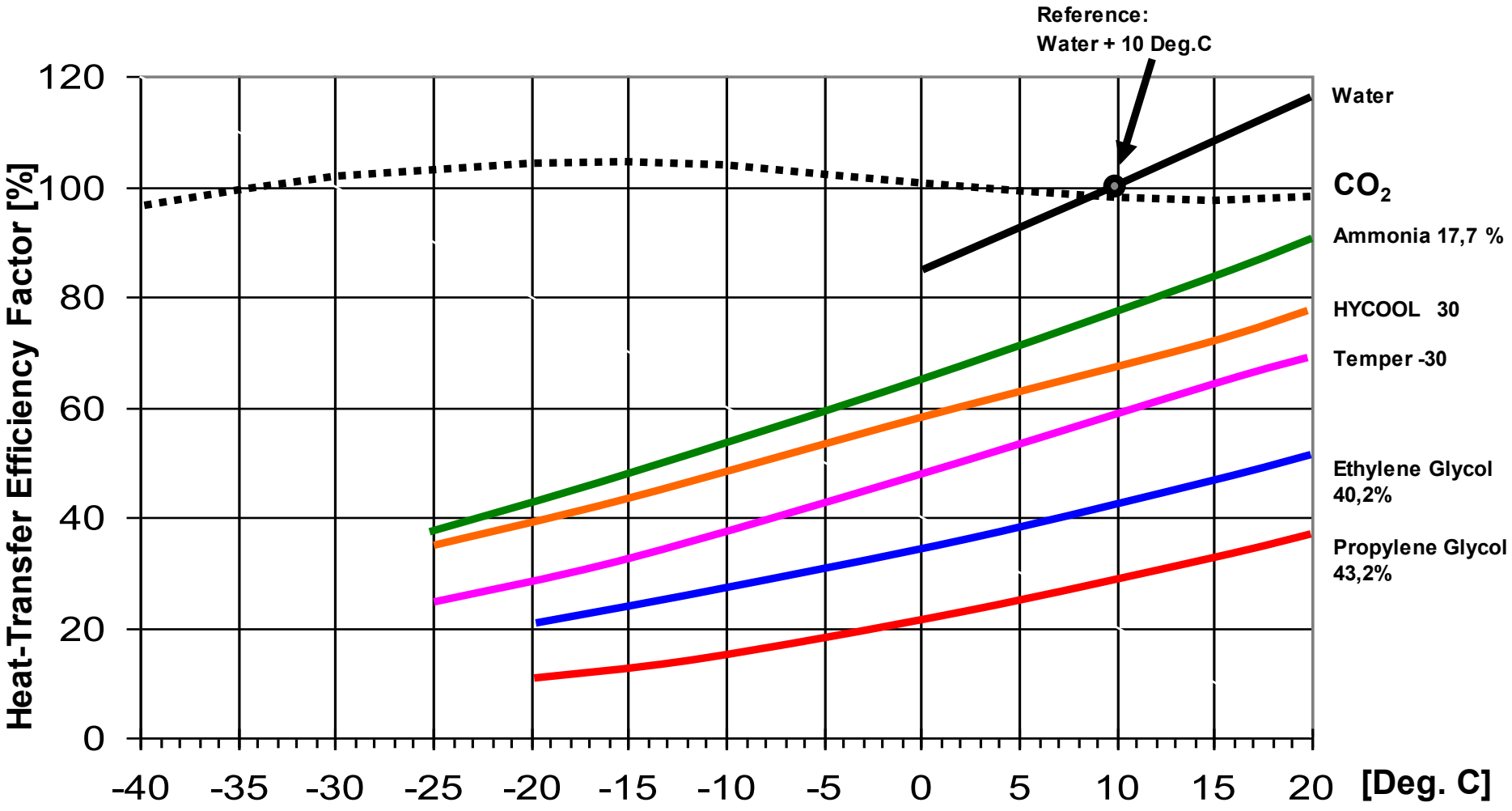
Example based on:
Cold Store: 580 kW freezing @ -35 °C and 800 kW cooling @ -5 °C total 1380 kW
14 evaporators @ -35 °C and 22 evaporators @ -5 ˚C

Ammonia vs. CO2/Ammonia and Glycol systems



CO2 <-> Secondary cooling systems *Heat-Transfer*

Efficiency Factor



The Heat-Transfer Efficiency Factor expresses the relation between the heat-transfer coefficient and the necessary pump power to overcome frictional pressure losses.

CO_2 as a brine
Calculation example : Energy consumption

		CO_2	Propylen Glycol	CO_2	Hycool
Air temperature	[°C]	**0**	**0**	**-20**	**-20**
Cooling capacity	[kW]	500	500	500	500
Evaporating temp	[°C]	**-7,0**	**-9,5**	**-28,0**	**-32,0**
Additional heat gains,	[%]	7%	10%	9%	12%
Additional heat gains,	[kW]	35	50	45	60
Pump power	[kW]	1	14	1	16
Cooling capacity adjusted	[kW]	536	564	546	576
Compressor power	[kW]	130	140	251	306
Pump power	[kW]	1	14	1	16
Total install	[kW]	**131**	**154**	**252**	**322**
Total energy difference (CO_2 vs. glycol)	[%]	**15%**		**22%**	

Comparison of ammonia vs. CO_2 systems

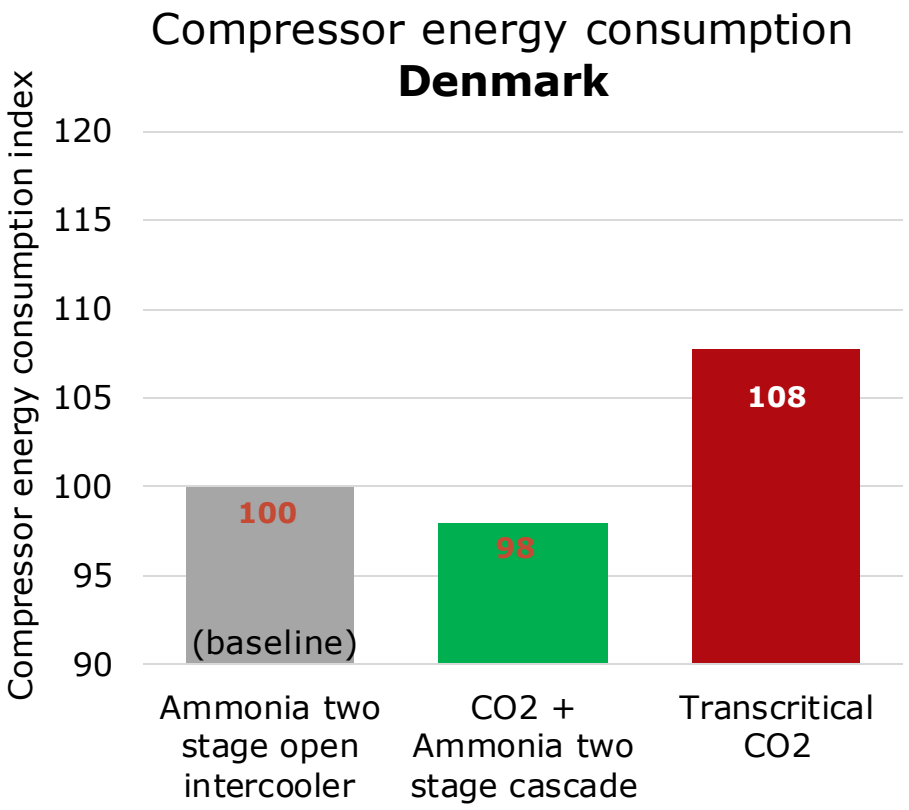
Pre-conditions

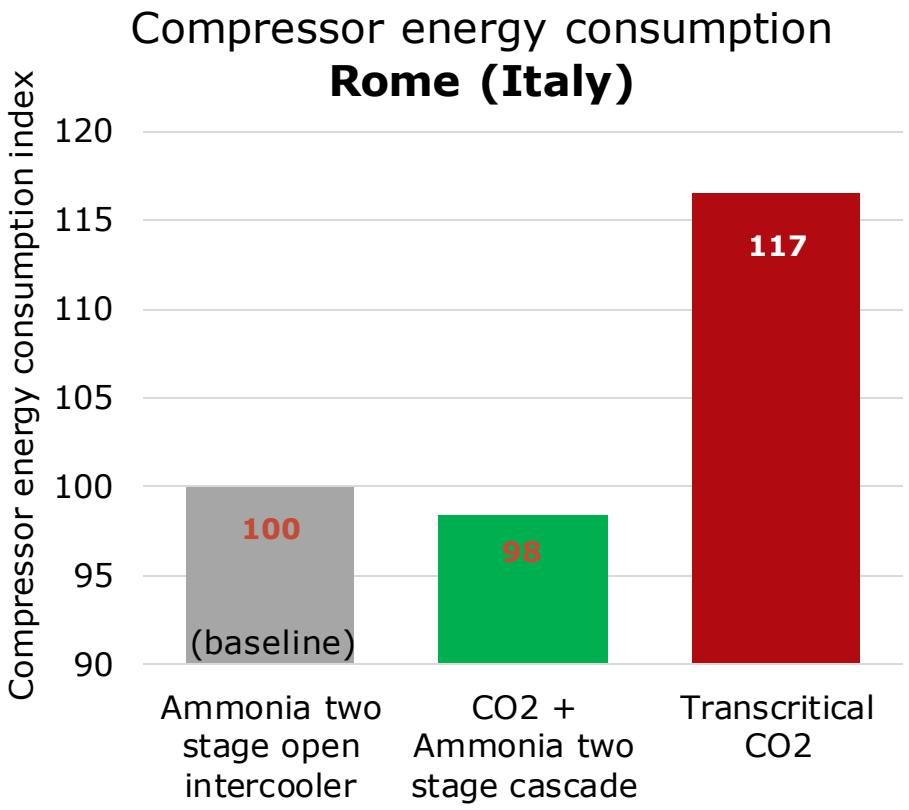
- Dimensioning capacity: **1000 kW @ -10 °C & 1000 kW @ - 40 °C**
- Floating condensing temperature: **TC_{min} = 15 °C for R717 & 10 °C for CO_2**

- **Ammonia two stage open intercooler**
  - HT: SAB 283 S VSD
  - LT: SAB 283 E male drive
  - Control system: Flooded evaporators
- **CO_2 + Ammonia two stage cascade**
  - HT: SAB 283 S VSD
  - LT: HPC 108 S Rotatune
  - Control system: Flooded evaporators & temperature difference in cascade cooler: **5 K**
- **Transcritical CO_2**
  - HT / IT: Bitzer 4CTC-30K
  - LT: Bitzer 4NSL-30K
  - Control system: DX

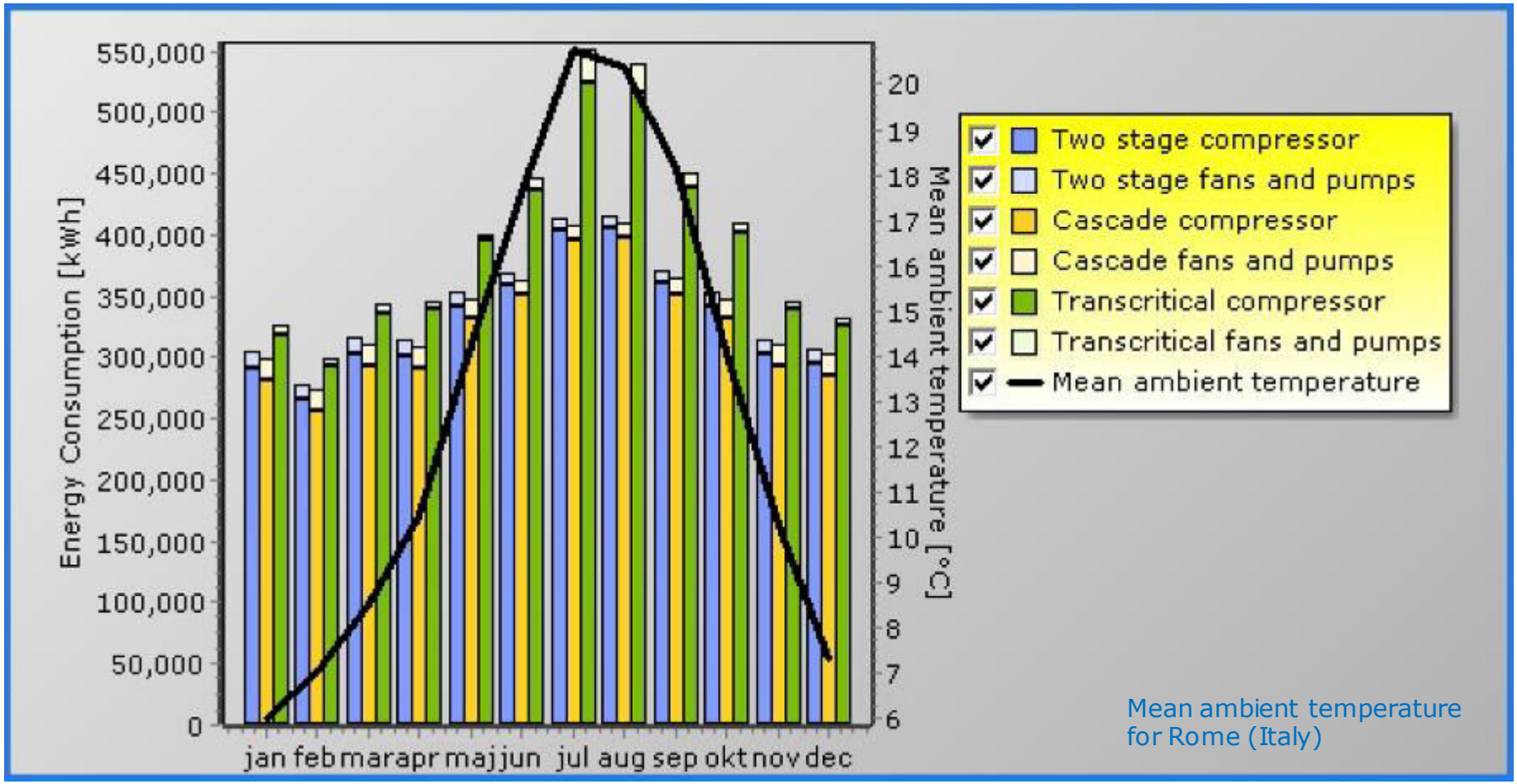
Calculation based on Pack Calculation Pro ver.4.20

Comparison of ammonia vs. CO_2 systems





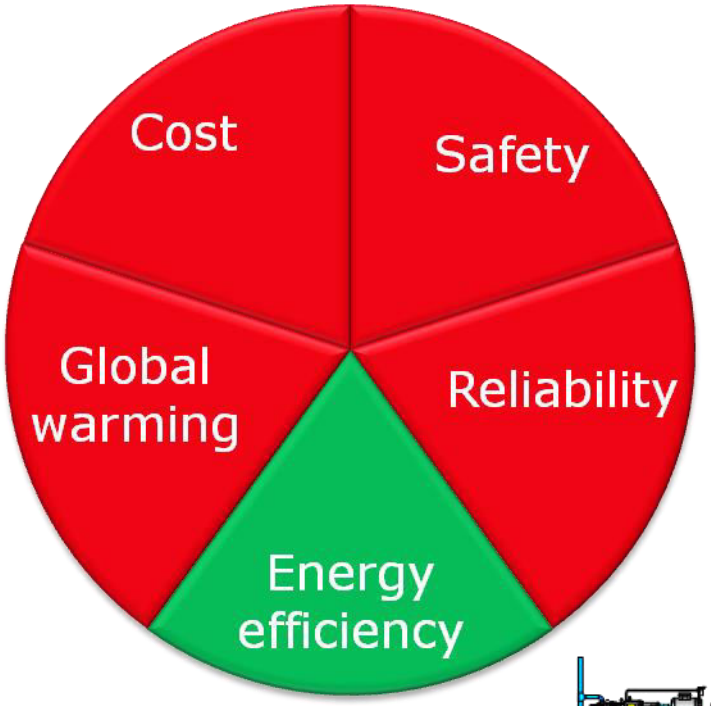
Comparison of ammonia vs. CO_2 systems



Mean ambient temperature for Rome (Italy)

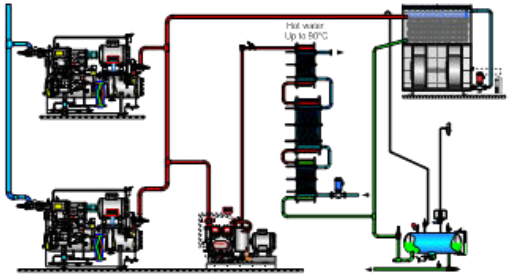
Industrial Refrigeration

Industry Drivers



Energy efficiency

- new and retrofit systems
- Industriel heat pumps



Utilize waste heat with Ammonia Heat pumps

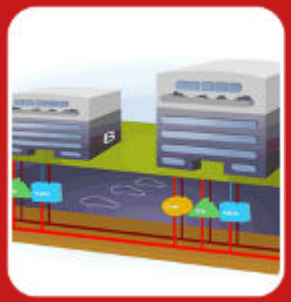

Dairies


Ice Rinks

Slaughter-houses

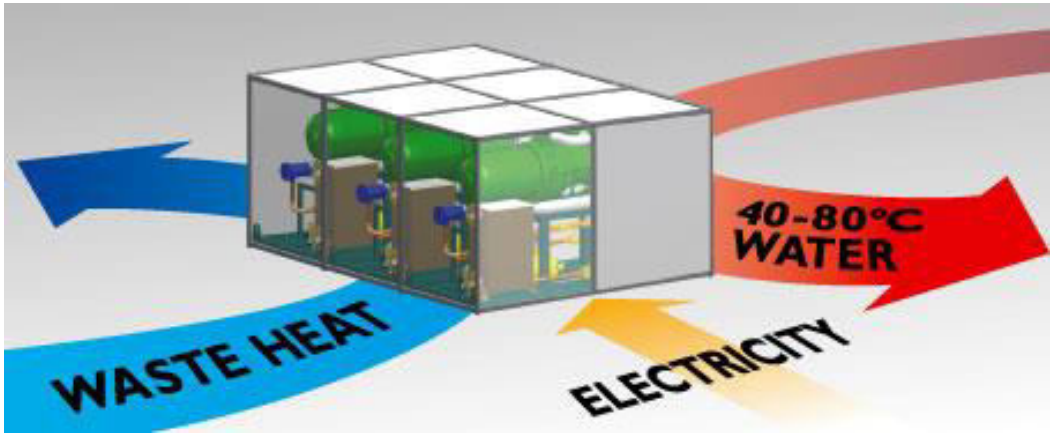

Breweries


Poultry


District Heating

Ammonia – high temperature

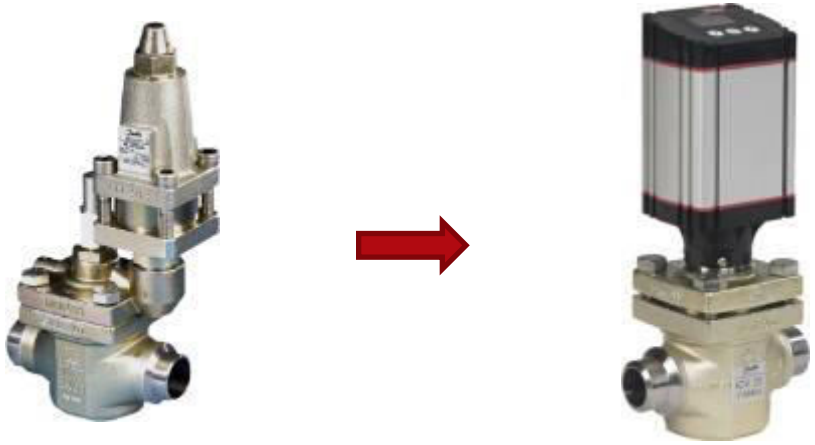
- Pressure: up to 65 bar
- COP: up to 5 or higher as add-on
- Temperature range: water up to **95°C**
- Applications: **food processing**, **process technologies** and **district heating**
- Capacity range: ~200 kW –> 30+ MW

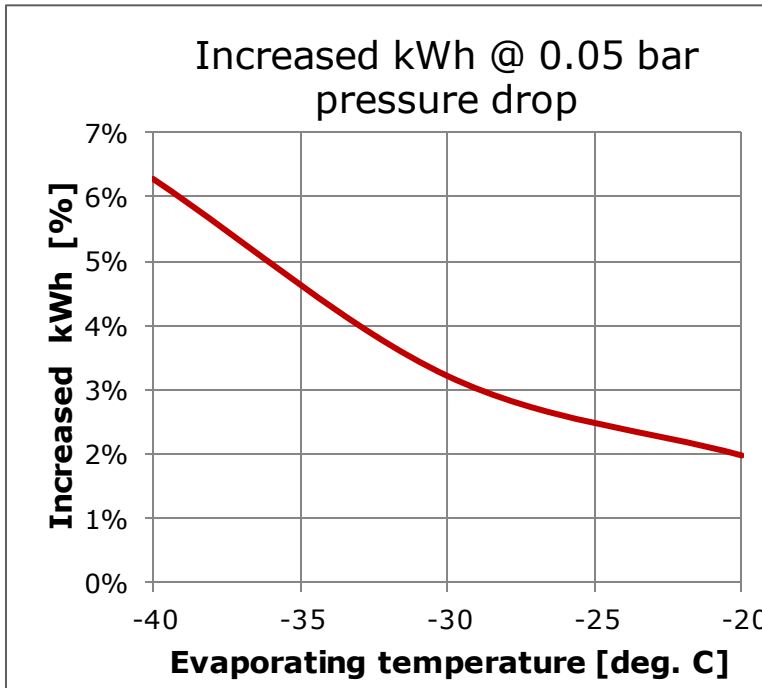


Benefit of implementing effective control systems

Servo operated valves vs. motorized valves

- Servo operated valves requires 0.2 bar for 100% opening, and min 0.05 bar
- Example: An additional pressure drop at e.g. 0.05 bar in a suction line of an Ammonia system with an evaporating temperature at -40 Deg. C correspond to a temperature drop on approx. 1.5 K.

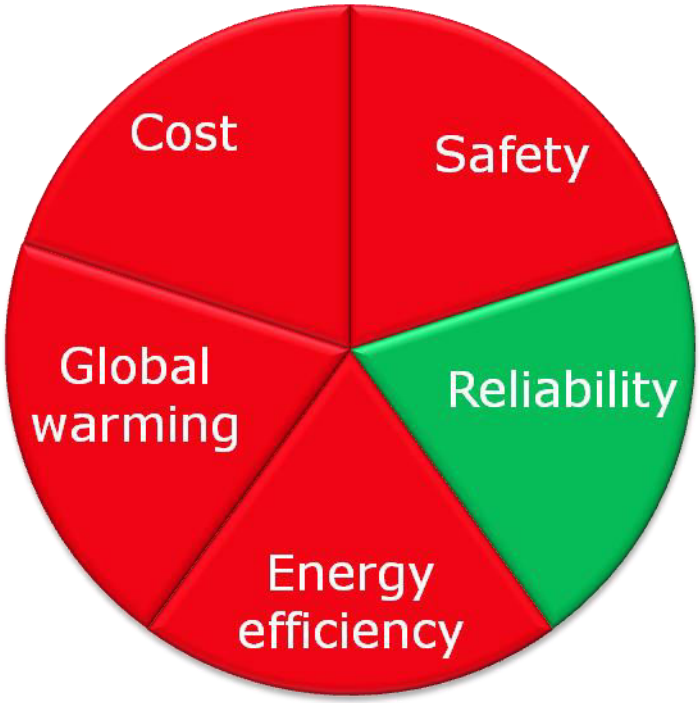




Increase in compressor energy @ 0.05 bar pressure drop in suction line. Screw compressor with Ammonia. (TE -40 to -20 Deg. C / TC +30 Deg. C)

Industrial Refrigeration

Industry Drivers



Reliability

- Automatic running

Danfoss Flexline™
Commonalities Across ICV, ICF And SVL

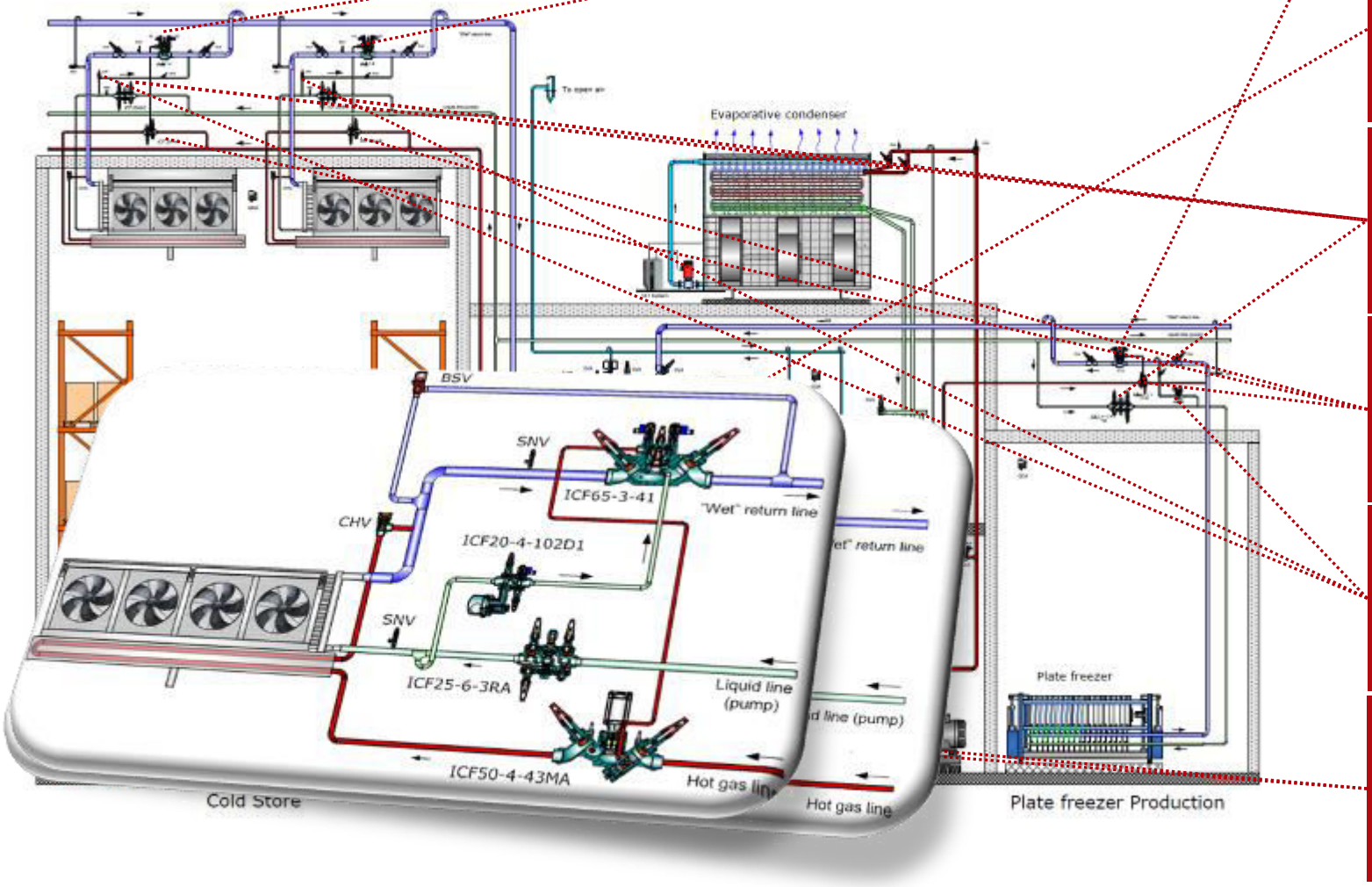
- Platform based concept offering a lot of benefits such as
  - Clever simplicity
  - Advanced flexibility
  - Timesaving efficiency
- All products are designed for Ammonia and CO_2
- Standard approval for 52 bar (65 bar on request)

ICV Flexline ™
- Control valve

ICF Flexline ™
- Complete valve stations

SVL Flexline ™
- Line components

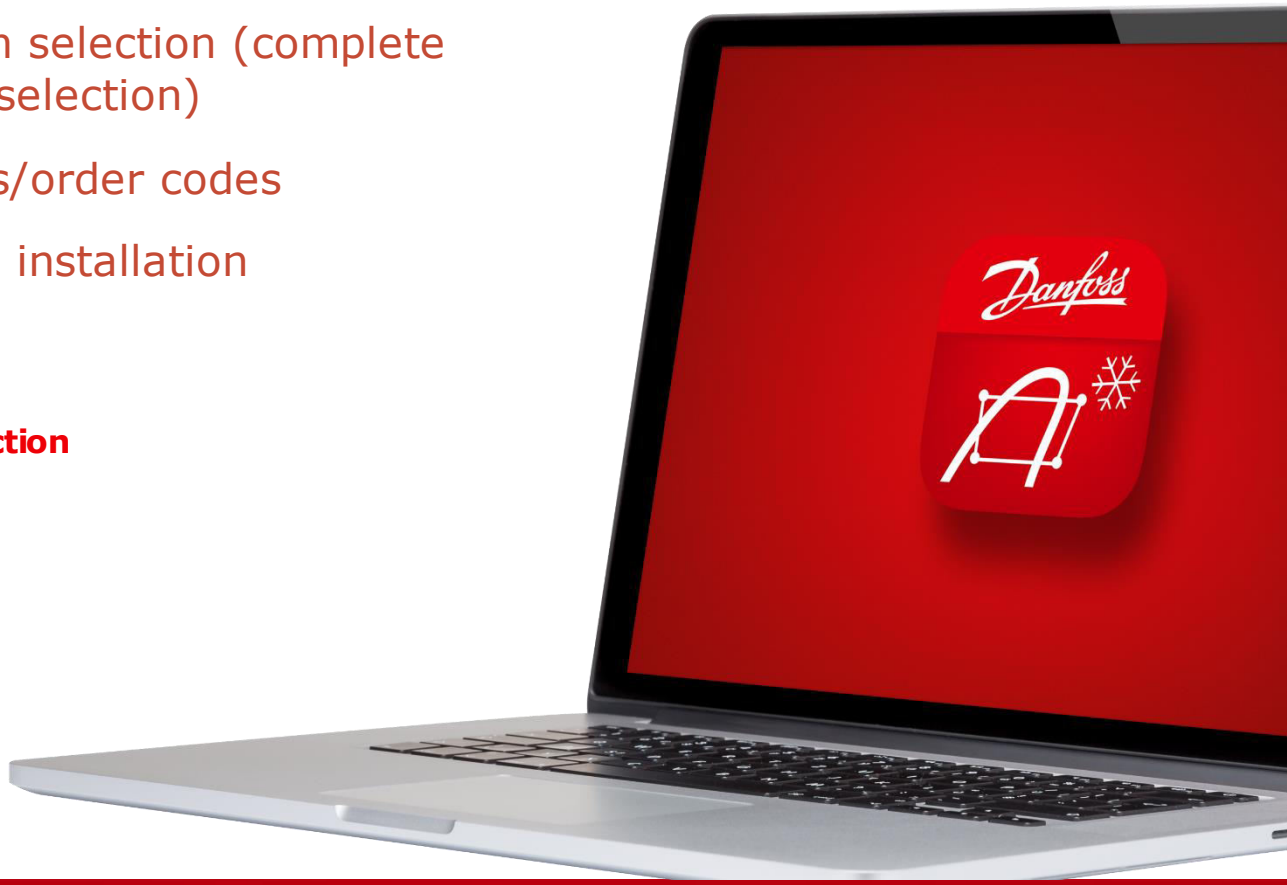
“State of the art” Cold Store application



Coolselector®2

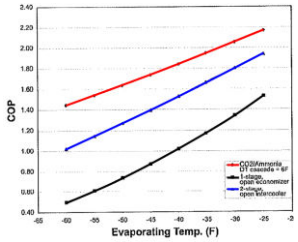
- Provides complete valve and piping calculation and selection
- Provides application selection (complete evaporator station selection)
- Offers specific sales/order codes
- Easy download and installation

Fast and easy selection



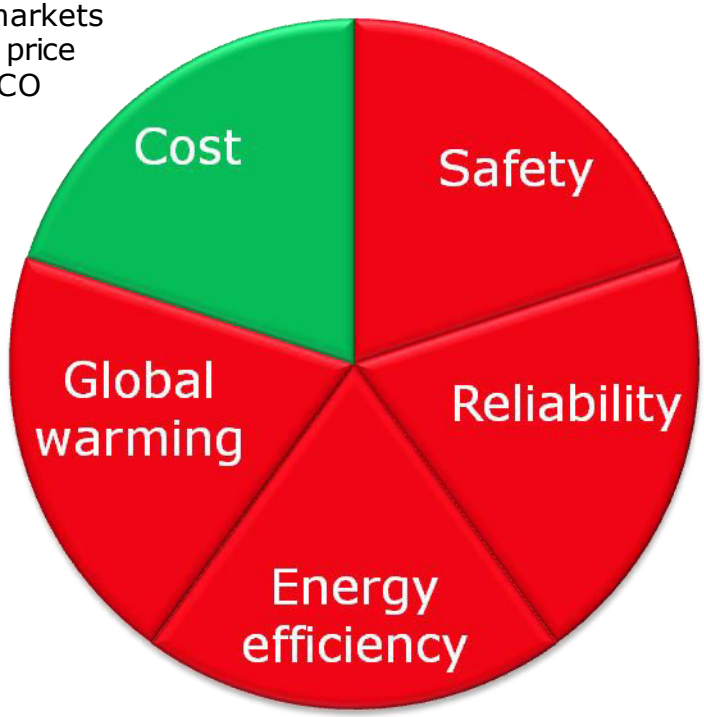
Industrial Refrigeration

Industry Drivers

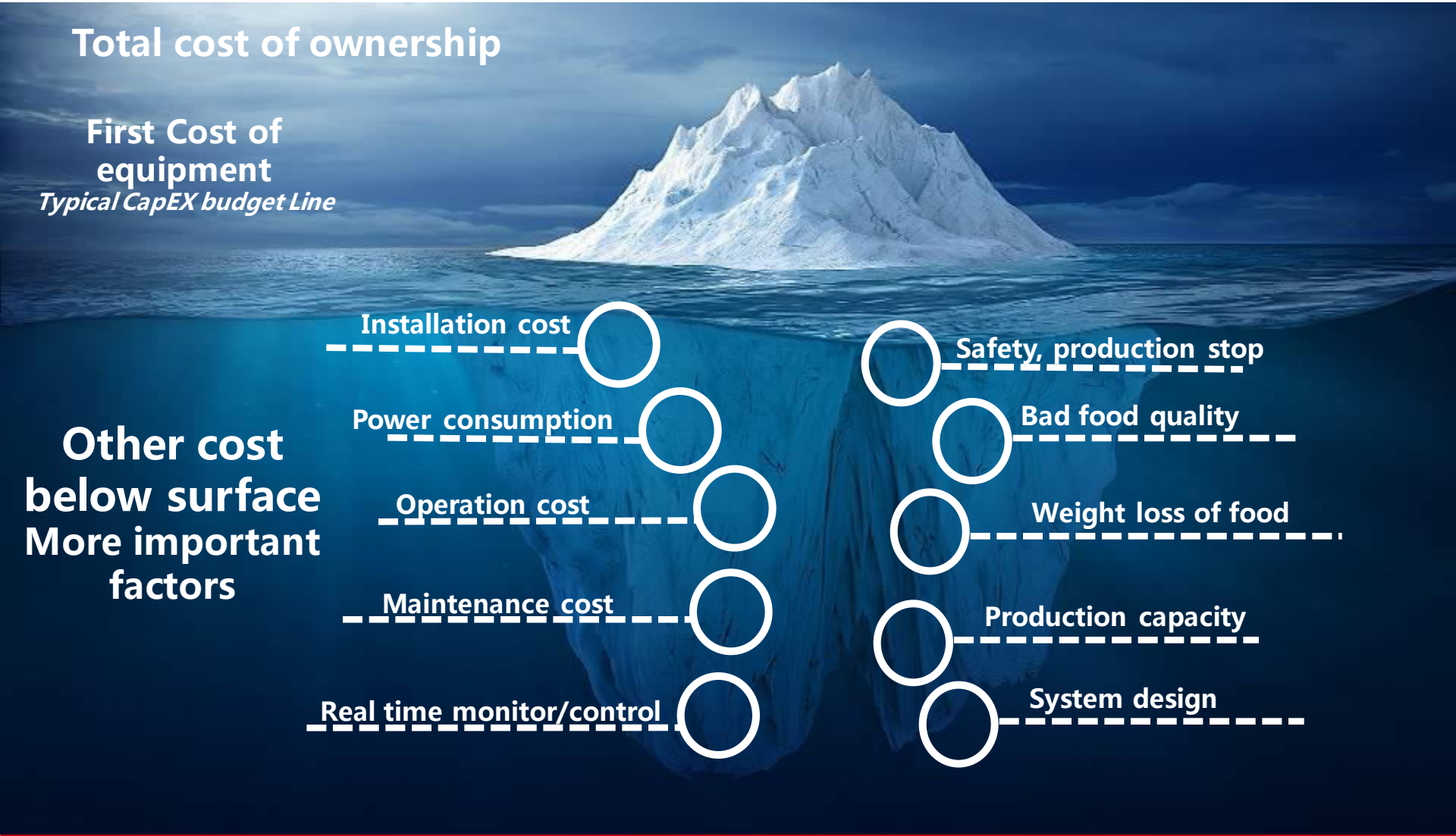


Cost

- primary growth in emerging markets with higher price pressure, TCO awareness



Total cost of ownership for complete system



Conclusion

- The ammonia industry has a long history with more than 100 years of experince.
- Today's challenges:
  - Ammonia is still the preferred refrigerant for industrial applications
  - Safety is a topic, that has to be treated professional
  - Low charge ammonia systems is an obvious solution
  - Low charge solutions can be obtained by:
    - Re-design traditional pump-systems
    - Combining ammonia and CO_2
    - Transcritical CO2
  - Increase energy efficiency

ENGINEERING
TOMORROW