





# Plate heat exchangers in CO<sub>2</sub> applications

– Webinar 21 July 2020



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# Agenda



- Introduction
- CO2 application overview
- Brazed plate heat exchangers
- System overview
- BHE's position and duties
- Product portfolio
- Supply map & availability
- Q&A





17 387

AVERAGE NO OF  
EMPLOYEES

Energy

Food & Water

Marine



44%  
Heat transfer

19%  
Separation



24%  
Fluid handling

# Why CO<sub>2</sub> solutions?

- Sustainability



Sustainability is both a necessity and a business opportunity.

- F-Gas legislation
- Replace older systems
- Reduce environmental impact



CO<sub>2</sub>

# Refrigerant Change

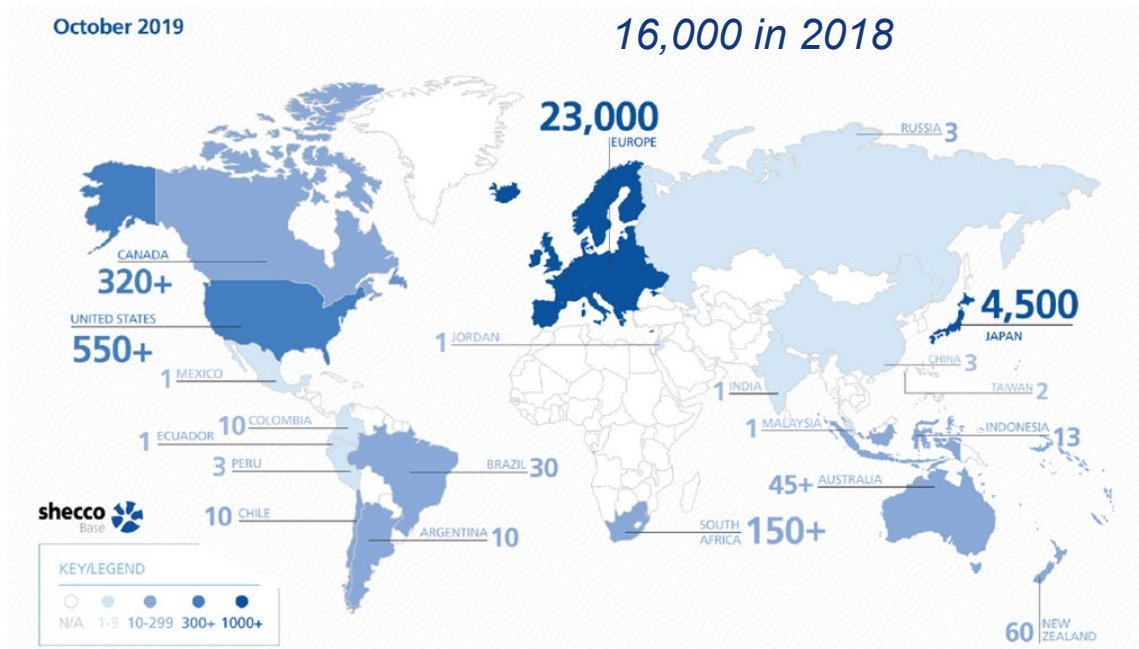
- The rise of CO<sub>2</sub>



**TODAY: close to 30,000 CO<sub>2</sub> TC installations globally**

October 2019

*16,000 in 2018*



#GoNatRefs

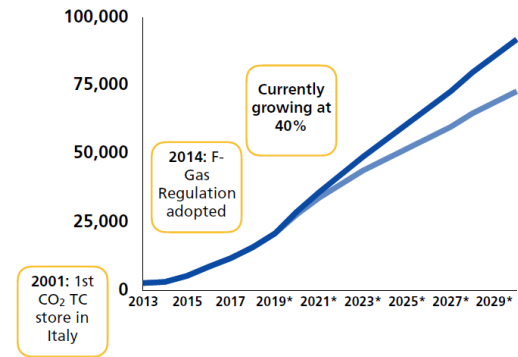
16-17/10/2019 - Warsaw

## Projected CO<sub>2</sub> TC stores in Europe

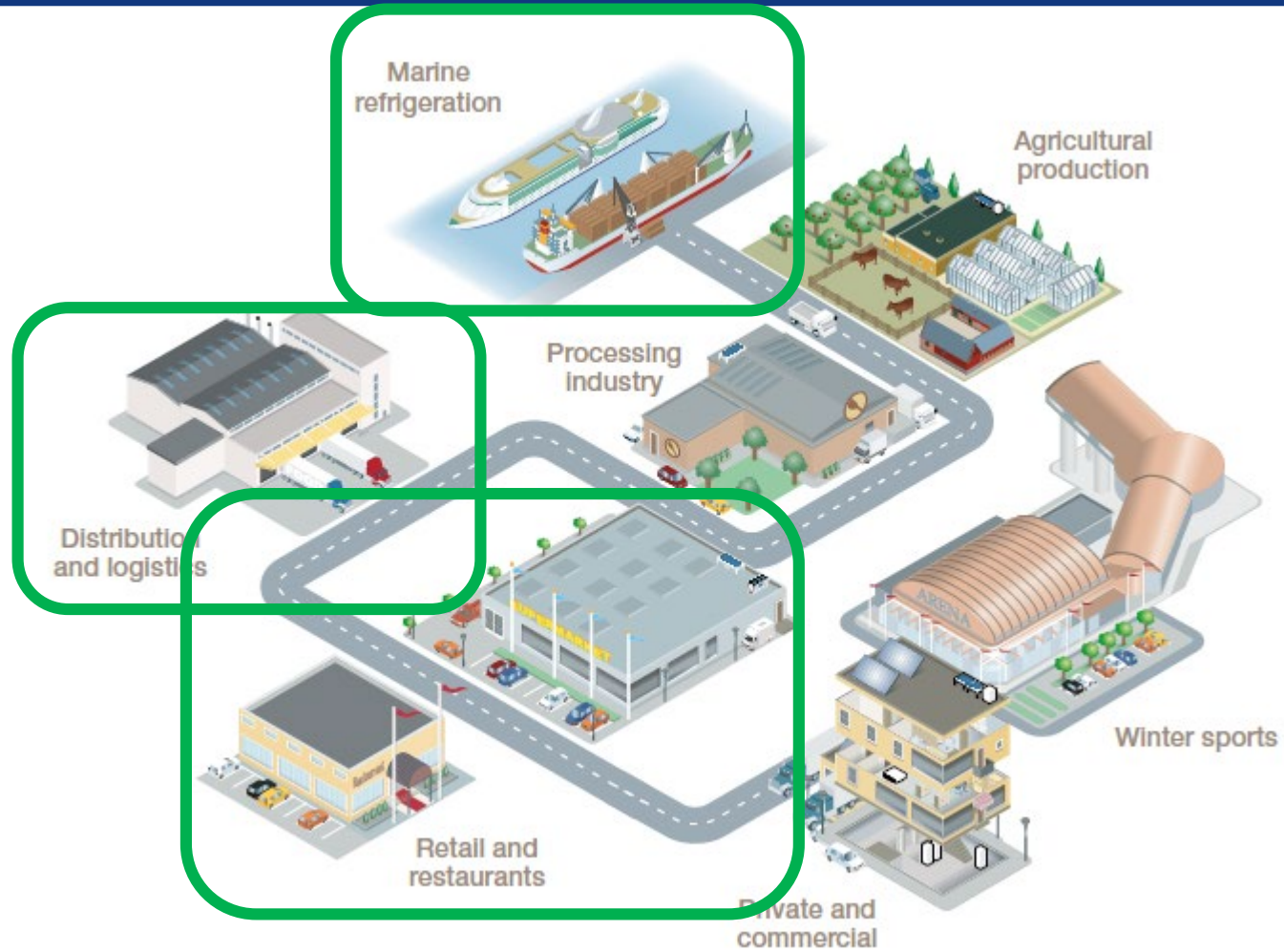
continued exponential growth of CO<sub>2</sub> TC in Europe

**4,000 – 7,000 new stores annually between 2020 – 2030**

expected to reach **73,000 – 92,000** CO<sub>2</sub> TC stores in Europe by 2030



# CO<sub>2</sub> application overview



# Copper brazed CO<sub>2</sub> plate heat exchangers



Evaporator



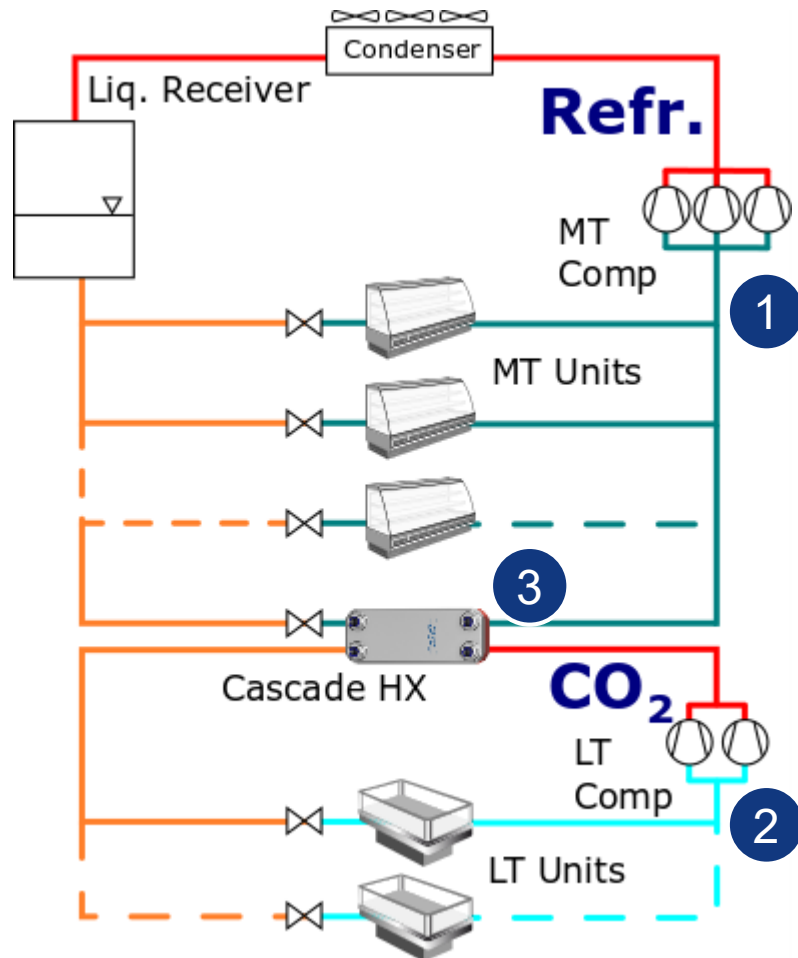
Condensor



# System overview

# Cascade system

- Supermarkets



## Cascade system (older system, less used)

- The Medium Temperature circuit is a standard system (e.g. R134a, NH3, R448) ①
- The Low Temperature circuit is a subcritical CO<sub>2</sub> ②
- The Cascade HX is a condenser for CO<sub>2</sub> and an evaporator for the other refrigerant ③
- For the MT point of view circuit it is like a user: temperatures and pressure are variable with high frequency
- Fatigue must be considered (both thermal and pressure related).

# Transcritical CO<sub>2</sub> Comp rack: installation

- Supermarket



## Gas Cooler

- Controls CO<sub>2</sub> outlet temperature
- Min temp CO<sub>2</sub> outlet: 5-10°C

A compressor rack includes different Types of BHE



## CO<sub>2</sub> Compressor Rack

- 1 liquid line
- 2 suction lines (booster):
  - Medium Temp (-10°C, 26 bar)
  - Low Temp (-30°C, 12 bar)

Another possible system is the subcritical Cascade



## MT cabinets

Air Temp  
0÷4°C



## Cold Rooms

MT and LT



## LT freezers

AirTemp  
-18÷-25°C

# Transcritical CO<sub>2</sub> Comp rack: Booster system components

- Supermarkets



CO<sub>2</sub>

## Gas cooler

Air cooled HX  
Sized to reject the full capacity

## High Pressure Valve

Controls HP to  
Optimal value as a function of GC outlet T

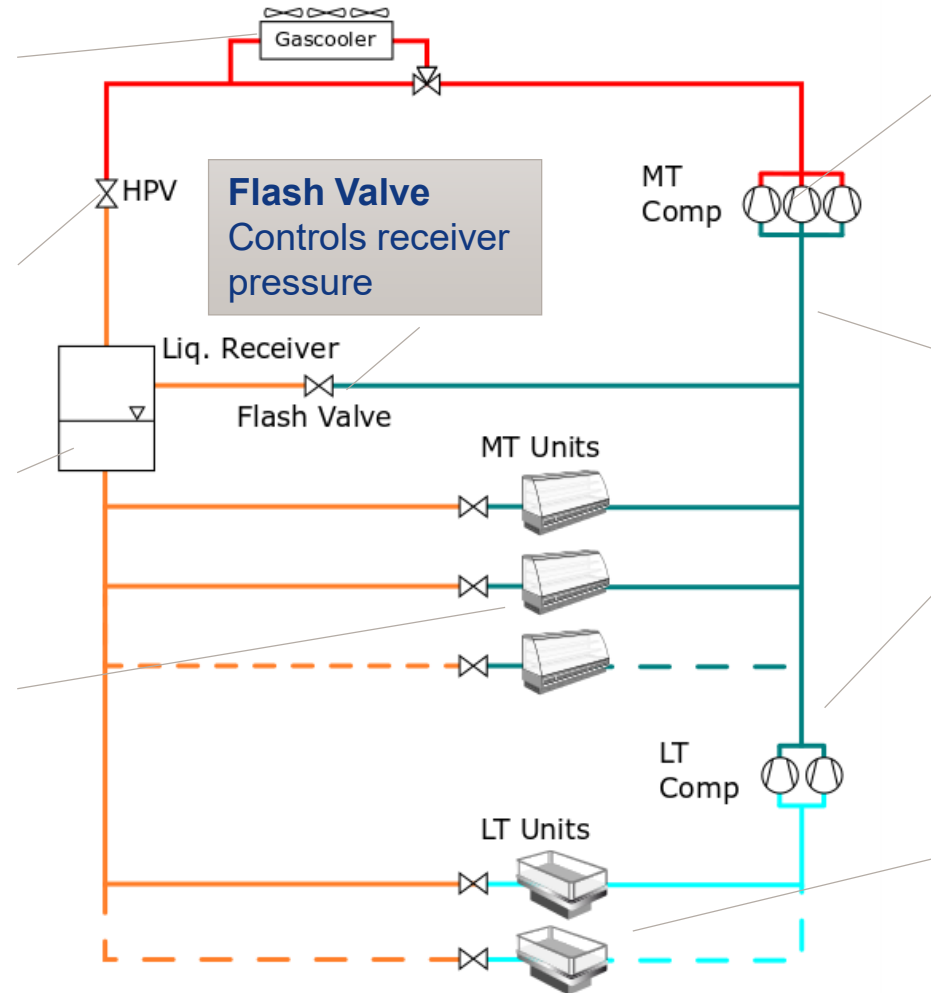
## Liquid receiver

Separates HP section from the liquid line  
35-45 barg

## MT cabinets

Different setpoints  
Independent regulation  
Evap: 26 barg = -10°C

Compressors are controlled by  
**suction pressure!**



## MT comps

Reciprocating  
1° comp variable speed  
Disch T 130-150°C  
HP 105-140 barg

## Suction MT

Total flowrate: MT + LT units  
+ Flash

## LT comps

Reciprocating  
1° comp variable speed  
Disch T 50-90°C  
HP 53 barg

## LT freezers

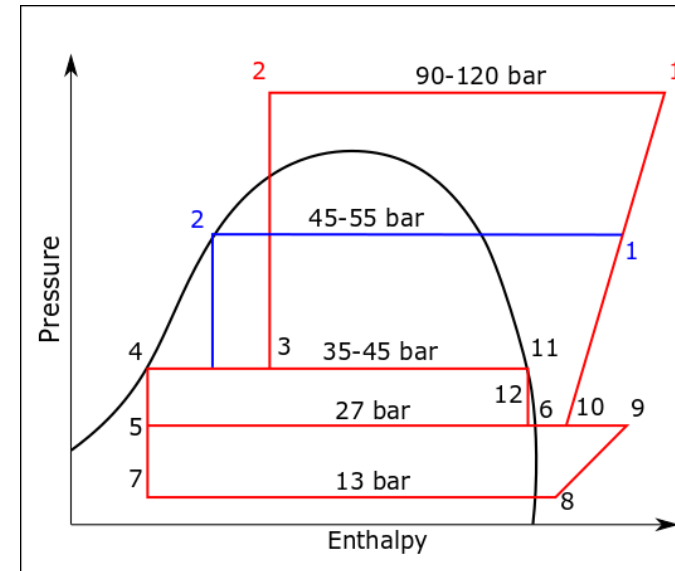
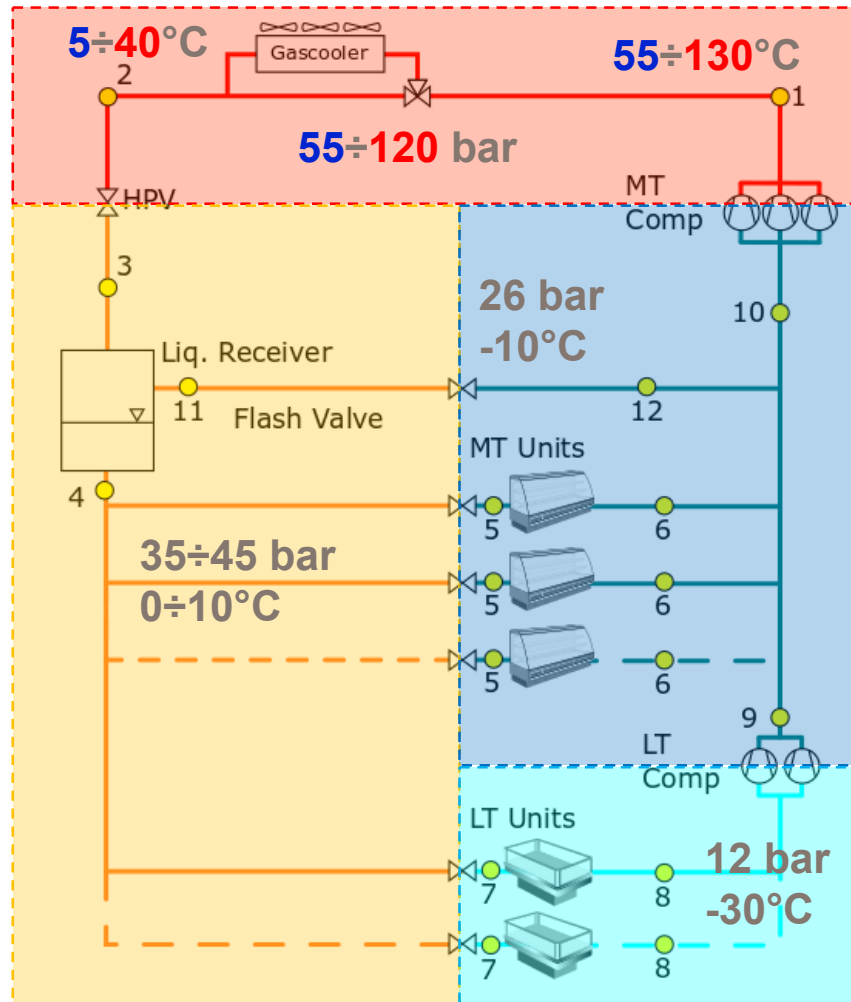
Different setpoints  
Independent regulation  
Evap: 12 barg = -30°C

# Transcritical CO<sub>2</sub> Comp rack: pressures and temperatures

- Supermarket

■ Subcr.  
■ Transcr.

Operating Pressures and temperatures



**Design pressure**

High pressure side

**DP ≥ 120 bar**, due to transcritical operation

**When the unit is OFF, pressure can rise up to 50-70 bar**

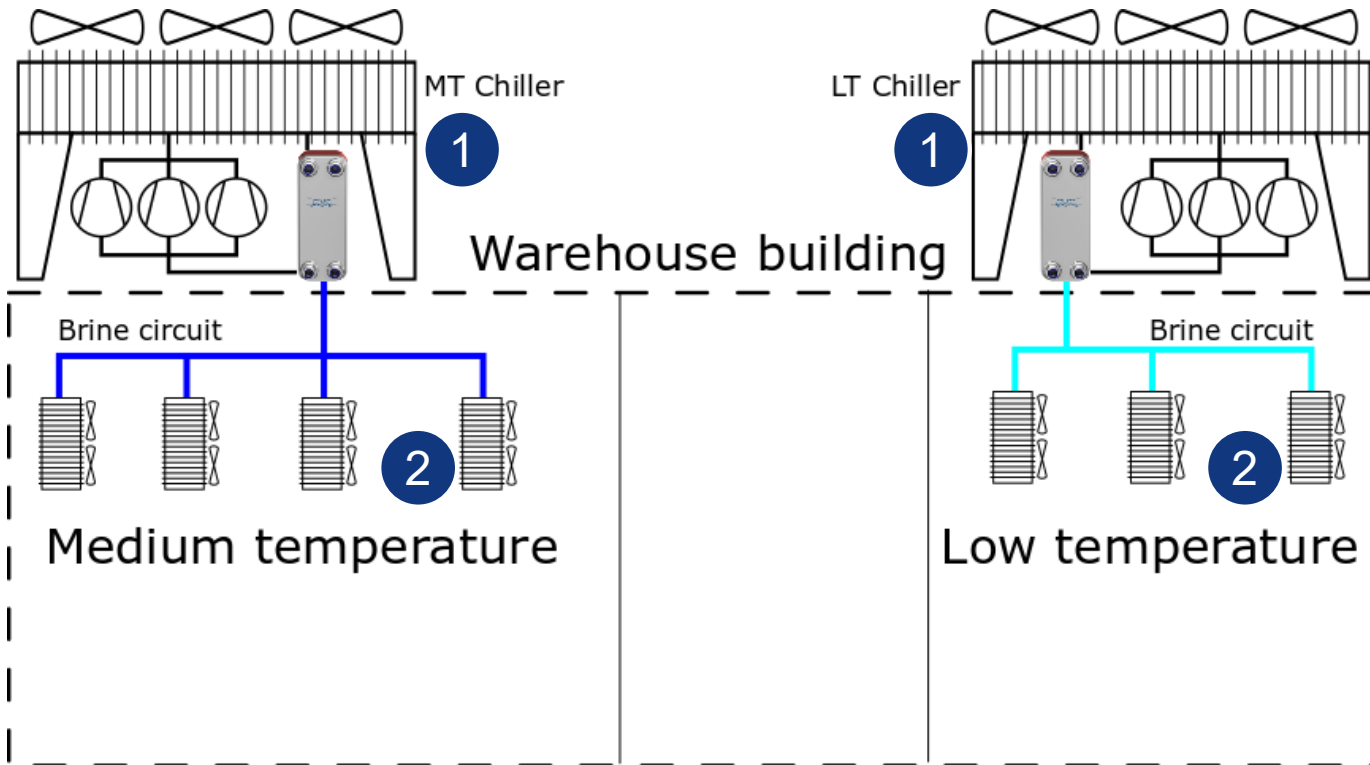
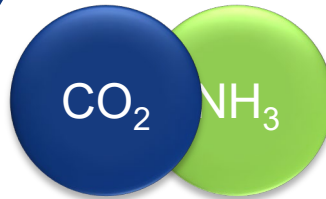


Medium and Low pressure side

**DP = 60-90 bar**, due to standstill operation

# Brine chiller, indirect system

- Distribution centers



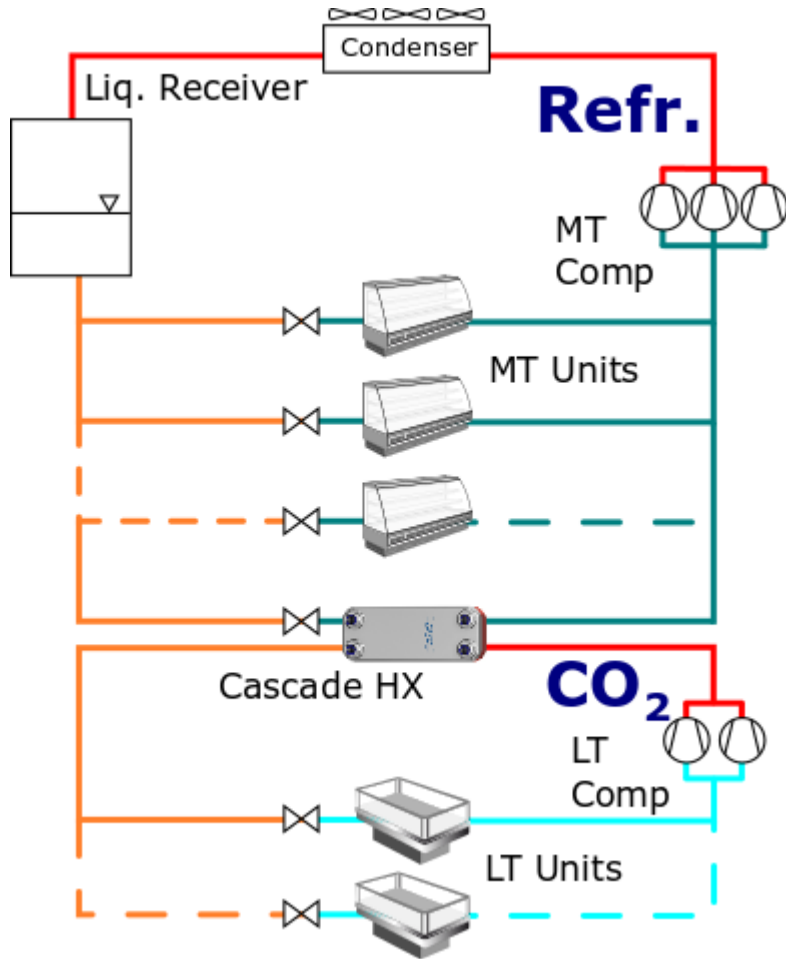
## Indirect system

- Large chillers are used to cool down brine 1
- Air coolers keep the warehouse cold storage areas at Medium or Low temperature 2
- Cooling Capacity is usually high
- Ammonia systems are widely used
- Increased presence of Transcritical CO<sub>2</sub> units, due to availability and limited risk compared to ammonia
- Large GPHE or BHEs in parallel
- Alternative: DX system (no plate HEs involved)

# BHEs Position and Duties

# Subcritical CO<sub>2</sub> (Cascade)

- Cascade Heat Exchanger



## Cascade Heat Exchanger

- It is a condenser for the Low temperature circuit CO<sub>2</sub>, while it is the evaporator for the MT circuit (usually a different refrigerant: e.g. R448A)
- The heat exchanger is controlled by an expansion valve on the evaporating side.

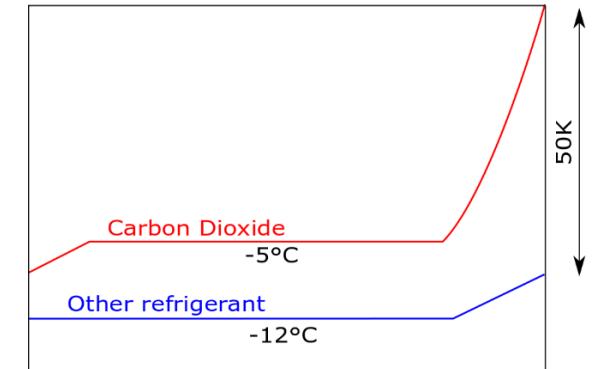
	Cascade HX
Source	MT evaporation
Capacity	<200 kW
Temp.	Evap (other refig.): -10°C Cond (CO <sub>2</sub> ): -5°C
Design P	≤90 bar
2 <sup>nd</sup> fluid	R134a, NH <sub>3</sub> , R448 or other



**Cascade** is a system less used than in the past

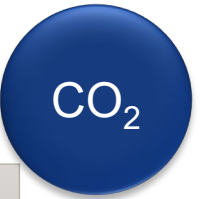
## Fatigue in cascade systems

Suggestion: keep  $\Delta T$  on both sides below **50K**



# Transcritical CO<sub>2</sub> comp rack

- BHEs



## External subcooler

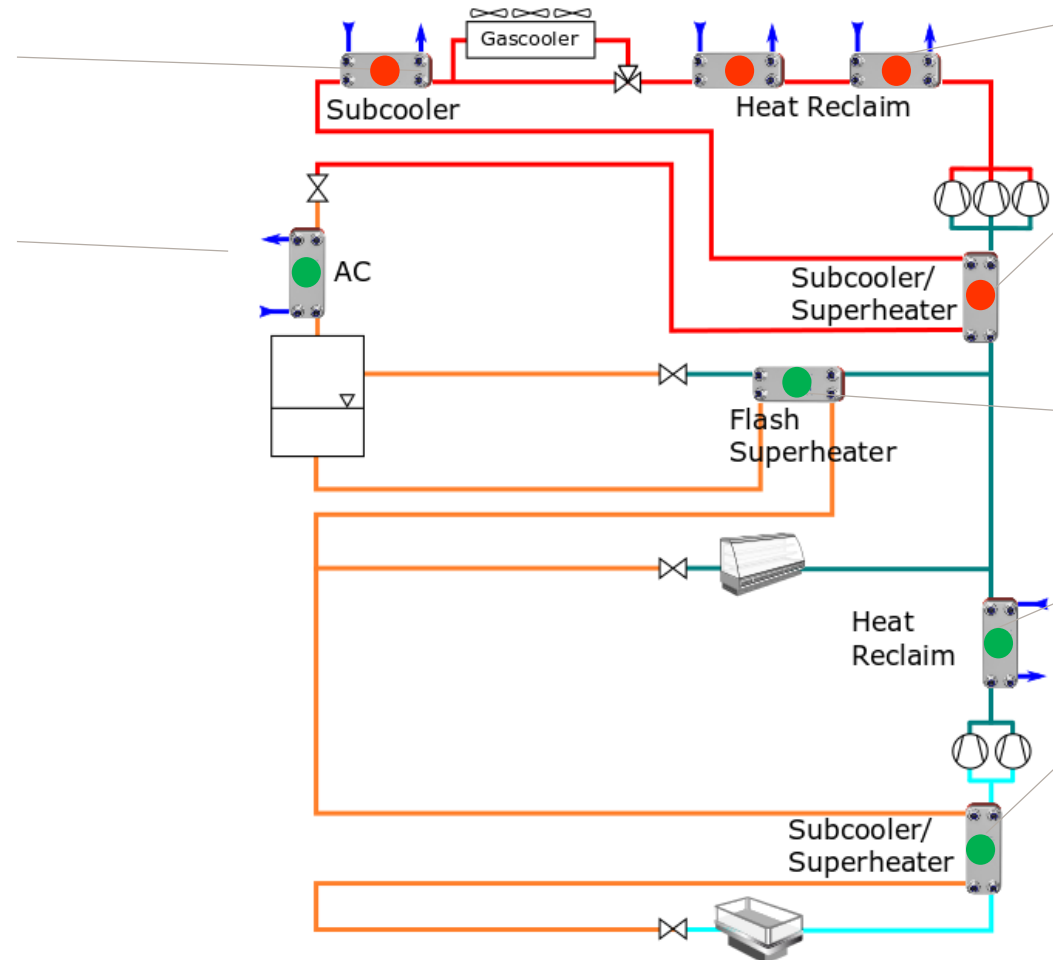
External ref unit  
Geothermal

## Air Conditioning

Requires parallel comps

● DP ≥ 120 bar

● DP ≤ 90 bar



## Heat Reclaim

Tap water (high ΔT)  
Space Heating (low ΔT)

## Internal Heat Exchanger (IHX)

Same flow on both sides  
Provides SH to MT comps

## Flash gas superheater

Different flowrates  
Superheats flash gas

## Heat Reclaim LT

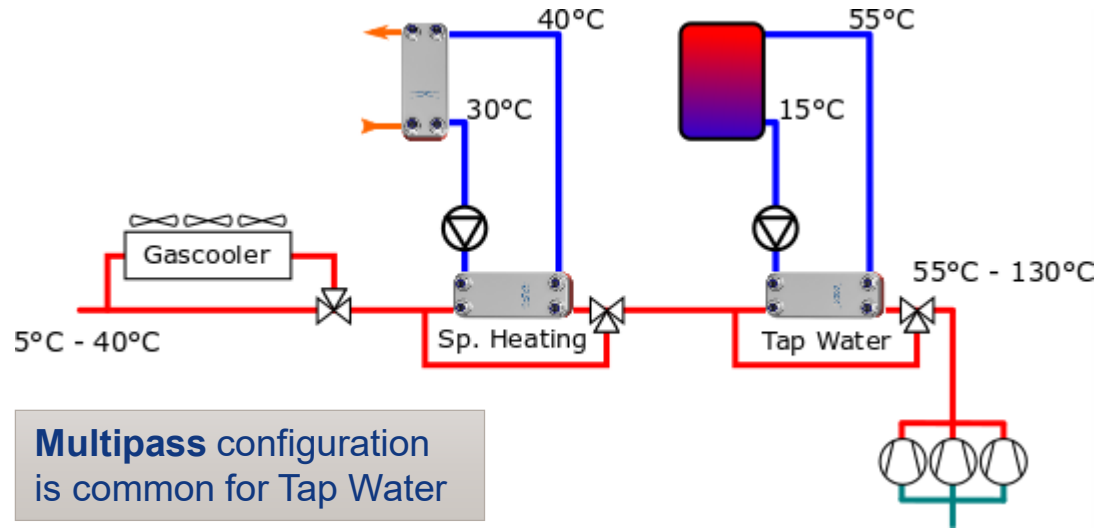
Small capacity

## IHX LT

Same flow on both sides  
Provides SH to LT comps

# Transcritical CO<sub>2</sub> comp rack

- Heat Reclaim



**Multipass** configuration is common for Tap Water

	Tap Water	Space Heating
Capacity	Lower	Full load (>500 kW)
Temp.	15-55°C (W)	30-40°C (W)
Load	All year	Winter
Design P	≥120 bar	≥120 bar
2 <sup>nd</sup> fluid	Water/Brine	Water/Brine

## Heat Reclaim or Heat Recovery

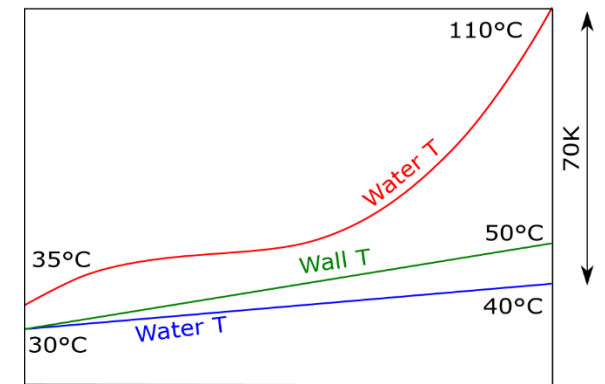
- The heat rejected by the rack, is not wasted in the air, but it is **recovered** to produce **Hot Tap Water** or to **heat the building**
- When they are not used, the BHE are **bypassed** and the pumps are stopped
- Gas cooler can be bypassed to recover all the heat from compressor



HR BHE are **the most common** in CO<sub>2</sub> racks

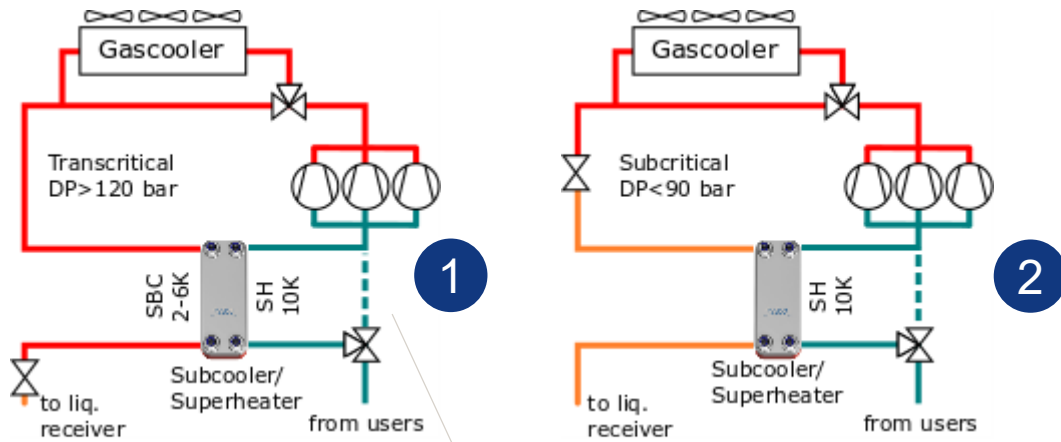
## Fatigue in HR BHEs

Suggestion: keep  $\Delta T$  on both sides below **70K**



# Transcritical CO<sub>2</sub> comp rack

- Internal HX: Superheater/Subcooler



## Superheater/Subcooler

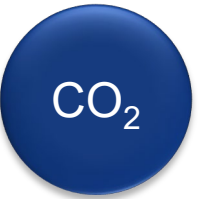
- Internal Heat Exchanger, provides **extra superheat** to the suction line, and extra **liquid** in the receiver
- Two different installations:
  - 1 Transcritical: Installation after Gas Cooler outlet. The single-phase transcritical gas is cooled down
  - 2 Subcritical: after HP Valve In subcritical conditions. The hot side is a condenser

 **ΔP can be critical on gas side. Possible solutions partial bypass**

	Superheater/Subcooler	
Source	Subcritical CO <sub>2</sub>	Transcritical CO <sub>2</sub>
Capacity	<100 kW	-100 kW
Temp.	HP: 15÷40°C – 10÷35°C LP: 0°C – 10°C	HP: 15÷40°C – 10÷35°C LP: 0°C – 10°C
DeltaT	SH = 10 K	SBC = 2÷6K SH = 10 K
Design P	≤90 bar	≥120 bar
2 <sup>nd</sup> fluid	CO <sub>2</sub>	CO <sub>2</sub>

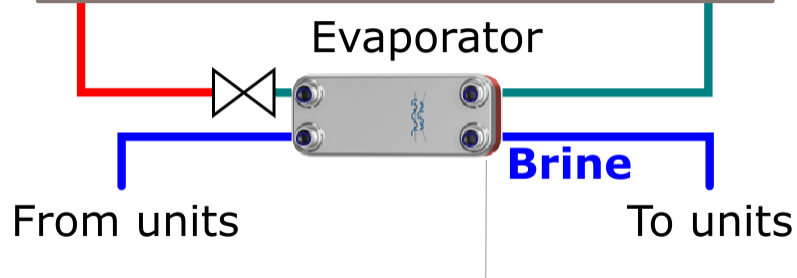
# CO<sub>2</sub> Evaporators


- Brine Chiller



- Usually large capacity (1000+ kW)
- Large GPHE or BHEs in parallel
- Different applications, with different temperature levels:
  - Air Conditioning
  - Process cooling
  - Commercial ref
- In most of the duties a distributor is required

Different type of refrigeration unit can be installed  
DX CO<sub>2</sub>, flooded system, ejectors



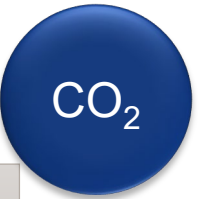
- CO<sub>2</sub> @ ambient T → high PS (i.e. ≥60 bar)
  - Design pressure (PS) NOT connected to operating conditions
  - PS depends on designer choice
  - ACK or ACP range can be suitable, distributor system must be optimized
- 

	CO <sub>2</sub> evaporator
Capacity	1000+ kW (units in parallel)
Temp.	Brine: from 7°C to -30°C temperature level
DeltaT	5K
Design P	≤90 bar
2 <sup>nd</sup> fluid	Water/Brine

# Product Portfolio

# Transcritical CO<sub>2</sub> comp rack

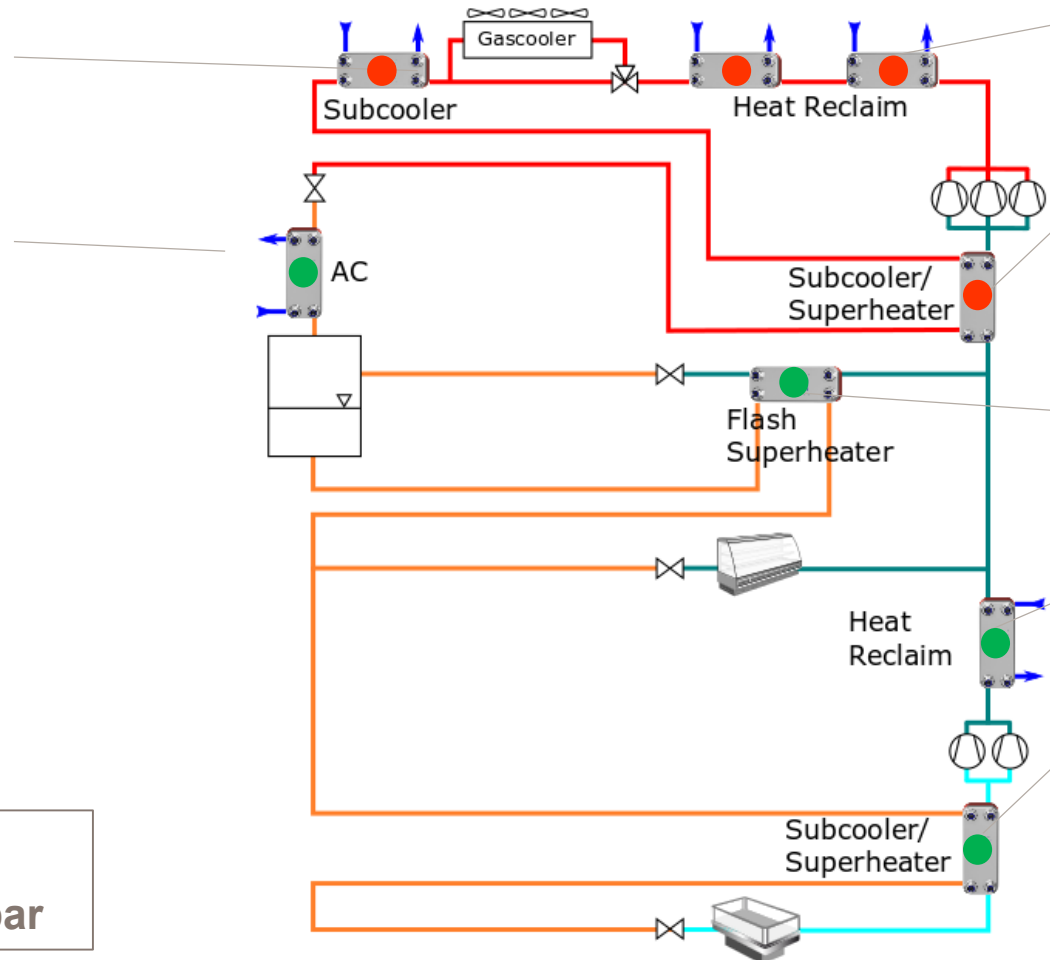
- BHEs



**External subcooler**  
External ref unit

**Air Conditioning**  
Requires parallel comps

● DP ≥ 120 bar  
● DP ≤ 90 bar or DP ≤ 60 bar



**Heat Reclaim**  
Tap water (high ΔT)  
Space Heating (low ΔT)

**Internal Heat Exchanger (IHX)**  
Same flow on both sides  
Provides SH to MT comps

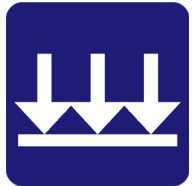
**Flash gas superheater**  
Different flowrates  
Superheats flash gas

**Heat Reclaim LT**  
Small capacity

**IHX LT**  
Same flow on both sides  
Provides SH to LT comps

# High pressure CO<sub>2</sub> Portfolio

- AXP & CBXP range



AXP PS ≥ 120 bar



CO<sub>2</sub> ready

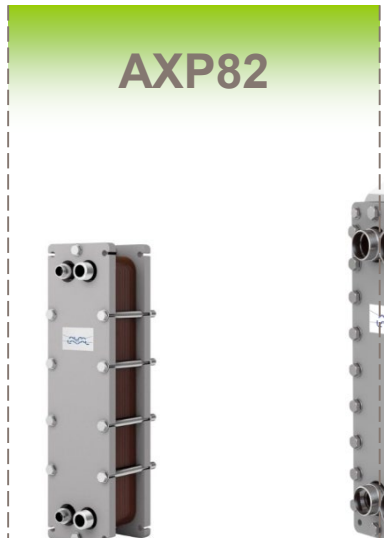
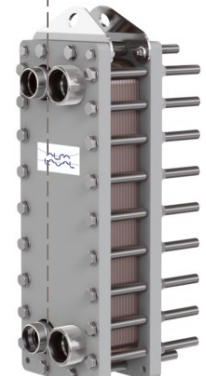


Optimized performance



ValuePlus

Challenges  
High pressures  
Transcritical operation



AXP10	AXP14	CBXP27	CBXP52	CBXP112	AXP27	AXP52	AXP112
15 kW (4 ton)	35kW (10ton)	70 kW (20 ton)	100 kW (28 ton)	250 kW (70 ton)	100 kW (28 ton)	150 kW (40 ton)	300 kW (85 ton)
76x190 mm	76x190 mm	111x310 mm	111x526 mm	191x616 mm	160x362 mm	160x582 mm	252x685mm
PS: 154 bar 2200 psi	PS: 140 bar 2030 psi	PS: 90 bar 1300 psi	PS: 90 bar 1300 psi	PS: 85 bar 1230 psi	PS: 130 bar 1880 psi	PS: 130 bar 1880 psi	PS: 140 bar 2030 psi

Ready for Natural Refrigerant: CO<sub>2</sub>

# New product 2020: AXP82 overview

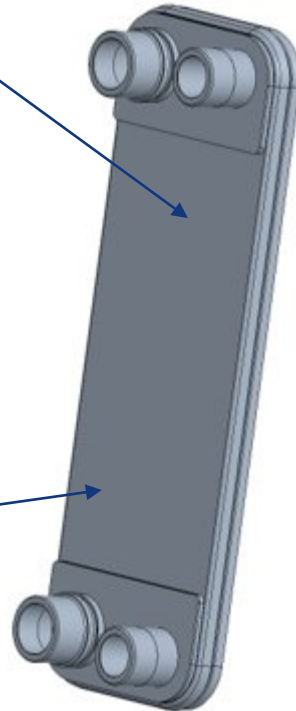


Front Area: **160 x 490 mm**  
(AXP 52 111 x 526 mm)

**PS 130 bar (S3S4)**  
**PS 90 bar (S1S2)**  
Transcritical operation



**No external frames**



## High pressure design

Reinforced **port design**



Reduced **pressing depth**

Optimal **plate thickness**

**Enlarged water ports** to reduce pressure drops

# Supply Map



CBXP27  
CBXP52  
CBXP112

AXP27  
AXP52  
AXP112

AXP82

AXP10  
AXP14

- BHE Factory
- BHE / FHE Regional Inventory
- FHE Factory

# Availability



A. Unique designs, not stocked

B. Lead Time units 10-15 Days depending on order size

C. Customer Unique Stock (per agreement with BU & Operations)



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