A REVIEW OF IMPROVEMENTS ON CO2 REFRIGERATION TECHNOLOGY AND APPLICATION

二氧化碳制冷技术提升及应用

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Commercial Refrigeration

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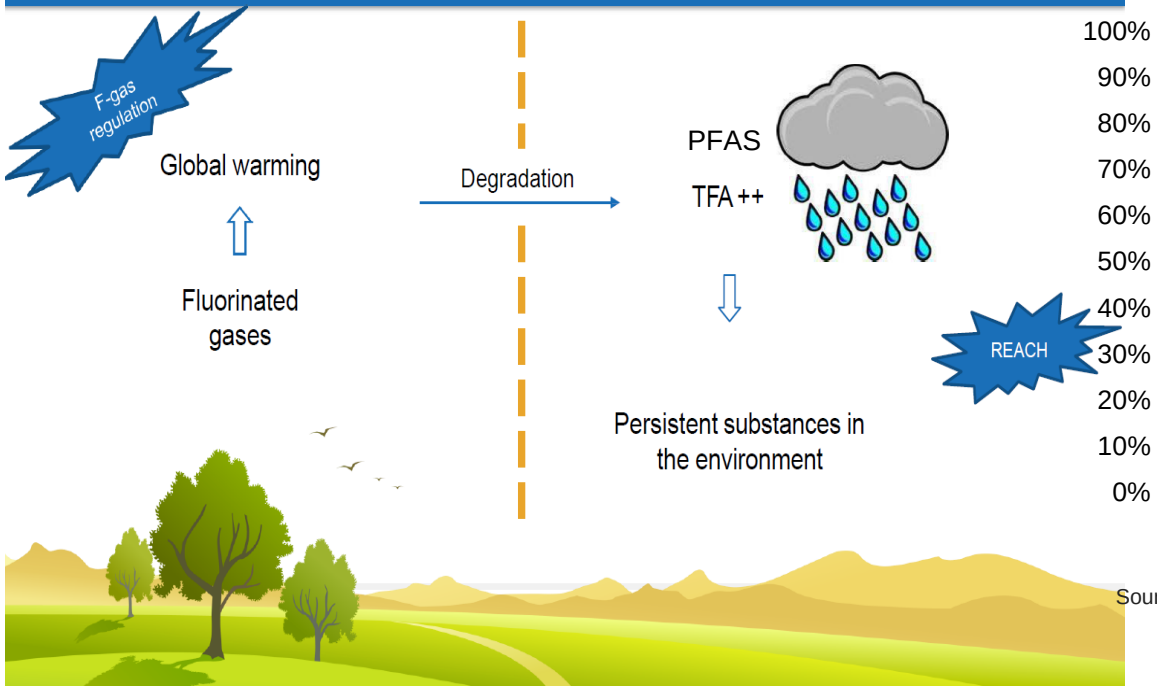
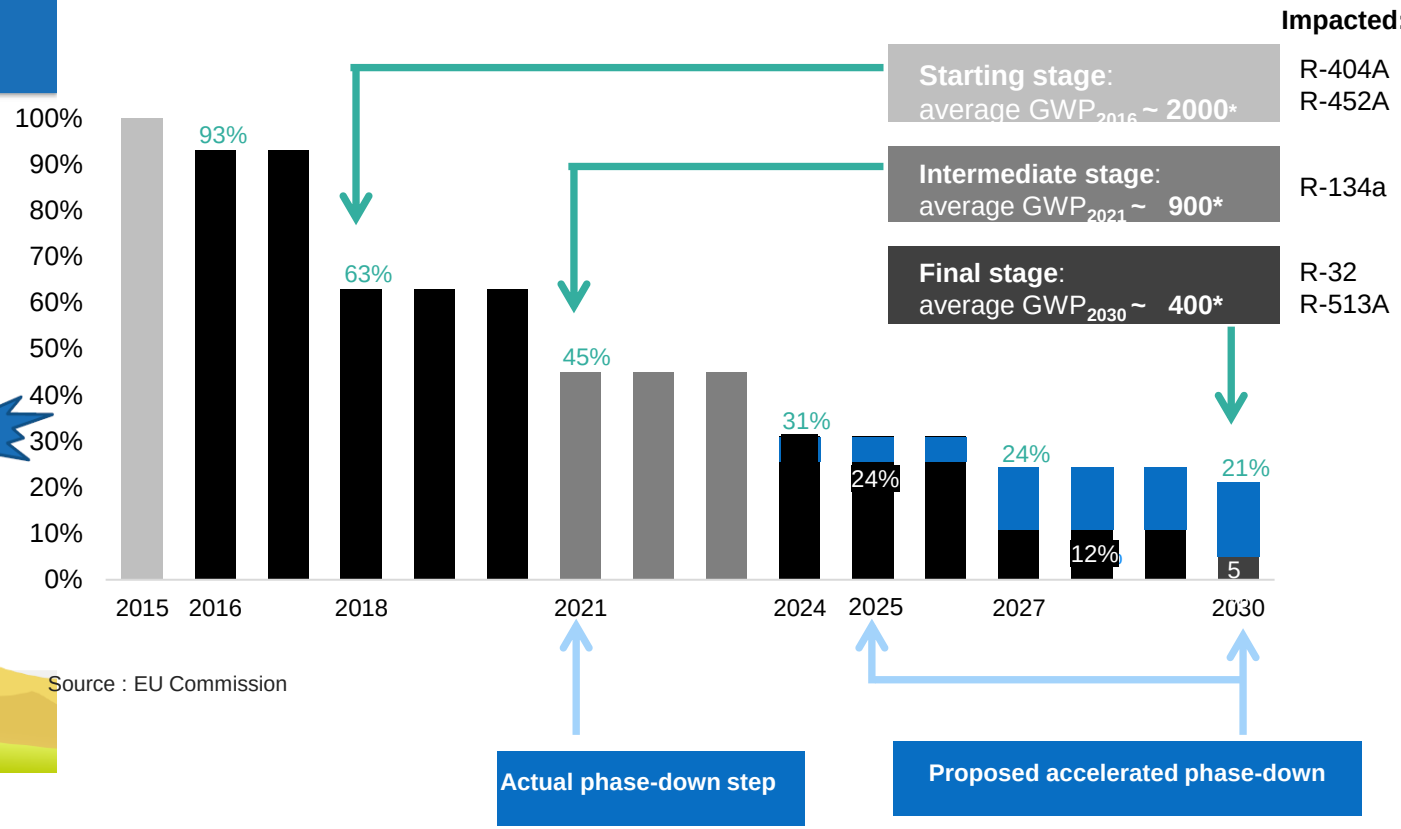
F-Gas Updates

F-Gas Revision –
REACH PFAS Restriction

Accelerated Phase-Down Scheme
in Annex VII

Fluorinated gases – atmospheric degradation and concerns





Source : EU Commission

F-GAS – Cooling Systems Impact

Bans in Annex IV : stationary Refrigeration

Ban 5 : no more products with GWP>2500 except for application <-50°C.
the one already with more restrictions remain unchanged

January 1, 2025

Ban 5 : no more products with GWP>150 except chillers

January 1, 2030

When safety requirements at the site of installation would not allow using alternatives to F-gases with a GWP of 150 or less, the GWP limit is 750

What does it mean for us ?

F-Gas – GWP Target <150 except safety issues

Safety Class

			AR4	AR5	AR6
	R410A	A1	2088	[illegible]	2255
	R407C	A1	1773	1624	1908
	R134a	A1	1430	1300	1530
<750	R32	A2L	675	677	771
<750	R513A	A1	[illegible]	573	673
<750	R454B	A2L	466	466	531
<750	R515B	A1	293	299	322
<150	R454C	A2L	145	145	166
<150	R1233zd	A1	4,5	1	3,88
<150	R1234ze	A2L	7	1	1,37
<150	R-290	A3	3	3	3
<150	NH3	B2L	0	0	0
<150	CO2	A1	1	1	1

REACH PFAS

Single Component Refrigerants Non-Concerned

Refrigerant	Formula
R-32	CH2F2
R-152	CH2FCH2F
R-152a	CH3CHF2
R-1132(E)	CHF=CHF
R-1270 (propene)	C3H6
R-290 (propane)	C3H8
R-744	CO2
R-717 (ammonia)	NH3
R-728 (nitrogen)	N2

Single Component Refrigerants Possibly Ban

Refrigerant	Formula
R-134a	CH2FCF3
R-1234yf	CF3CF=CH2
R-1234ze(E)	CF3CH=CFH
R-1233zd(E)	CF3CH=CHCl

Blended Refrigerants Possibly Ban

Refrigerant	Components	Formula
R-410A	R-32	CH2F2
	R-125	CHF2-CF3
R-404A	R-125	CHF2-CF3
	R-143a	CH3CF3
	R-134a	CH2FCF3
R452A	R-32	CH2F2
	R-125	CHF2-CF3
	R-1234yf	CF3CF=CH2
R-454A/B/C	R-32	CH2F2
	R-1234yf	CF3CF=CH2
R-513A	R-1234yf	CF3CF=CH2
	R-134a	CH2FCF3
R-515B	R-1234ze(E)	CF3CH=CFH
	R-227ea	CF3CHFCF3

Most Likely Scenario : consensus as F-Gas + PFAS may result in only Natural Refrigerants use

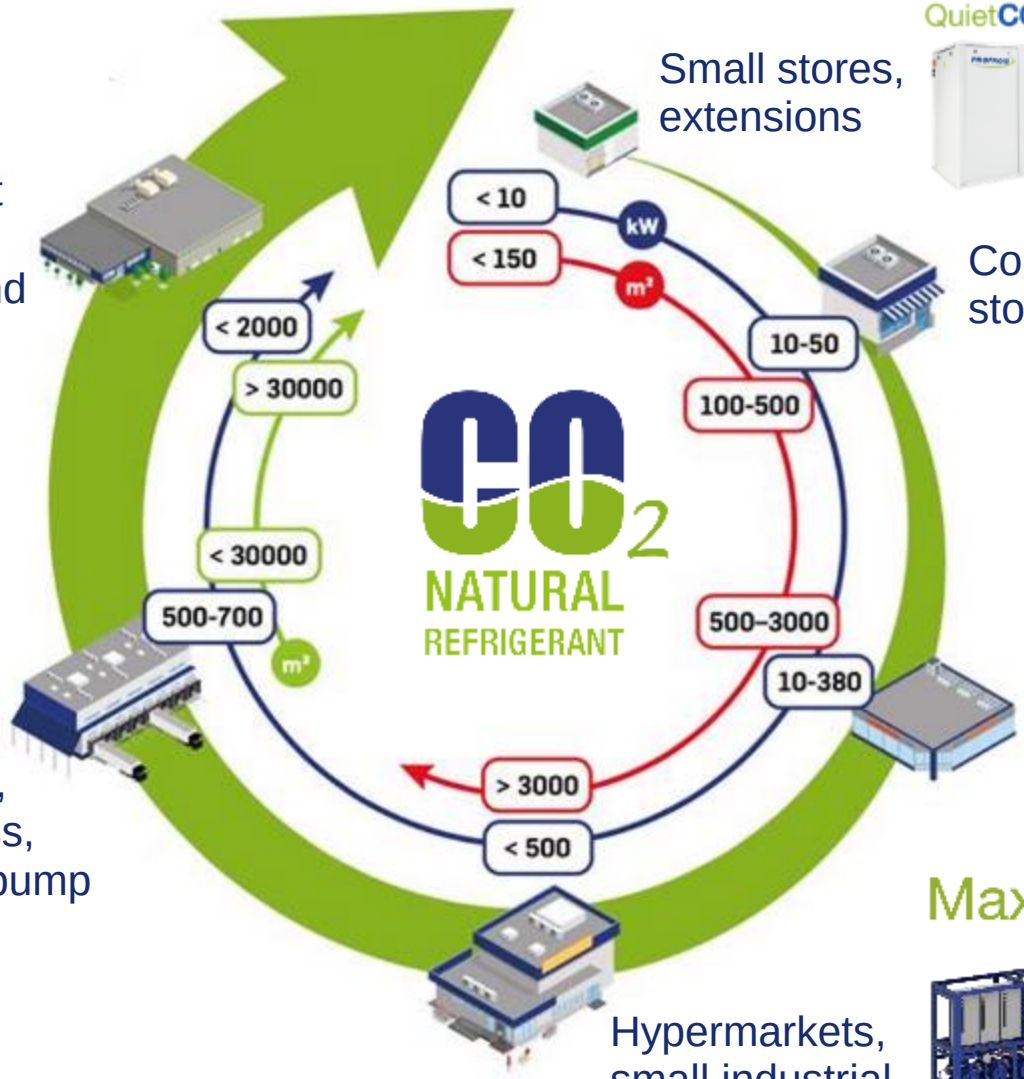
CO_2 - Product Portfolio

More than 20 000 CO_2 units produced

Sustainable. Efficient.

PowerCOOL

Industrial heat pump, large warehouse and process



QuietCOOL

Small stores, extensions

Convenience stores

QuietCOOL Multi-Compressor

MiniCOOL

Supermarkets

PowerCOOL S

Warehouse, food process, small heat pump

MaxiCOOL

Hypermarkets, small industrial

A complete solution form convenience store to industrial application

CO_2 - Product Emission Reduction

Type of unit	Carbon dioxide emission reduction over 15 years*	CO2 emission reduction equivalence in cars**
SMALL UNIT 	91 – 96 tons	x 4
MEDIUM UNIT 	614 – 685 tons	x 30
LARGE UNIT 	3,090 – 3,263 tons	x 140
LARGE UNIT - SEMI-INDUSTRIAL 	4,659 – 5,719 tons	x 230
HIGH-CAPACITY UNIT - INDUSTRIAL 	14,088 – 18,564 tons	x 720

**The simulation model is based on TEWI index (Total Equivalent Warming Impact), which is assessing the global warming impact by combining refrigerant loss during lifetime, refrigerant end of life loss (recovery losses during dismantling), savings due to heat recovery and heat pump function, as well as the impact of power consumption reduction of the equipment. All the figures are indicative and based on estimations.*

***Estimation based on car emissions of 1515 kg CO2 / year (medium size car) multiplied by 15 years, with a distance traveled of 15,000 km / year. Data from 2022. Source: Statista Mobility Market Outlook.*

Carrier

CO_2 – As Refrigerant

Natural refrigerant

- contained with a ratio of 0.04% in air
- additive in mineral water or beer
- chemically stable and non-toxic or explosive

Safe refrigerant

- non-flammable
- classified as A1

Energy efficient refrigerant

- very good heat transfer properties
- less sensitive to pressure loss
- high volumetric cooling capacity

Sustainable refrigerant

- non-fluorinated
- ultra-low GWP
- no PFAS/TFA

Refrigerant Type		R-12	R-22	R-134	R-404A	R-410A	R-717	R-744
ENVIRONMENT	ODP	1	0.05	0	0	0	0	0
	GWP	8,500	1,700	1,300	3,760	1,900	0	1
SAFETY	Flammability/Toxicity	N/N	N/N	N/N	N/N	N/N	Y/Y	N/N
THERMO-DYNAMIC	Molecular Mass (kg/kmol)	121	87	102	98	73	17	44
	Critical Pressure (bar)	41	50	41	37	48	114	74
	Pressure at Room Temp (20C) (bar)	5.7	9.1	5.7	10.8	14.5	8.6	57.3
	Critical Temperature (dC)	112	96	101	72	70	133	31
	Normal Boiling Point (dC)*	-30	-41	-26	-48	-53	-33	-78
	Refrigeration Capacity (kJ/m3) **	2,734	4,356	2,868	5,074	6,763	4,382	22,545
HISTORICAL	First Commercial Use as a refrigerant	1931	1936	1990	1990s	1998	1859	1869

CO_2 is the best candidate for a sustainable solution

Carrier

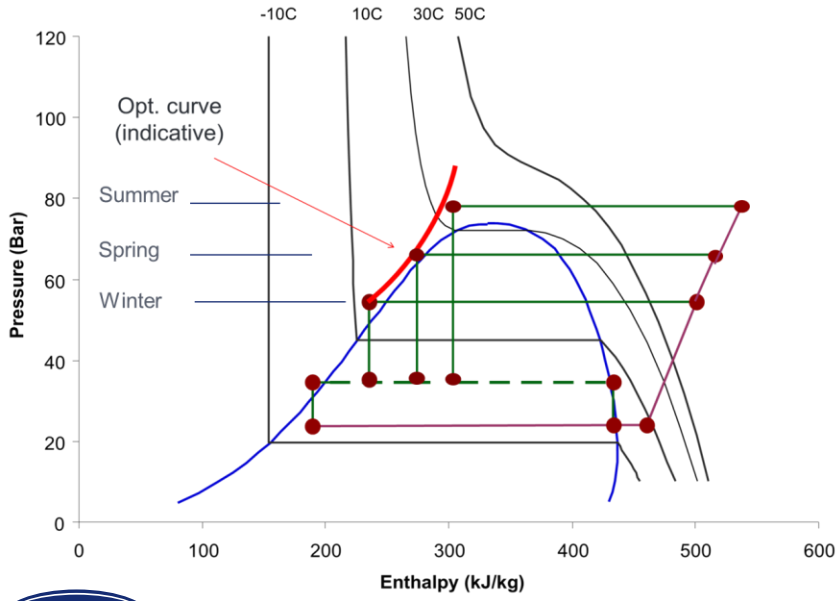
CO_2 Refrigeration Technology Enhancement

Higher ambinet temperature

Increased ambient conditions =
Increase significantly flash gas

Solutions :

- Parallel Compression, DVI compression
- Reduce of flash vapor (subcooler, IHX,adiabatic)

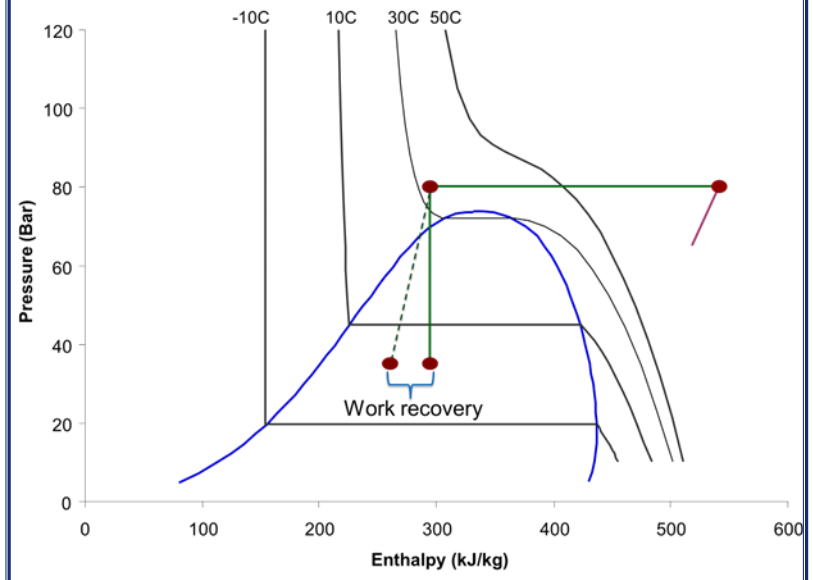


High absolute pressure difference

High Throttled lost =potential energy recovery on high pressure side

Solutions :Work recovery by

- Expander
- Ejector
- Pressure eXchanger

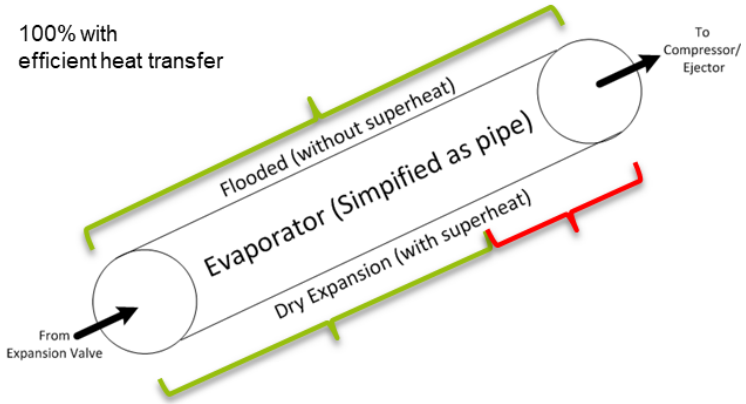


Reduce superheat on evaporator

Heat transfer during evaporation = High
Heat transfer during superheating = Low

Solutions :

- Flooded evaporator

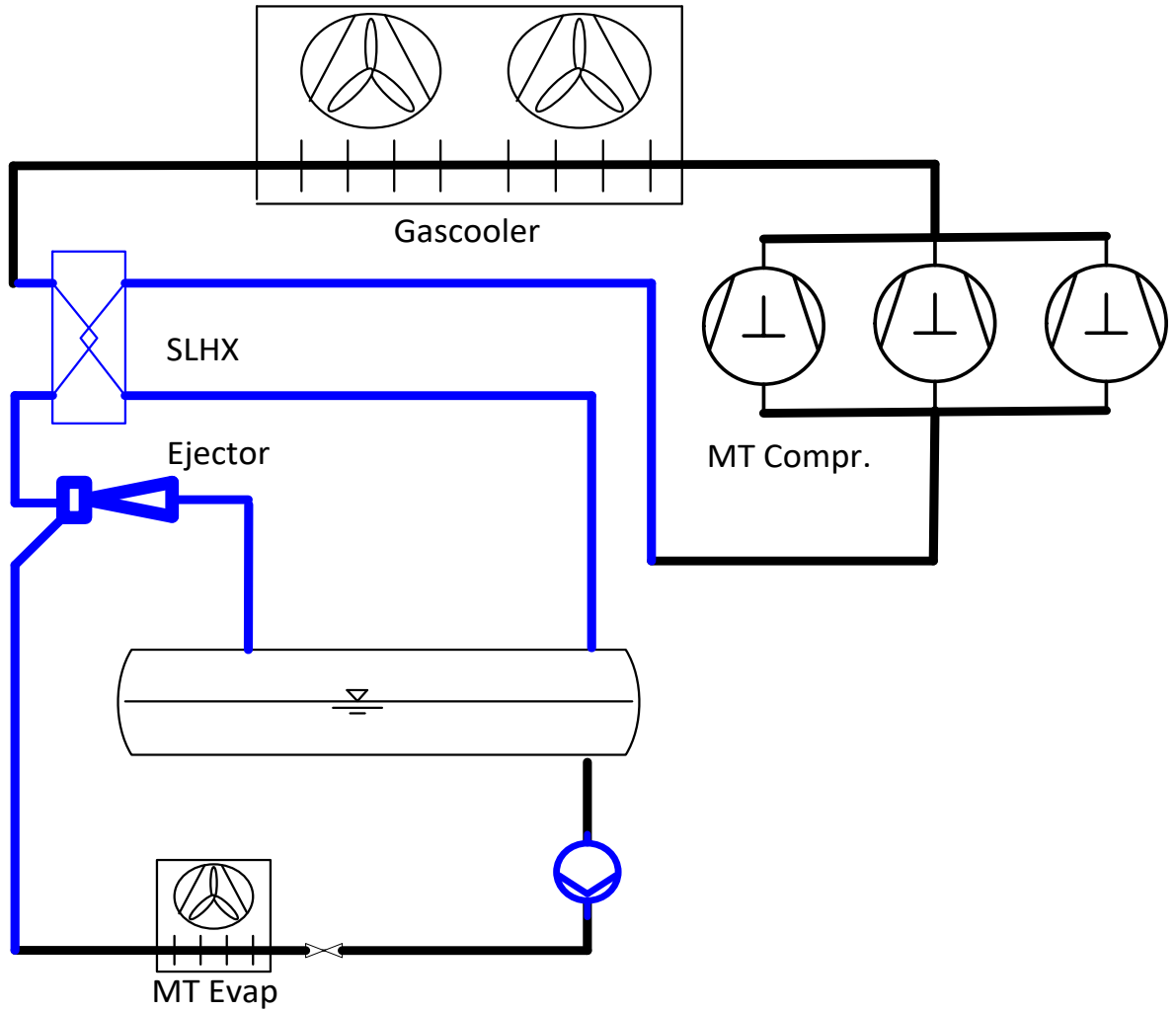


CO_2 Refrigeration Full Enhanced Cycle

Combines all enhancements

- Efficient flashgas use
- Work recovery
- Flooded operation

"all climate" Ejector system



CO_2 Footprint

Distribution Center

Supermarket

Large Cold Room

E-commerce Logistic Center

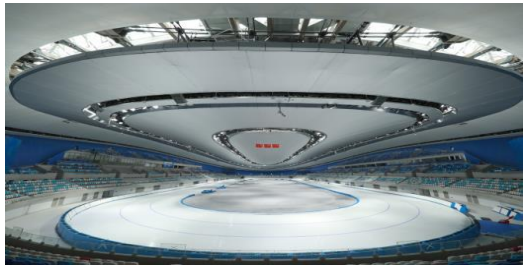
Food Process

Table Margarine Process

Dairy process

Slaughtering & process

Other application scenarios



Ice Rink

Infrastructure

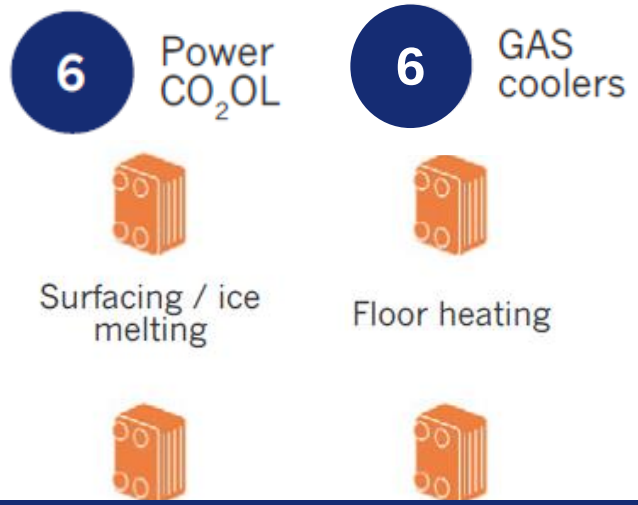
Pharmacy

Case Study1: National Speed Skating Oval

Beijing, China
Installed in Q3 2020

12.000 m² ice surface
(400m Oval + training Oval + 2 ice hockey rinks)

Equipment

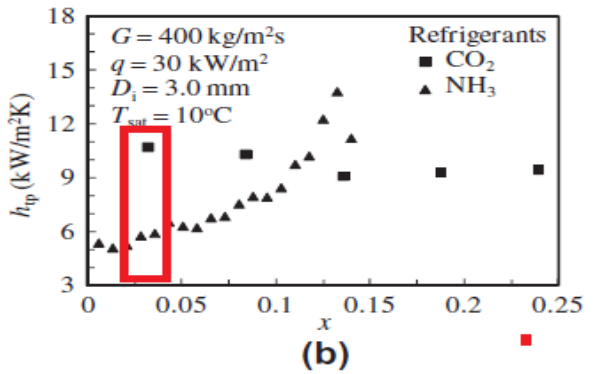


Direct-expansion ice making technology

Ice temperature control variances within **0.5** degrees , from hard ice for speed skating to smooth for dancing, at the same time.

Optimum ice quality – reuse of the heat

Case Study2: XX In Food Process Industry



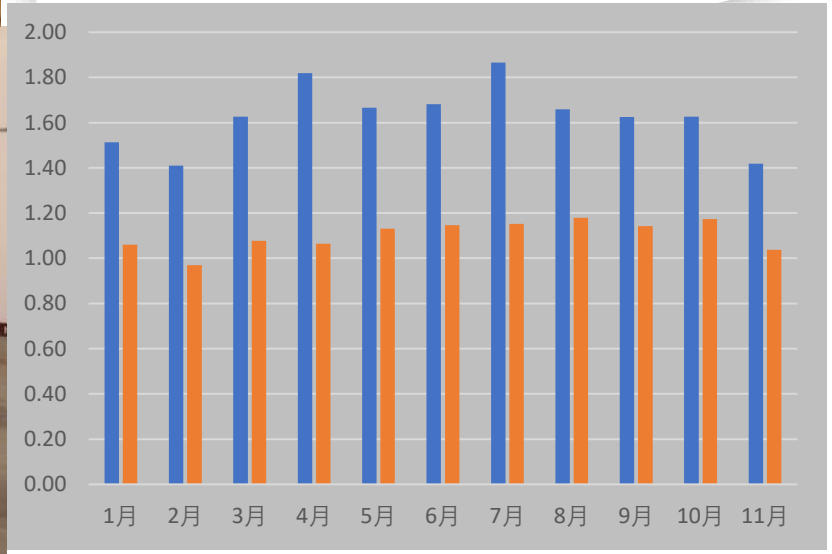
ig. 6. Comparison of heat transfer coefficients of C_3H_8, NH_3, and CO_2.

350
Kw HR

260
kW MT

Flooded
MT

Heat
reclaim



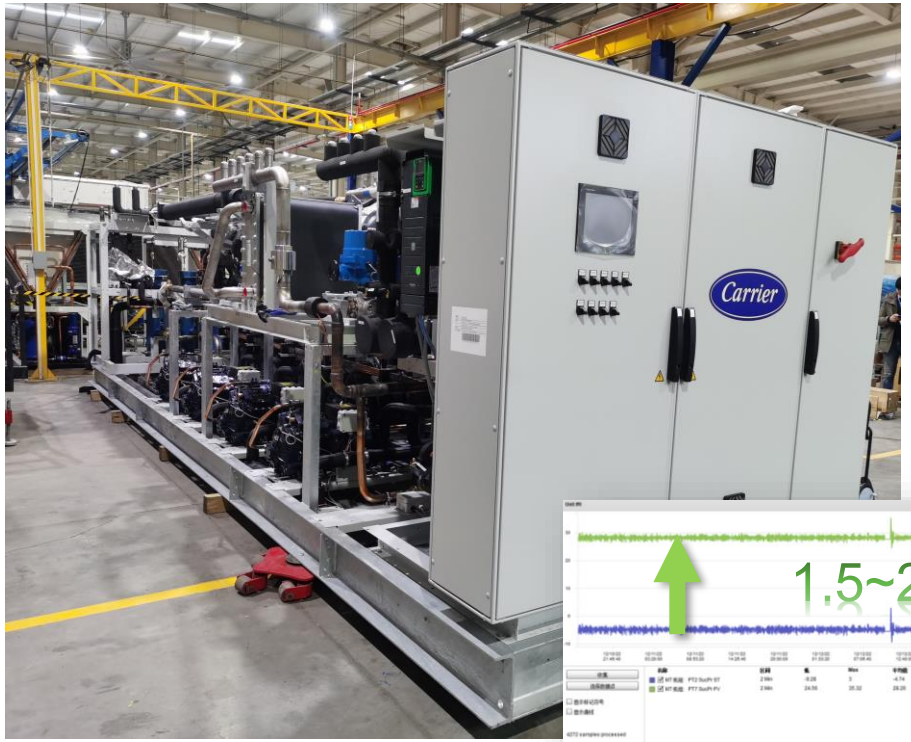
Energy Consumption Saving VS. NH_3 By Measured Data

Case Study3: Walmart Sam's Club, Beijing/Shanghai/Fuzhou

1028
Kw HR

441
kW MT

280
kW LT



Modulating Ejector

CO_2 pump (MT semi-flood

semi flood LT

Adiabatic gas cooler

Shanghai Store-biggest one in Asia, BIC CO_2 technology

What is Next

Key drivers for new generation of CO_2 refrigeration

- Smart grid (power consumption management, green energy,…)
- Thermal storage(ice bank, heat storage)
- Fuel battery used in refrigeration system
- Digital twin(performance optimization, diagnostics, intelligent system)
- LFR3 (CO2 based blend)
- ……

Koura LFR3
Development Refrigerant

Koura has over 50 years of experience delivering trusted solutions, with innovation, sustainability and customer focus driving our approach.

Our latest innovation, LFR 3 is designed to achieve a lower environmental impact and better performance than CO_2 across a range of ambient temperatures – it will be suitable for a range of cooling applications across the industry.

Applications
- Vehicle and passenger transportation air-conditioning
- Heat pump systems
- Cold chain refrigeration and transport refrigeration
- Commercial refrigeration applications

Expected Performance
- More energy efficient than CO_2
- Excellent performance in residential heat pump and mobile air-conditioning systems
- Energy efficiency up to 20% higher than CO_2
- Operating pressure 15 - 20% lower than CO_2

Expected Benefits
- Designed to have lower environmental impact than CO_2
- Non-flammable as formulated
- Lower operating pressure than CO_2
- Low GWP (140 AR5)

Carrier

THANK YOU