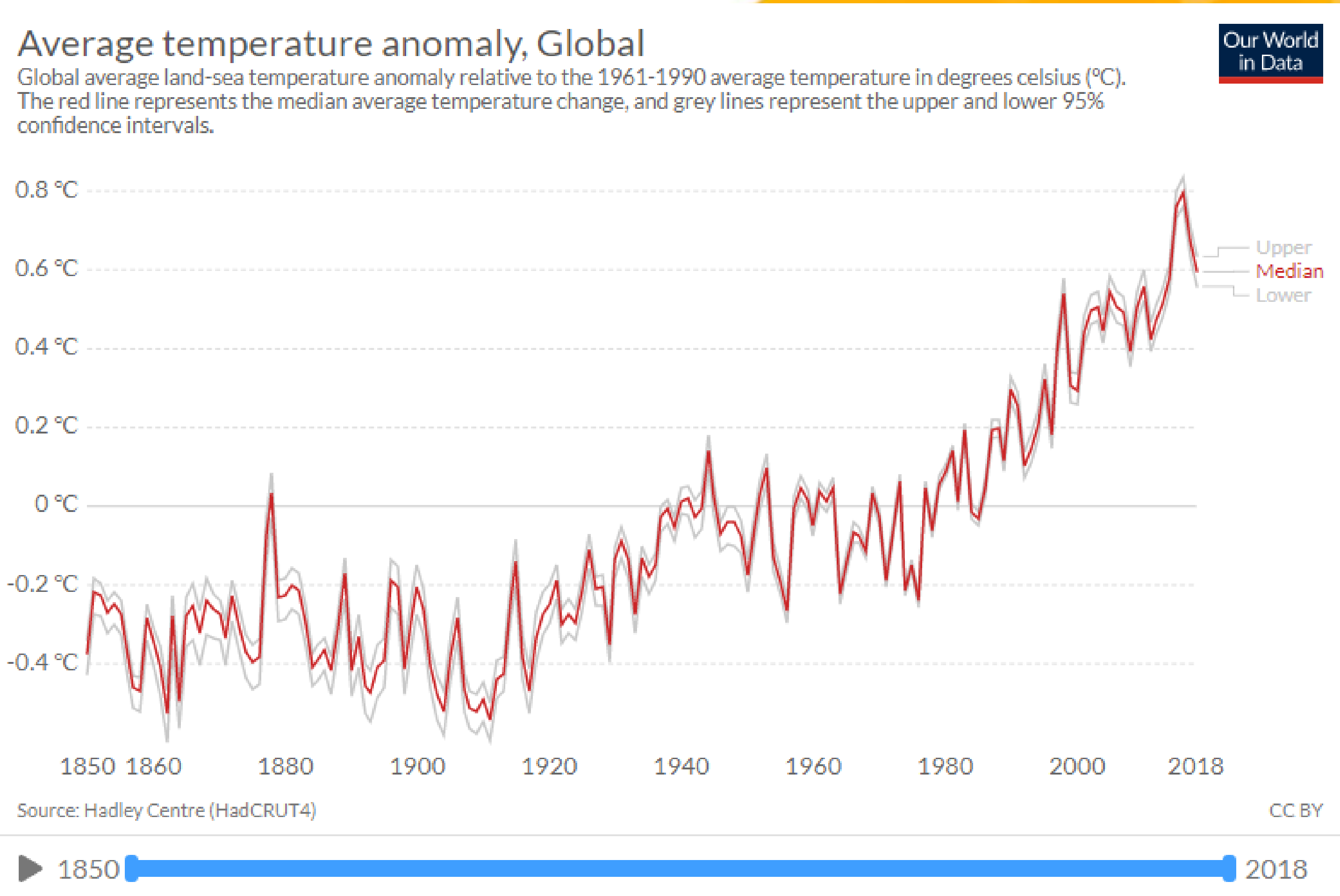
UNIDO - ÇŞİDB

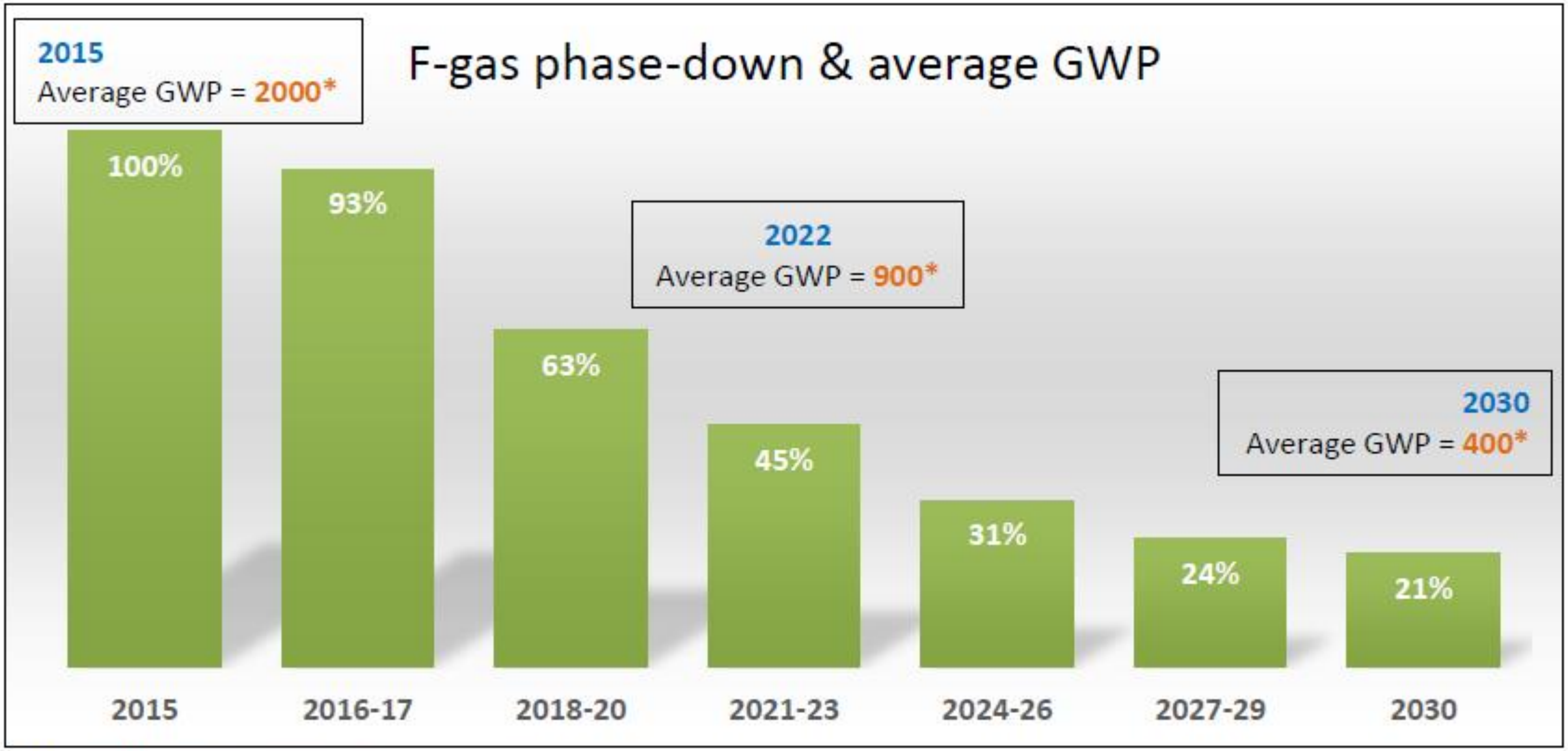
Türkiye'de Soğuk Zincir Lojistiği ve Soğuk Zincirde İklim Dostu Teknolojiler/Alternatifler

Dr. Hüseyin ONBAŞIOĞLU
İSKİD

Global Warming Potential



Global Warming Potential



* Source: European Commission

Global Warming Potential

Chances to leapfrog to Green Cooling Technologies

CFCs...

... are ozone depleting and contribute to global warming

... deplete natural resources

... are phased out by the Montreal Protocol

HCFCs...

... were introduced as transitional substitutes for CFCs

... deplete natural resources

... are less ozone depleting but contribute to global warming

... are phased out by the Montreal Protocol

High-GWP-HFCs...

... were introduced as transitional substitutes for CFCs and HCFCs

... deplete natural resources

... contribute to global warming

... are controlled by climate regime and may be phased down by the Montreal Protocol

Low-GWP-HFCs...

... were developed as „climate-friendly“ alternatives

... deplete natural resources

... produce dangerous hydrogen fluoride when they burn and transform to trifluoro-acetic acid in the atmosphere

...are patented and manufactured by chemical industry and costly

Green Cooling

Natural refrigerants... + Energy efficiency

... are naturally occuring substances that can be used as refrigerants in almost all RAC applications

... are typically more energy efficient than F-gases

... do not harm the environment

... can be handled safely with due care

... are not patented by chemical industry and less costly than HFCs

SOURCE: Green Cooling Technologies Market trends in selected refrigeration and air conditioning subsectors .
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Global Warming Potential

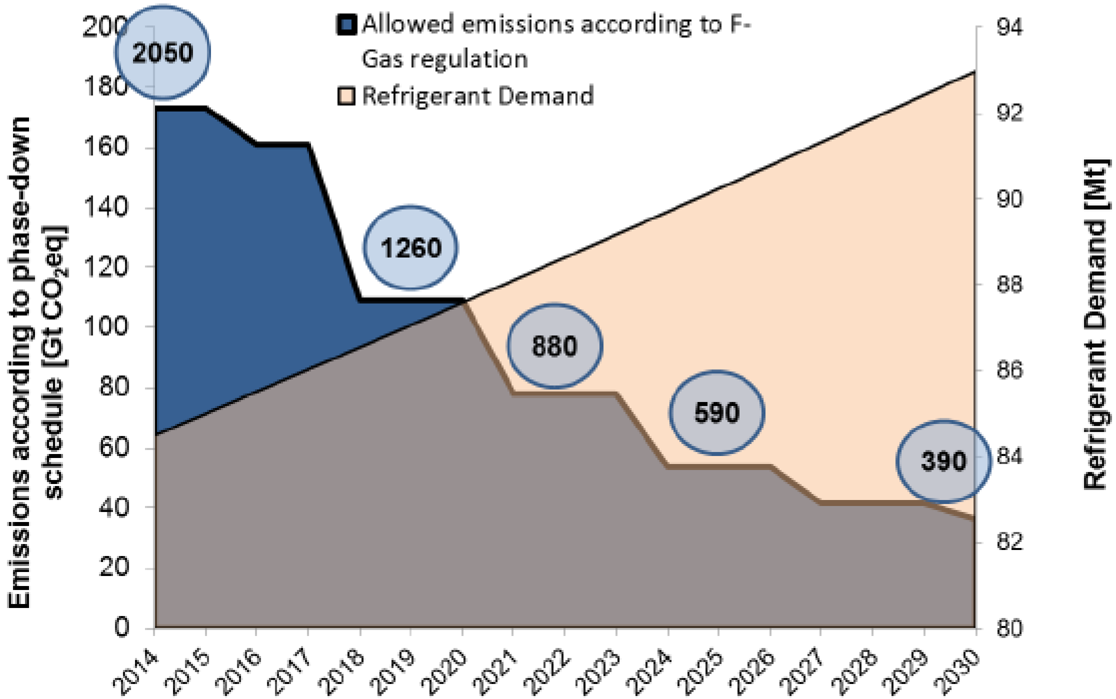


Figure 8: Comparison of allowed emissions according to phase-down in the F-Gas regulation and the expected refrigerant demand (Clodic et al., 2010). Blue circles indicate the average GWP that matches both the demand and the phase-down.

SOURCE: Green Cooling Technologies Market trends in selected refrigeration and air conditioning subsectors .
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

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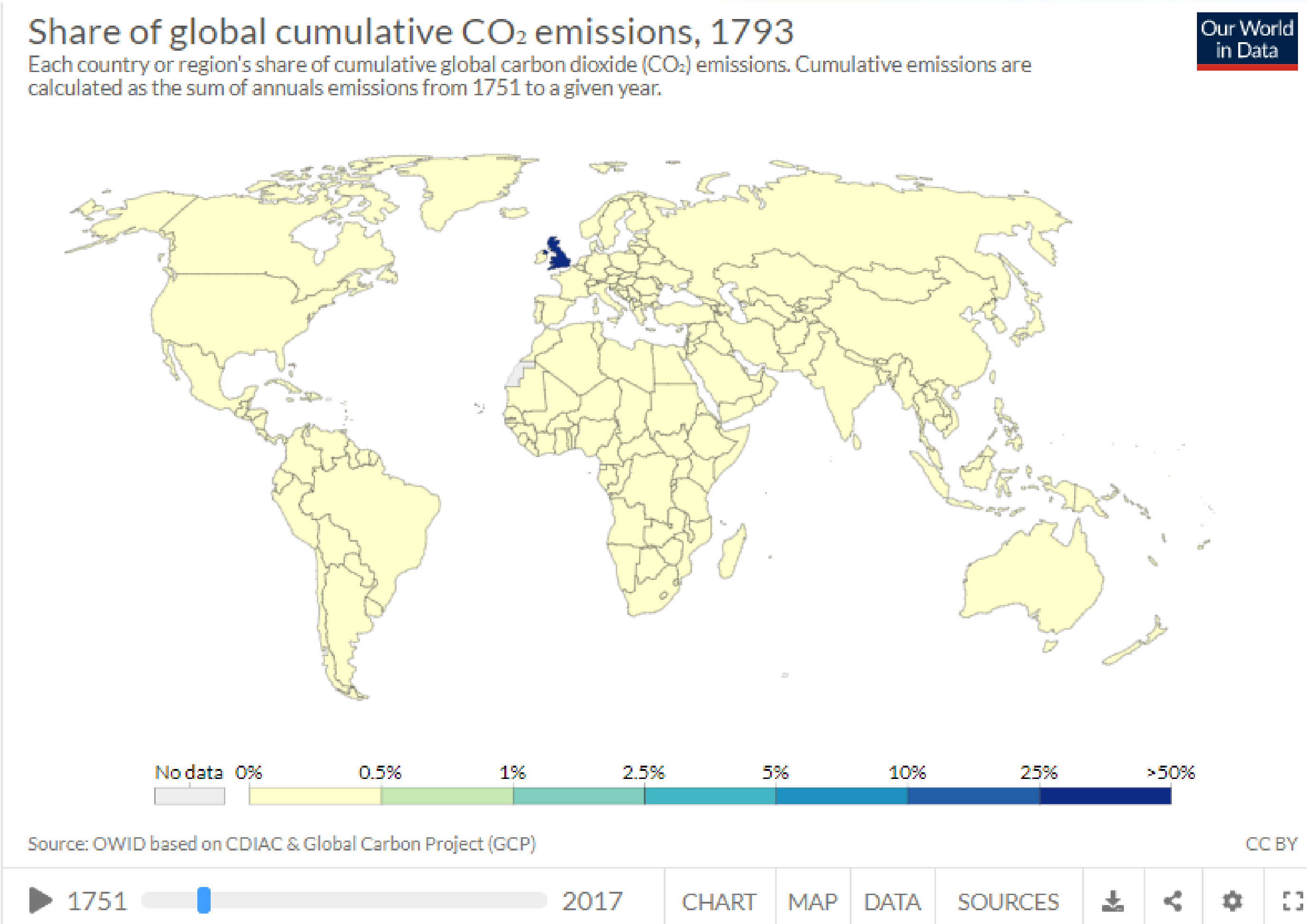
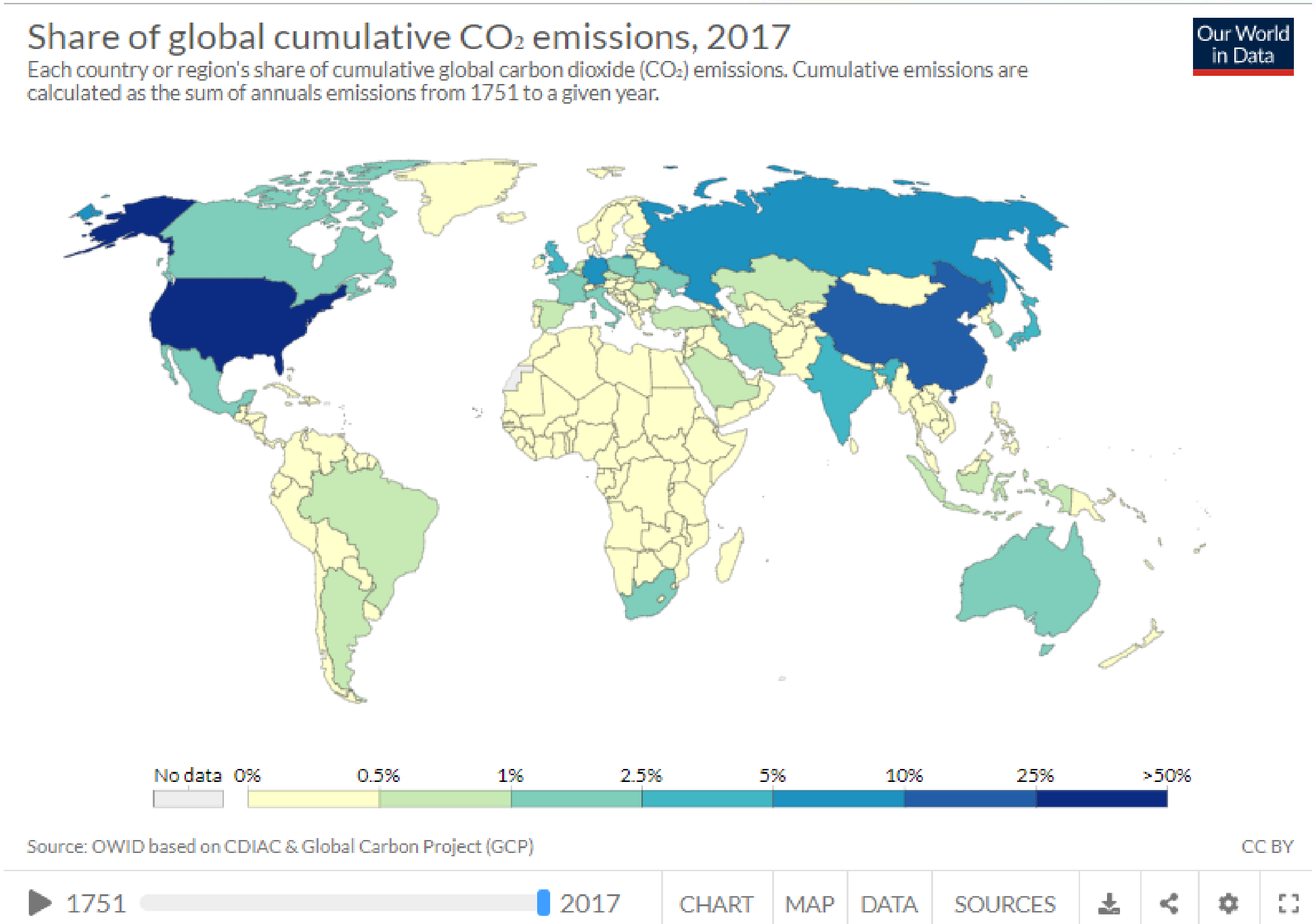
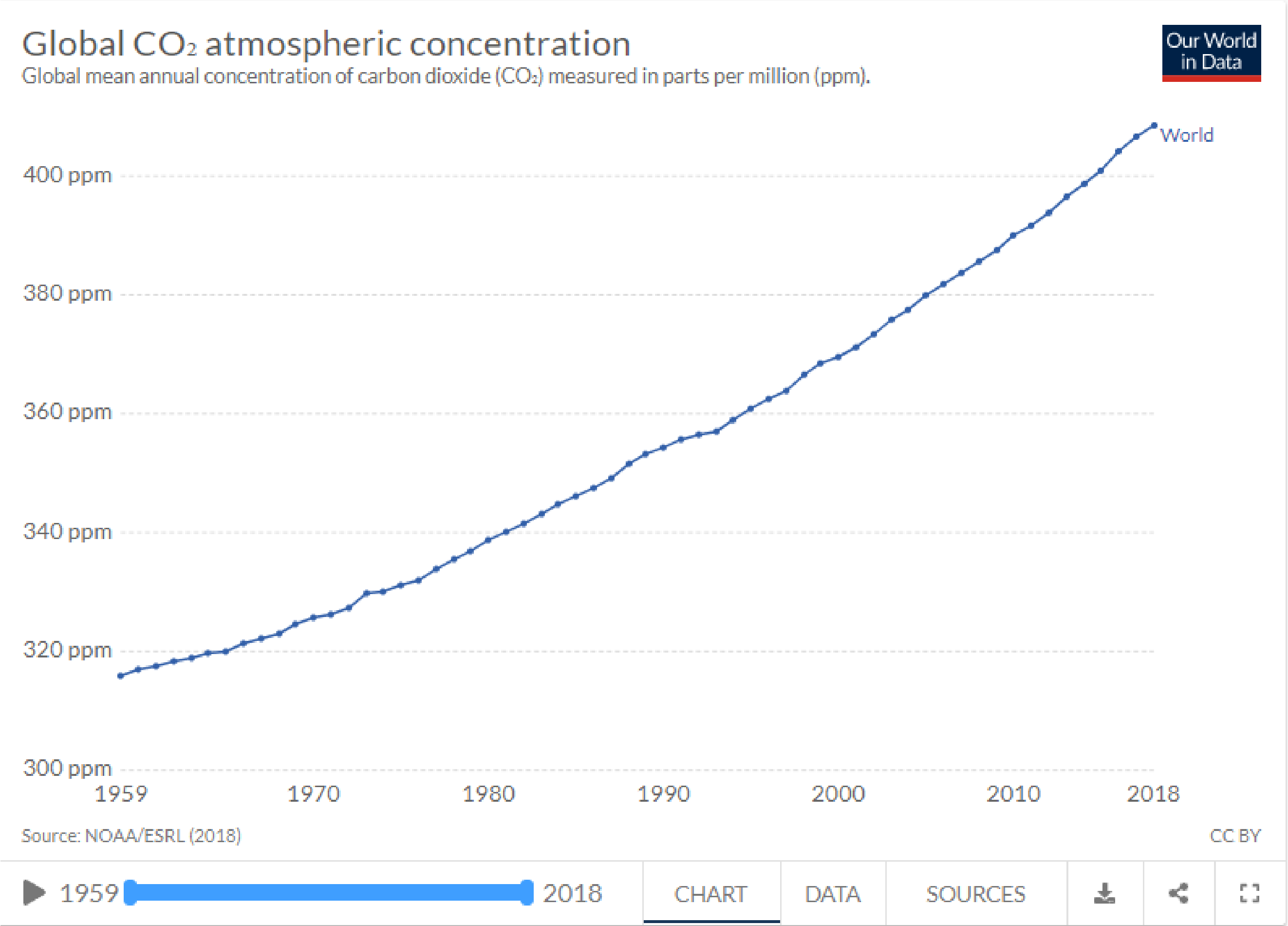
Global Warming Potential



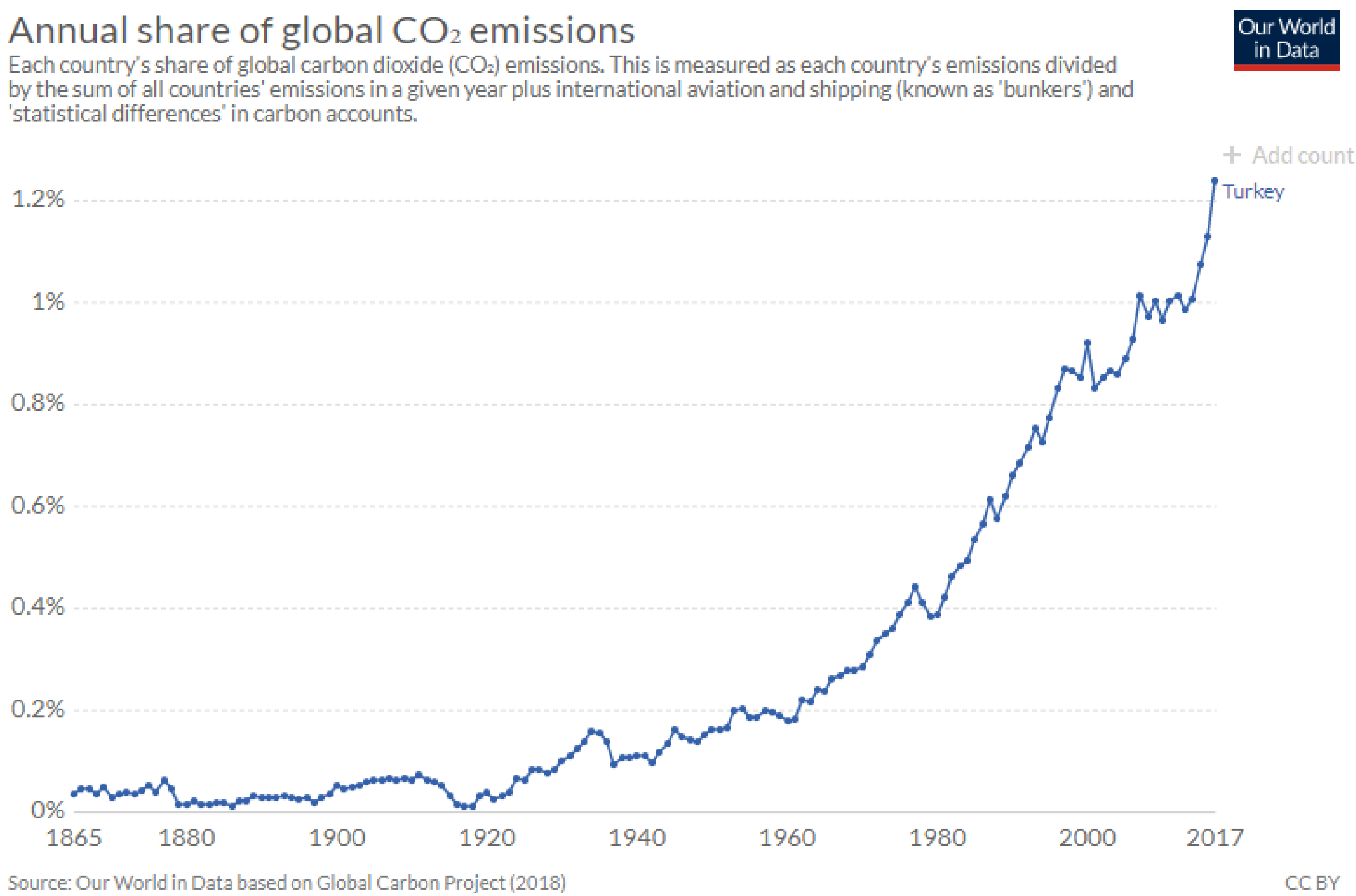
Global Warming Potential



Global Warming Potential



Global Warming Potential



Global Warming Potential

Refrigerant	Critical temperature (ºC)	Critical pressure (bar)	Ozone depletion potential	Global warming potential (100 years)	Flammable or explosive	Toxicity
			CFCs and HCFCs			
R12	100.9	40.6	0.9	8100	No	No
R22	96.2	49.8	0.055	1500	No	No
			Pure HFCs			
R32	78.4	58.3	0	650	Yes	No
R134a	101.1	40.7	0	1200	No	No
R152a	113.5	45.2	0	140	Yes	No
			HFC mixtures			
R404A	72.1	37.4	0	3300	No	No
R407C	86.8	46.0	0	1600	No	No
R410A	72.5	49.6	0	1900	No	No
			Natural refrigerants			
Propane (R290)	96.8	42.5	0	3	Yes	No
Isobutane (R600a)	135.0	36.5	0	3	Yes	No
Ammonia (R717)	132.2	113.5	0	0	Yes	Yes
Carbon dioxide (R744)	31.0	73.8	0	1	No	No

CFC, chlorofluorocarbon; HCFC, hydrochlorofluorocarbon; HFC, hydrofluorocarbon

CO2 (R744) Refrigerant

Table 5. Comparison of R-744 with other refrigerants

	R-744	HFOs	HCs	R-717
Capacity	Better	Similar	Similar	Similar
Efficiency	Similar / Worse	Similar	Better	Better
Pressure	Worse	Similar	Similar	Similar
Environmental impact	Better	Similar	Better	Better
Flammability	Better	Worse	Worse	Worse
Toxicity	Similar / Worse	Similar	Better	Worse
Availability of refrigerant	Similar / Worse	Worse	Better	Better
Availability of components	Similar / Worse	Similar	Better	Better
Availability of expertise	Similar / Worse	Worse	Similar / Worse	Better
Cost of refrigerant	Better	Worse	Better	Better
Cost of system	Worse	Similar	Similar / Worse	Worse

Refrigerant is similar to HFCs; (Similar)
Aspect of the refrigerant is worse than HFCs; (Worse)
Aspect of the refrigerant is better than HFCs. (Better) 11

Refrigerants Comparison

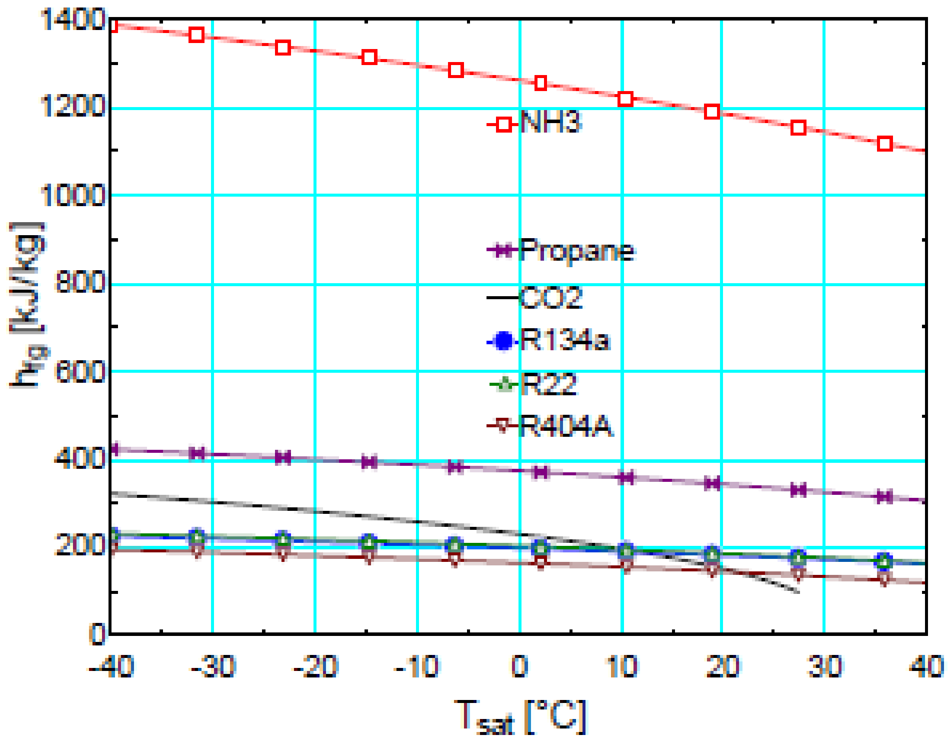


Figure 3: Latent heat of vaporization/condensation for selected refrigerants.

Figure 4 shows the values for the volumetric refrigeration effect of the selected refrigerants. As can be seen in the plot CO_2 has values which are

Refrigerants Comparison

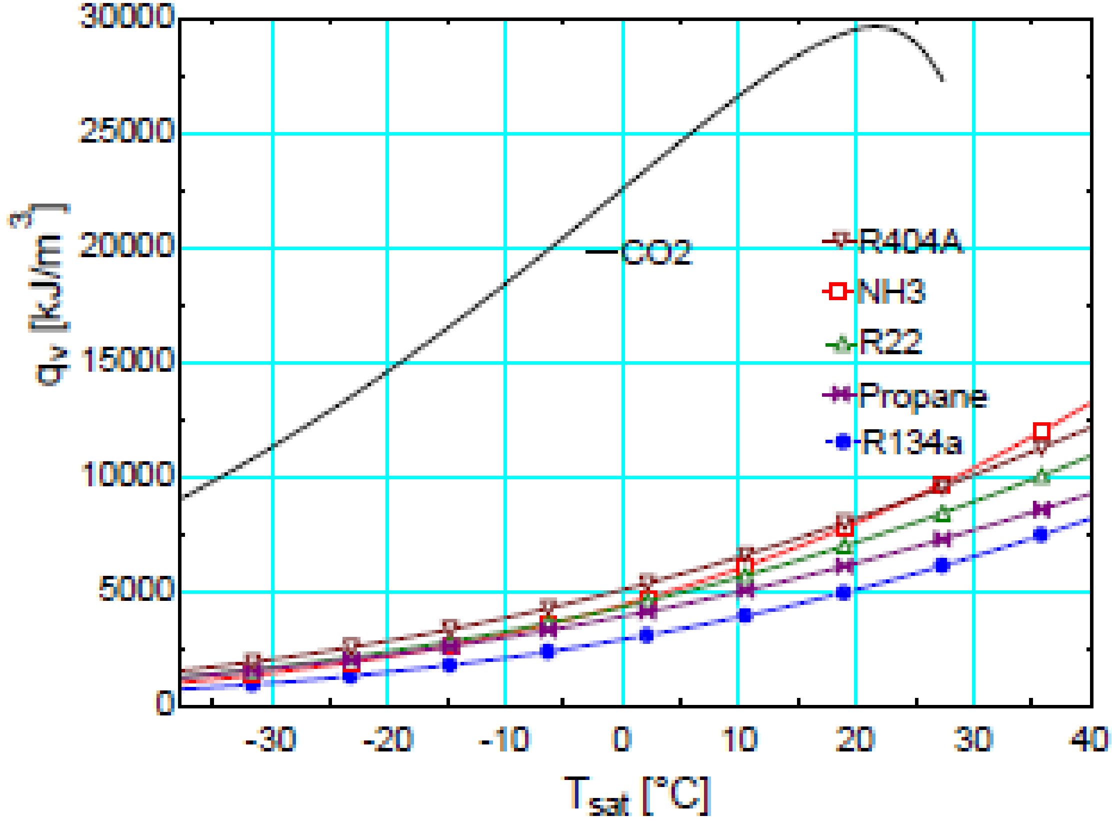
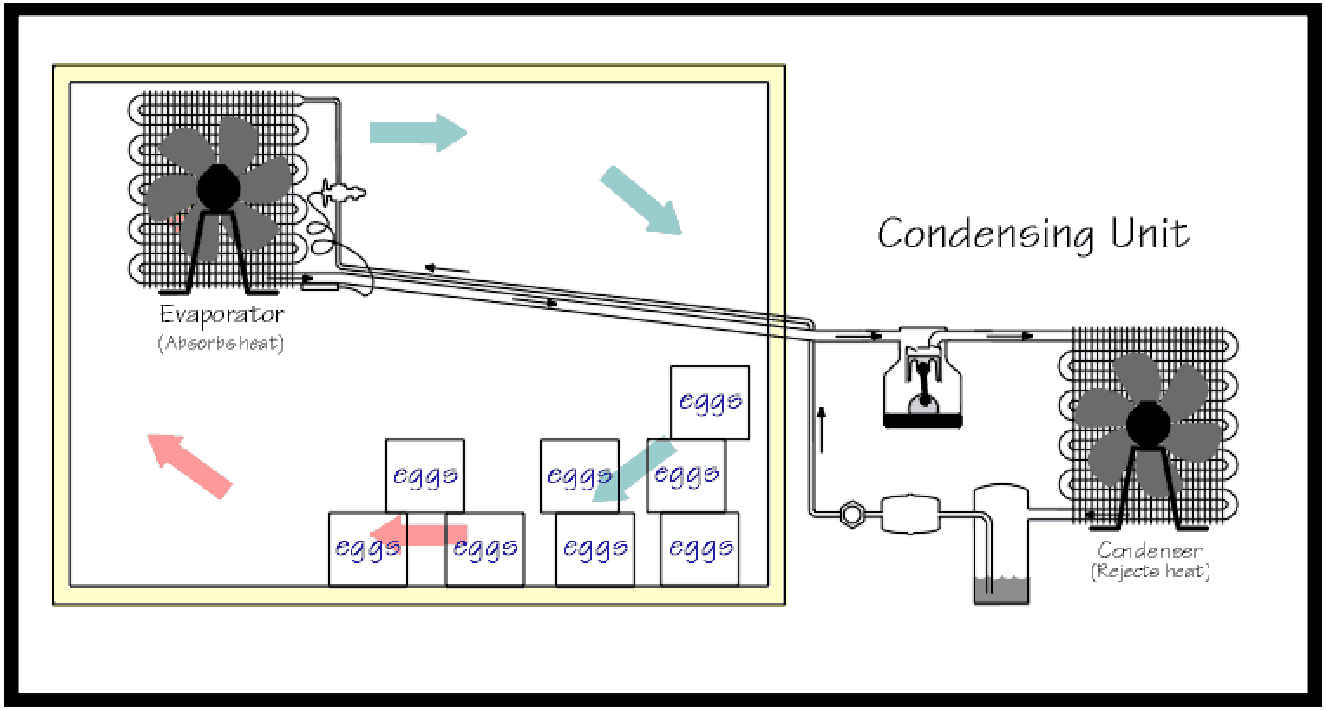


Figure 4: Volumetric refrigeration capacity (complete evaporation) for selected refrigerants.

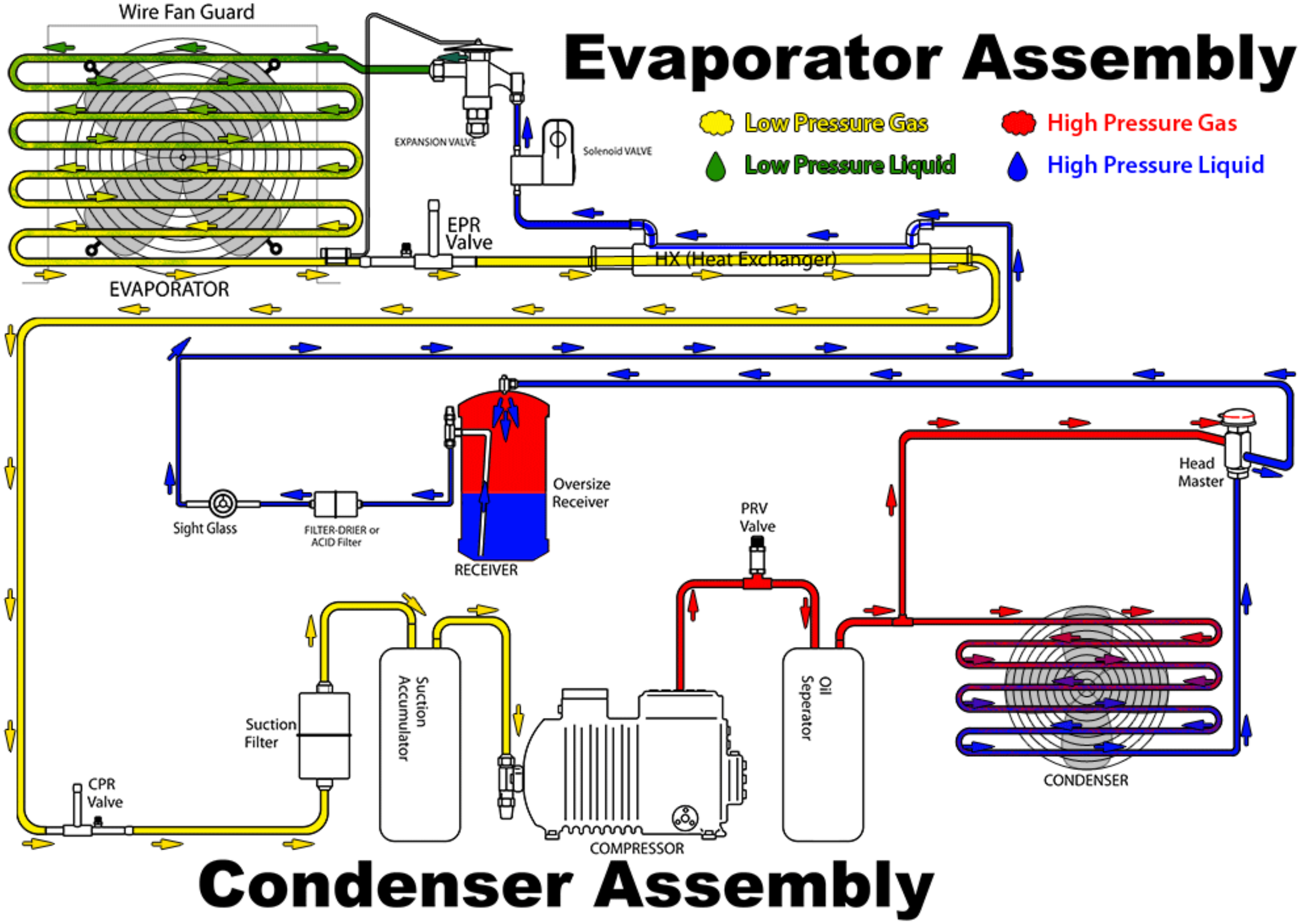
Refrigeration Cycle

Cold Storage Refrigeration



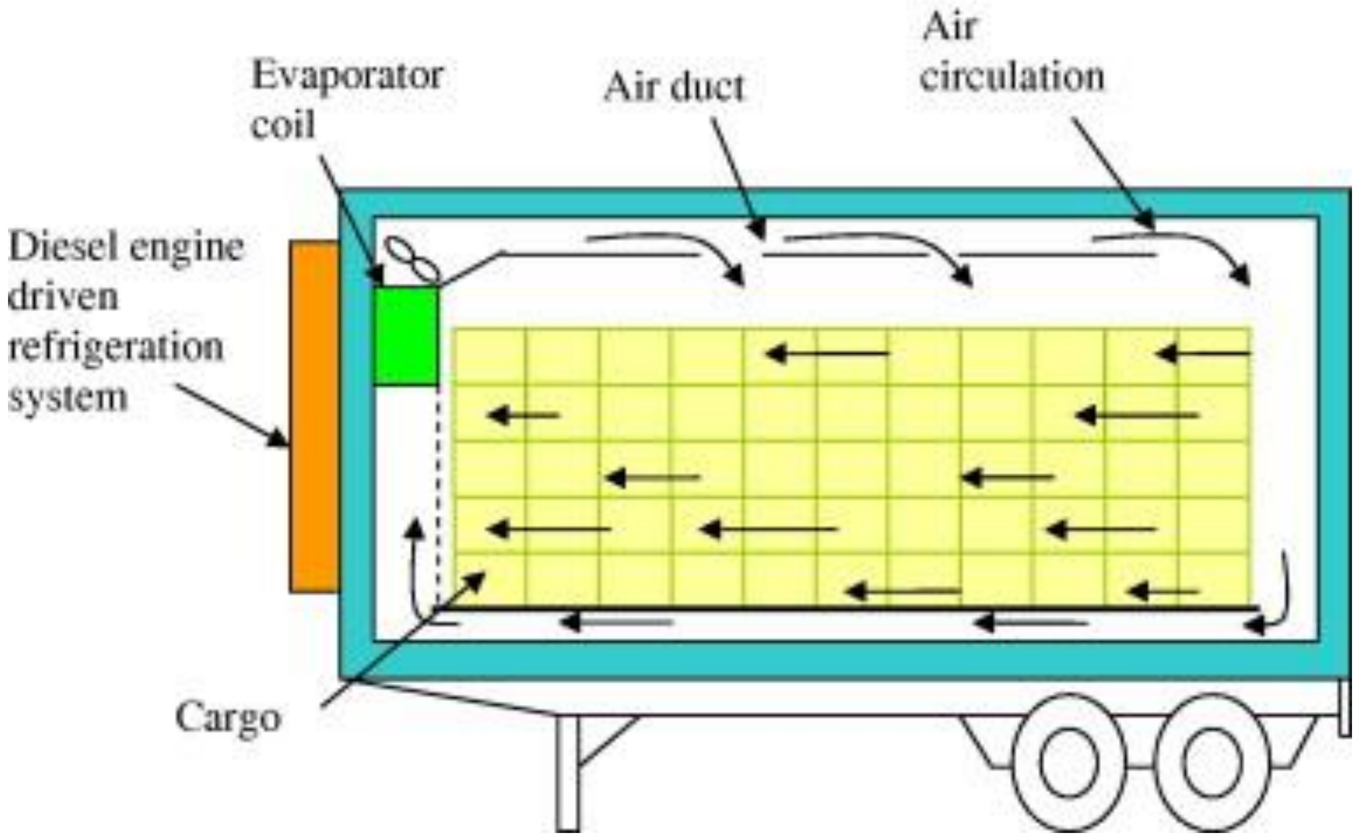
Refrigeration Cycle

Refrigeration Cycle



Transport Refrigeration

Refrigerated Truck



Transport Refrigeration

Energy Consumption for refrigerated road transport

- Approximately 650000 refrigerated road vehicles are currently in use within the EU. These vehicles can be grouped into three main types:
- Small converted vans (up to 3.5 tonnes, for example for catering or ice cream distribution),
- Rigid vehicles (trucks, up to 32 tonnes) and
- Articulated vehicles (up to 44 tonnes), which are used for the majority of refrigerated road transportation operations.
- Food transport estimated to be responsible for 1.8 % of total emissions.

Transport Refrigeration

Refrigerated Truck Energy Consumption

Body Length/Volume/Type	Minimum refrigeration duty (W) for ATP based on 0.4 W/m^2 K		Fuel consumption (l/hr)		Associated refrigeration Duty (W)	
	-20 °C	0 °C	-20 °C	0 °C	-20 °C	0 °C
6 m/ 30 m^3/ Rigid Lorry	2380	1428	1.5	2.0	3000	5000
<9 m/ 30 m^3/ Rigid Lorry	3850	2310	2.5	3.0	6000	9000
13.6 m/90 m^3/Rigid Semi Trailer	5250	3150	3.0	4.0	7500	13500
13.6 m/>90 m3/Rigid Semi Trailer	-	-	4.5	5	9500	17500

Transport Refrigeration

Vapour Compression Refrigeration Unit

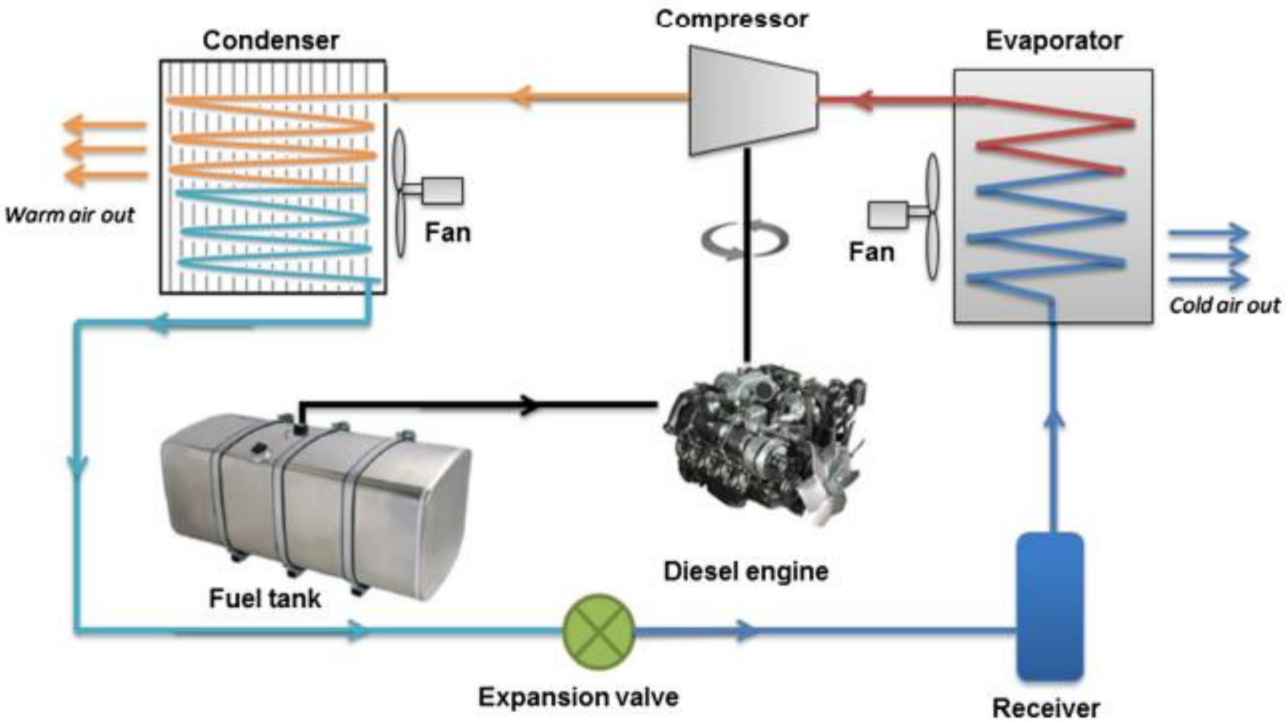
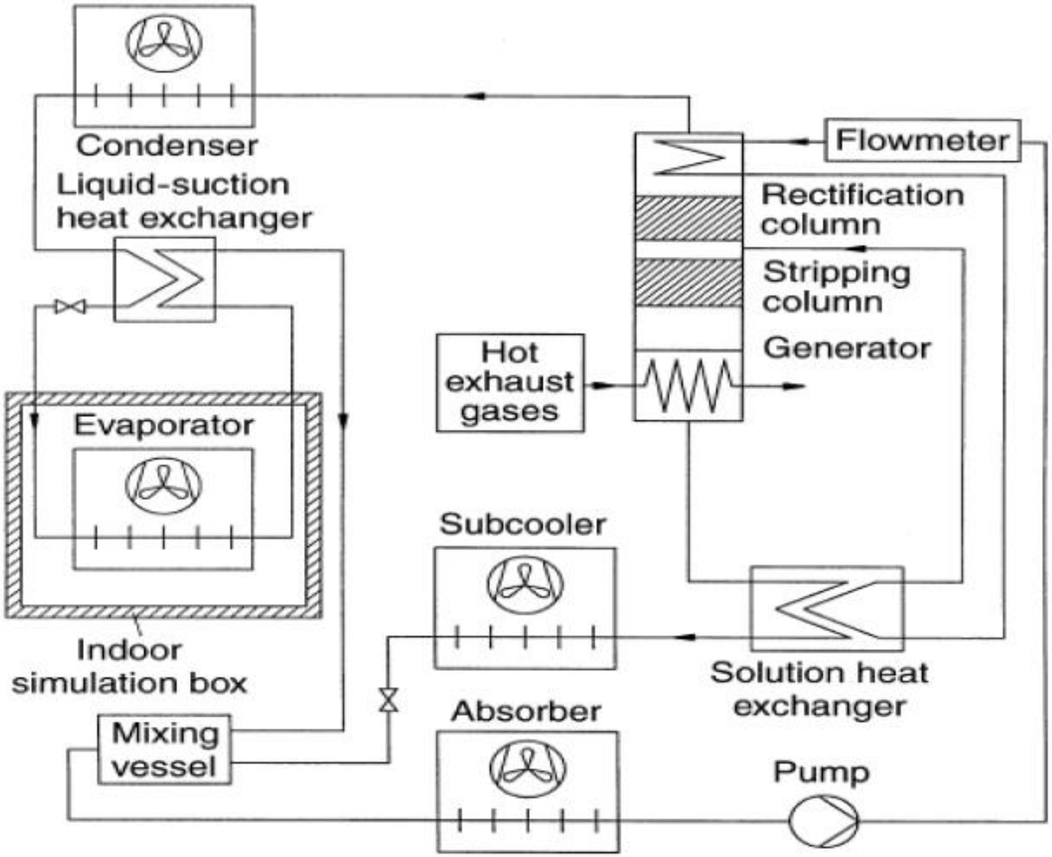


Fig. 1. Schematic diagram of vapour compression transport refrigeration unit driven by a diesel engine.

Absorption Refrigeration utilising exhaust heat



Transport Refrigeration

Eutectic systems

- Phase Change Materials
- Combined Phase Change Materials and Vapor Compression System

Cryogenic Cooling Systems

- Liquid Nitrogen or Carbon Dioxide Injection
- Mechanical Systems

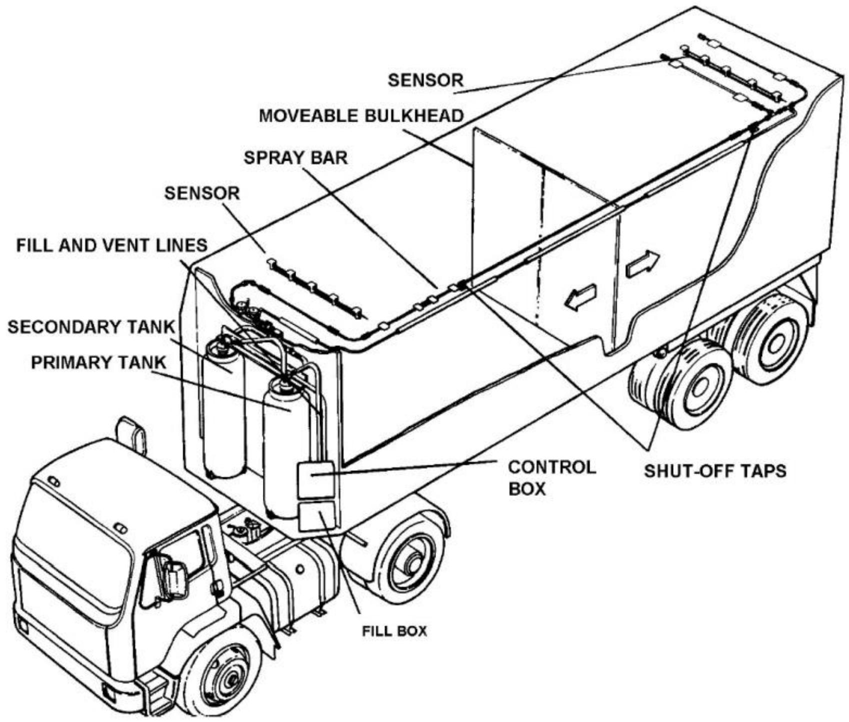
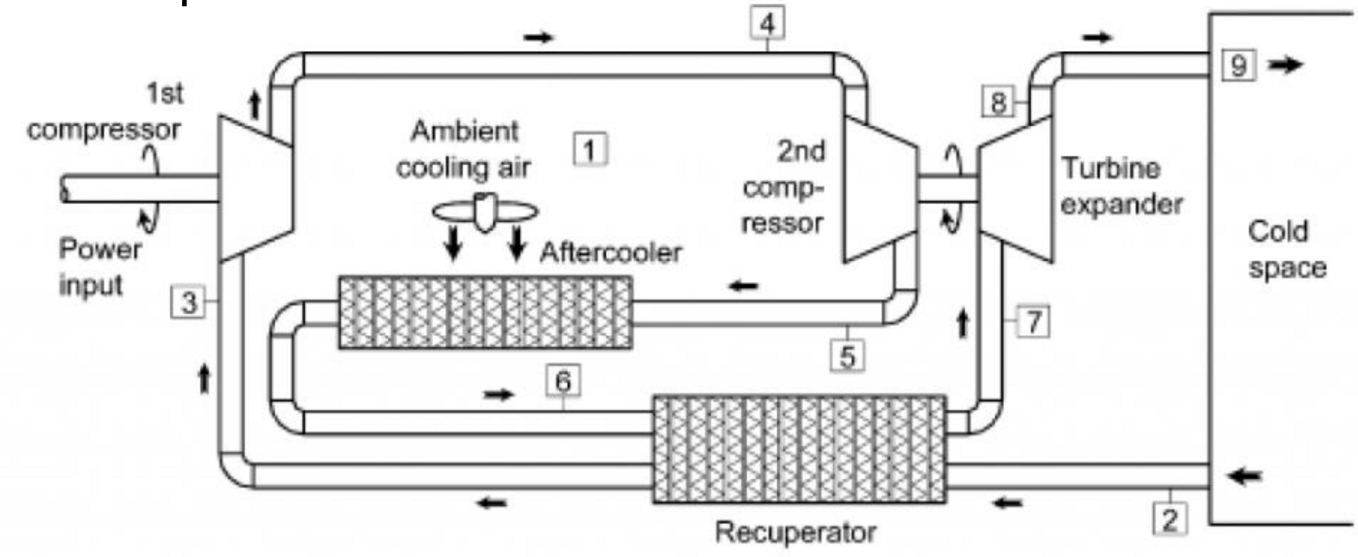


Figure 5. BOC 'Polarstream' Liquid Nitrogen Cooling System

Air Cycle Refrigeration

Transport refrigeration has been identified as a potential application area for air cycle systems on the grounds of weight, robustness, leakage, reliability and maintenance. Air cycle systems are also less sensitive to part-load operation.



Transport Refrigeration

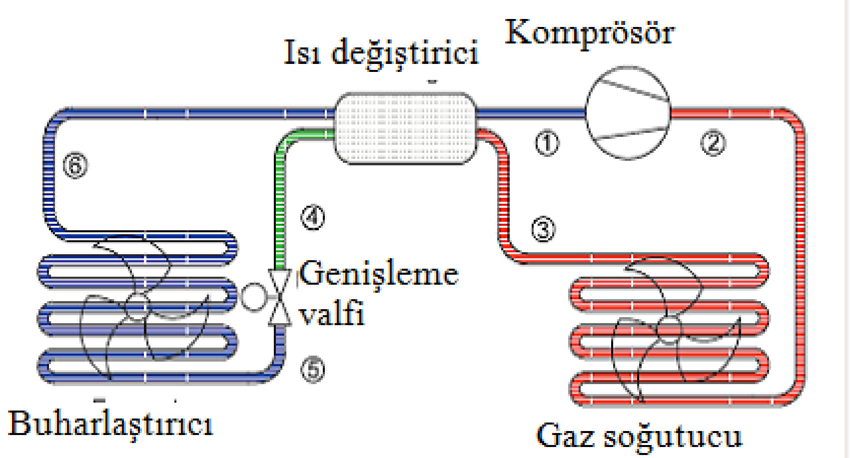
Solar Powered Transport Refrigeration

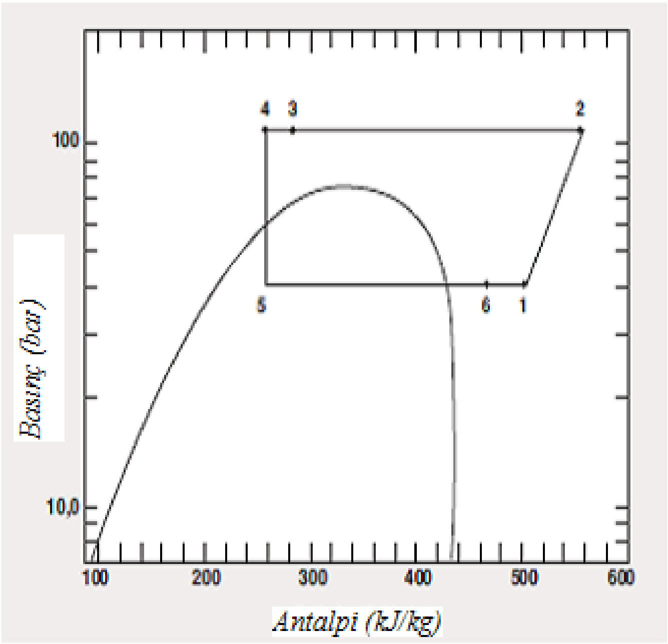
Natural Refrigerant System Types

- Low-temperature (LT) or medium-temperature (MT) CO_2 overfeed
- MT HFC DX with LT CO_2 DX cascade
- HFC DX primary over combined MT overfeed with LT CO_2 DX
- NH_3-flooded primary over combined MT overfeed with LT CO_2 DX
- CO_2 transcritical booster system
- Self-contained water-cooled hydrocarbon

R744 Refrigeration Cyle

Tek kademeli basit transkritik çevrim





R744 Refrigeration Cyle

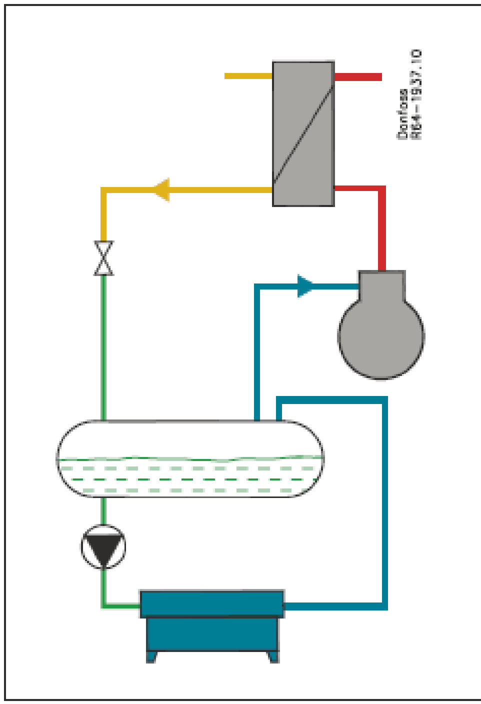


Fig. 3.1.1: Pumped system

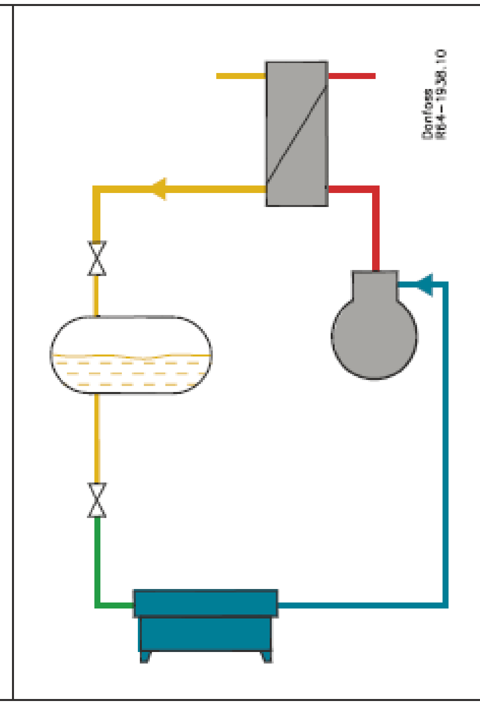


Fig. 3.1.2: DX system

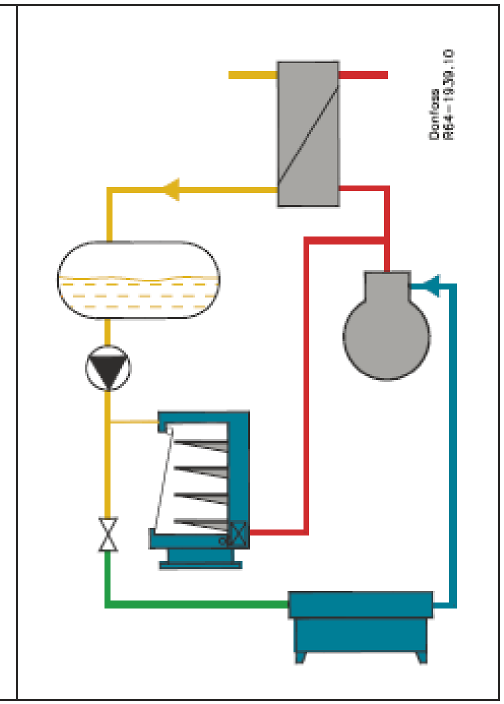
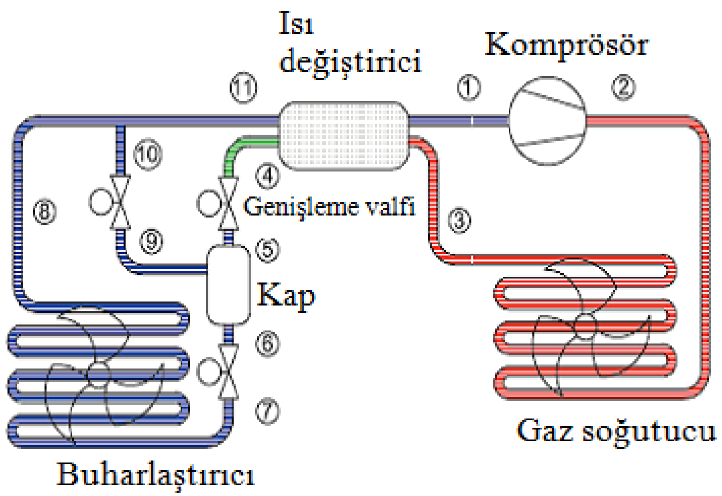
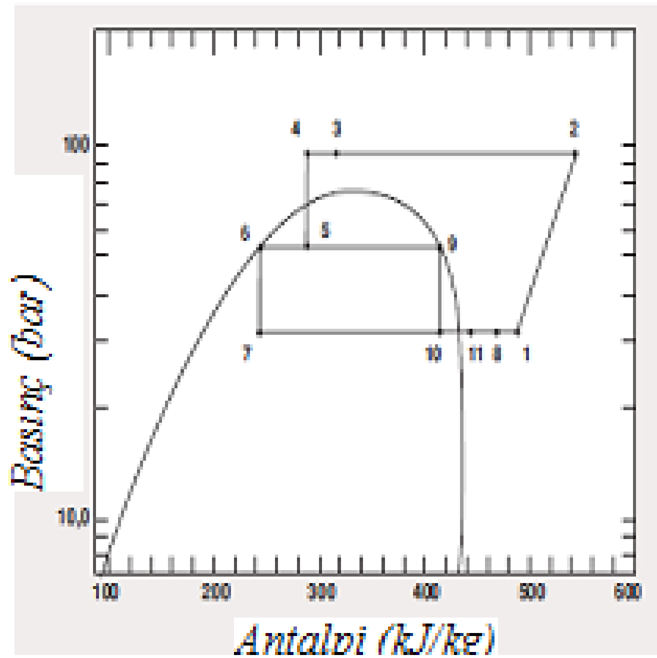


Fig. 3.1.3: Combined system

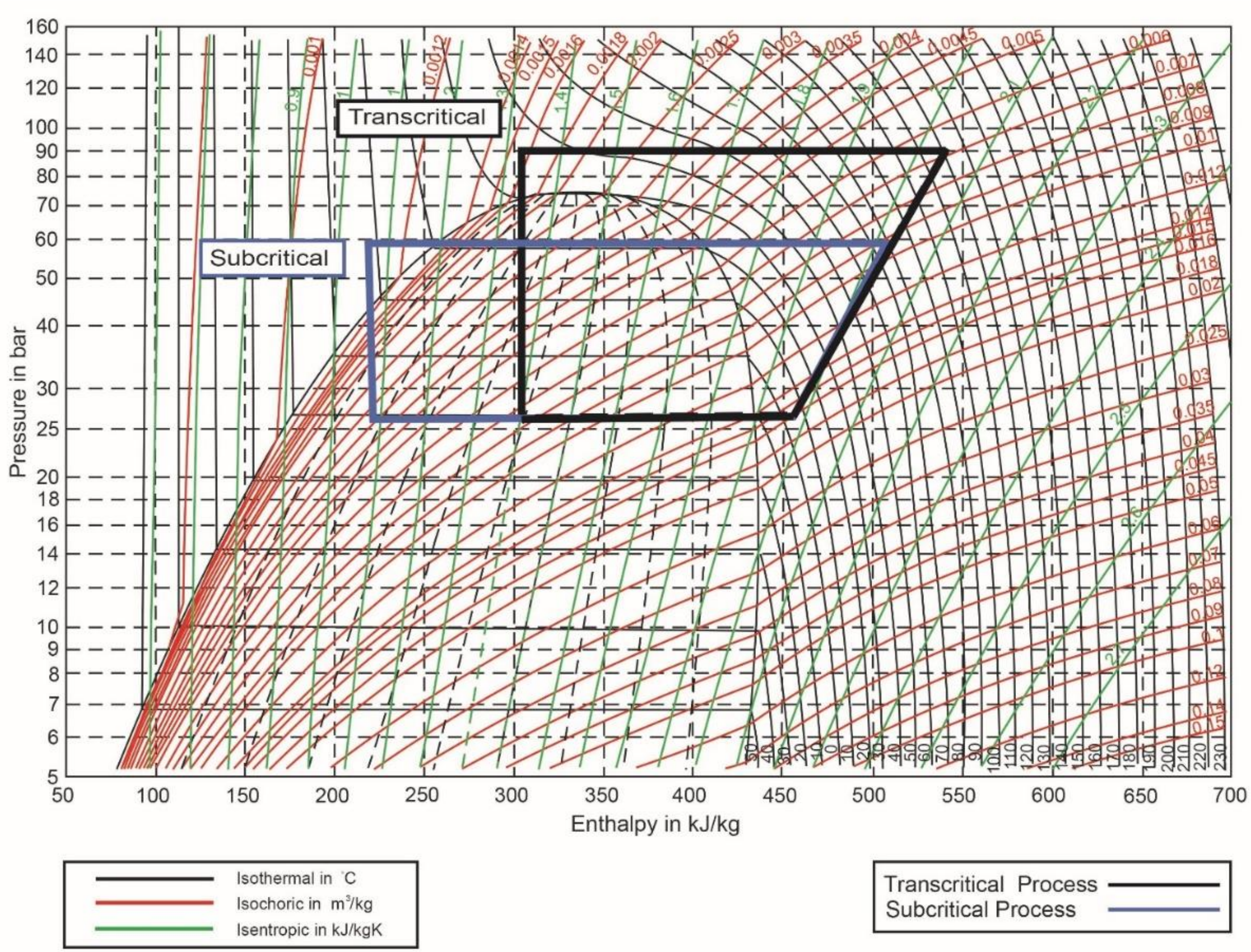
R744 Refrigeration Cyle

Tek kademeli sıvı/gaz ayırıcılı transkritik çevrim





R744 Refrigeration Cyle



R744 Refrigeration Cyle

- CO2 (R744) Ejector Integration

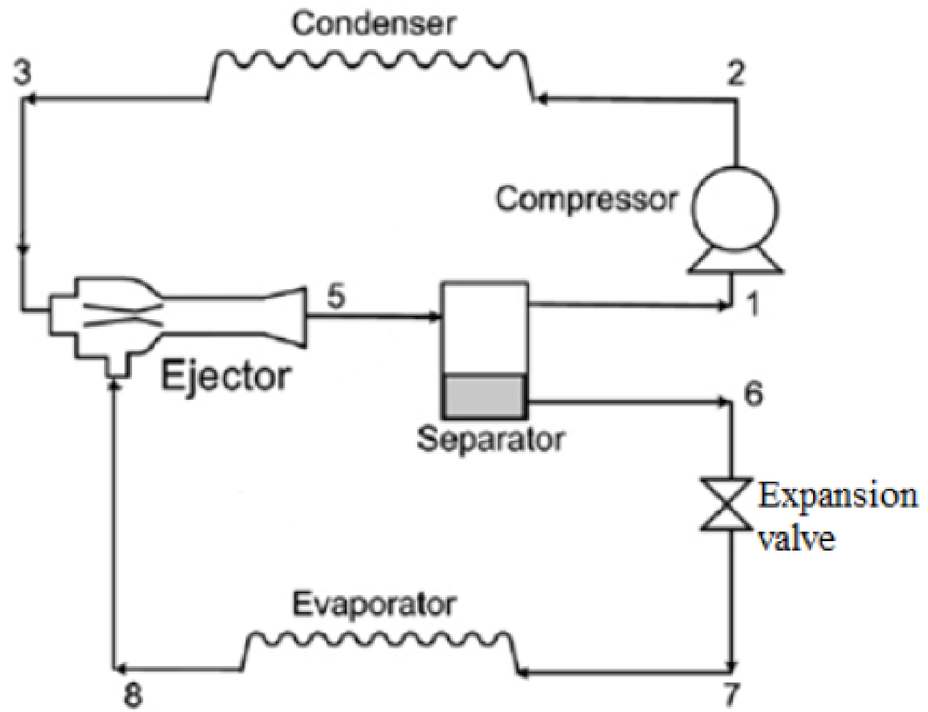


Figure 3.8 Schematic of R744 vapour compression refrigeration cycle with a two-phase ejector. Adapted from Sumeru et al. (2012)

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R744 Refrigeration Cyle

- CO_2 (R744) Ejector Integration

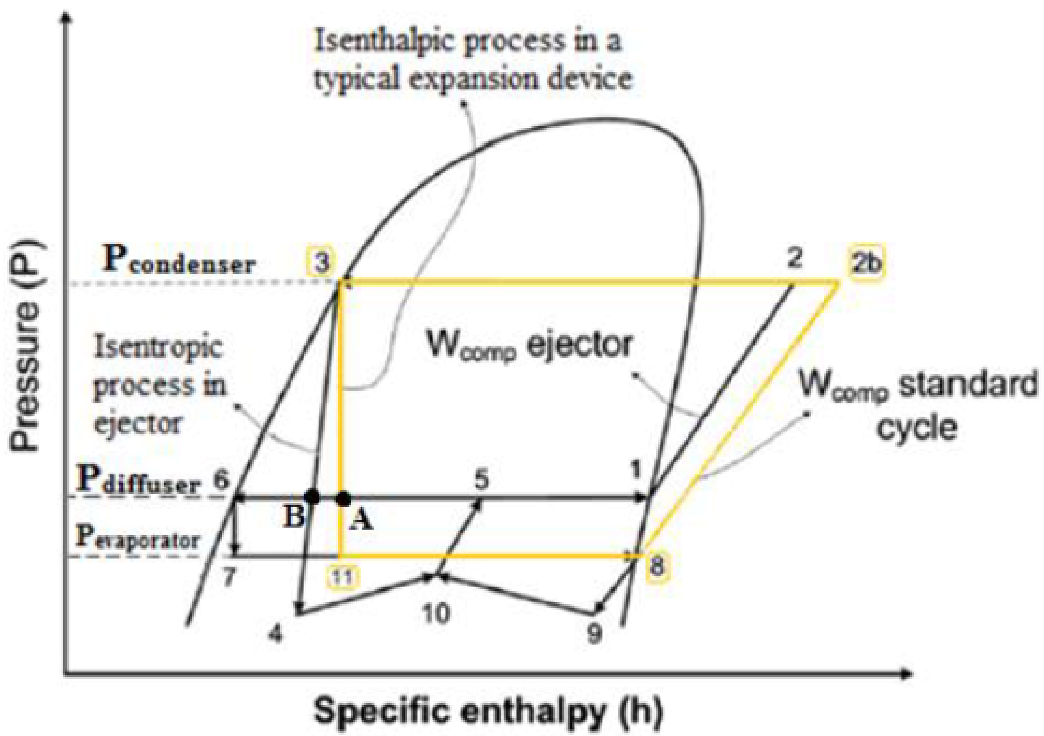
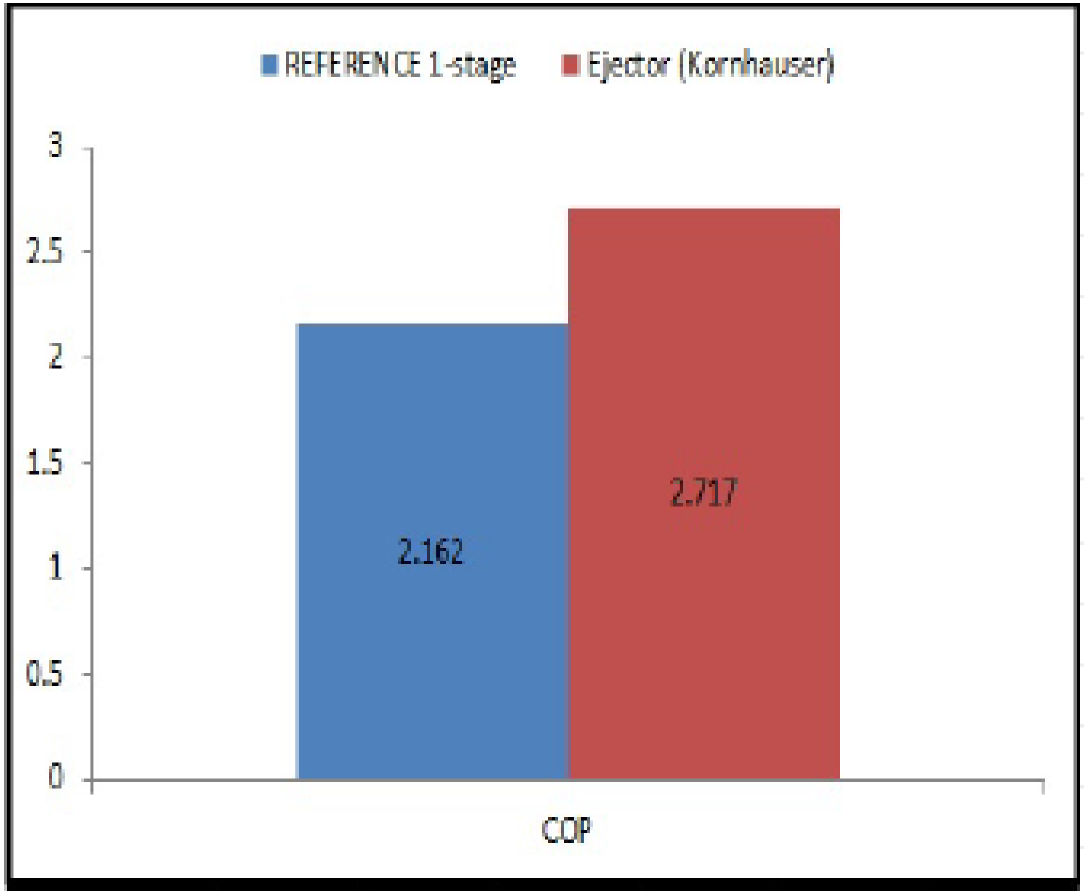


Figure 3.9 P-h diagram of R744 vapour compression refrigeration cycle with a two-phase ejector and comparison with standard cycle. Adapted and modified from Sumeru et al. (2012)

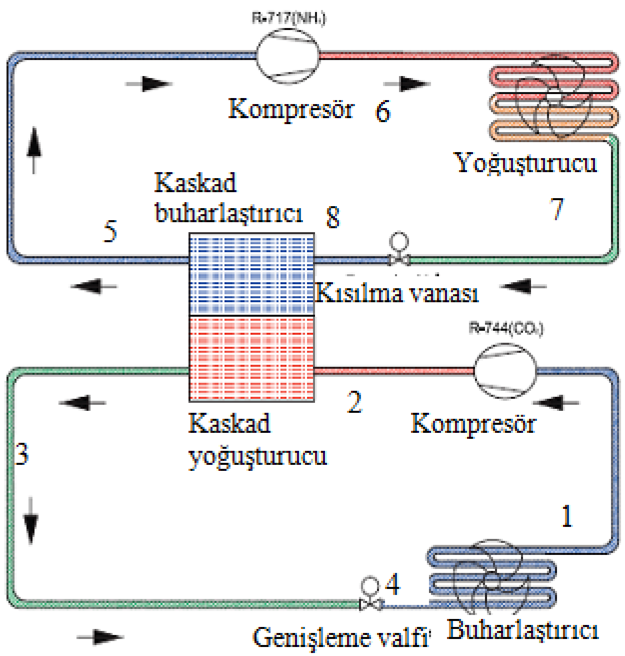
R744 Refrigeration Cyle

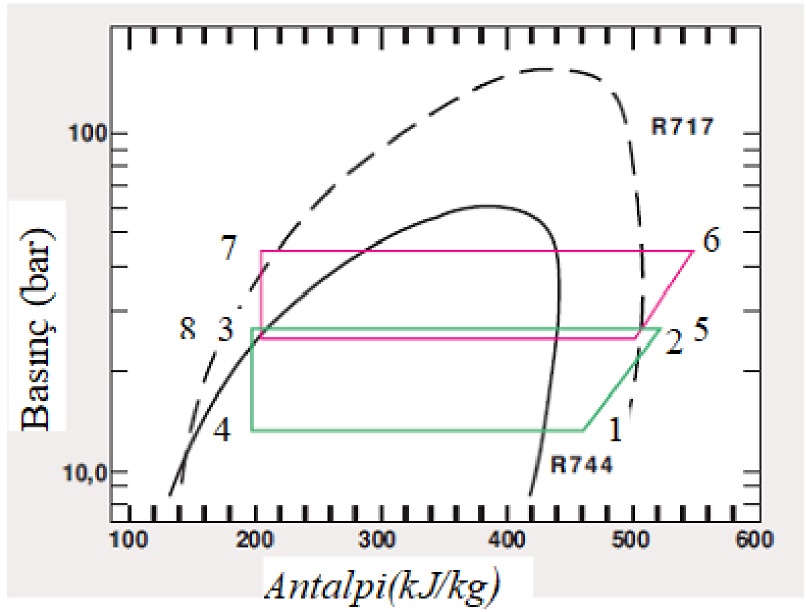
- CO2 (R744) Ejector Integration



R744 Refrigeration Cyle

- CO2 (R744) Cascade System





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R744 Refrigeration Cyle

- CO2 (R744) Booster System

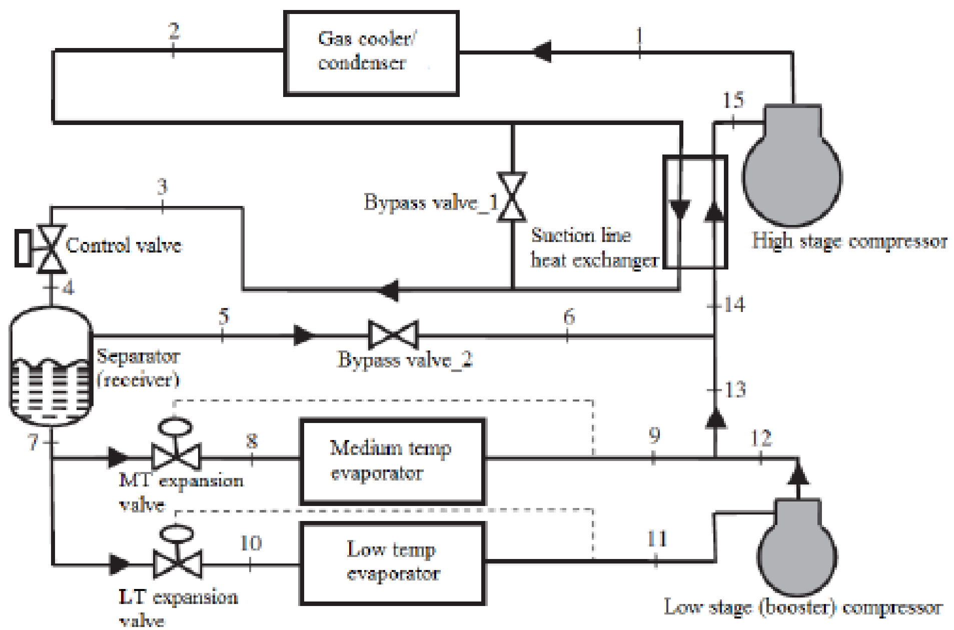

Figure 3.5 Schematic of a transcritical booster system. Adapted and modified from Ge & Tassou (2011)

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R744 Refrigeration Cyle

- CO2 (R744) Booster System

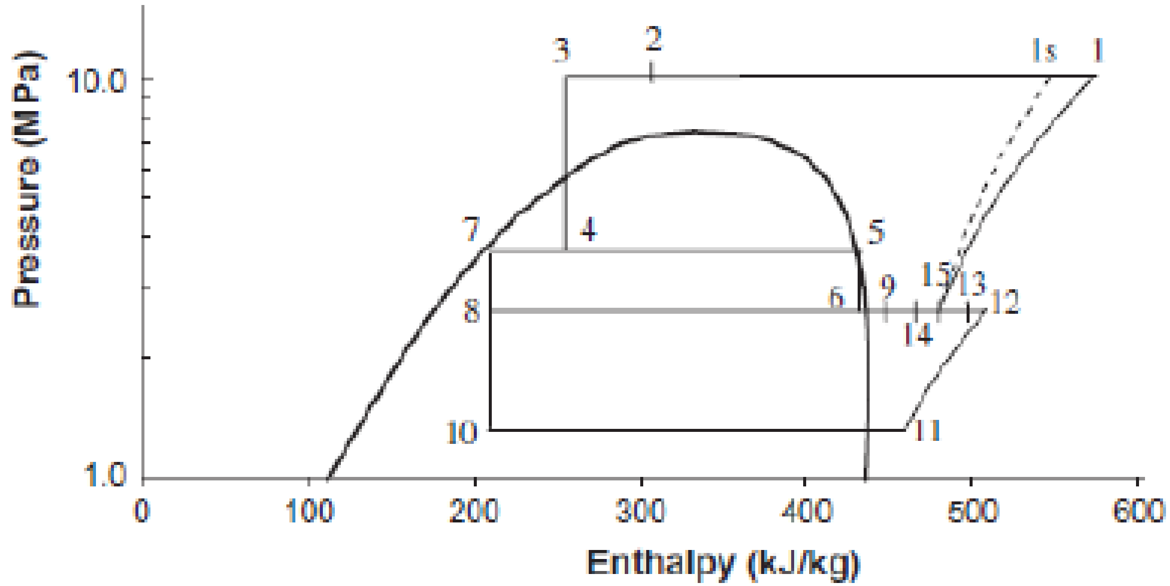

Figure 3.6 Transcritical booster system in P-h layout. Adapted from Ge & Tassou (2011)

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Supermarket Refrigeration

- **Supermarkets are energy intensive buildings consuming 3-4% of the total annual electricity in industrialized countries**
- **35-50% of this total electricity is consumed in the supermarket refrigeration systems.**
- **Supermarket refrigeration systems are one of the largest consumers and emitters of high GWP refrigerants; 30% of Europe HFC consumption 22% annual leakage rate.**

Supermarket Refrigeration

- CO2 (R744) Booster System

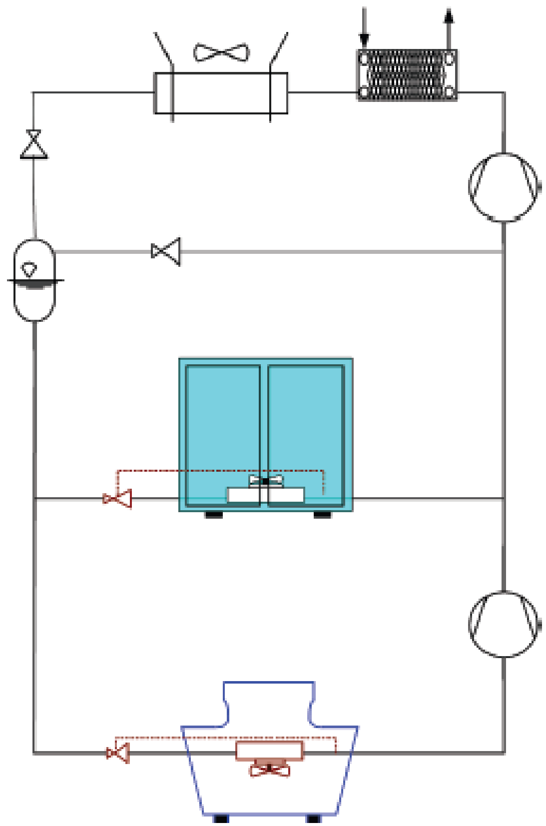


Figure 1: a CO2 trans-critical booster system

Supermarket Refrigeration

- CO2 (R744) Transritical System

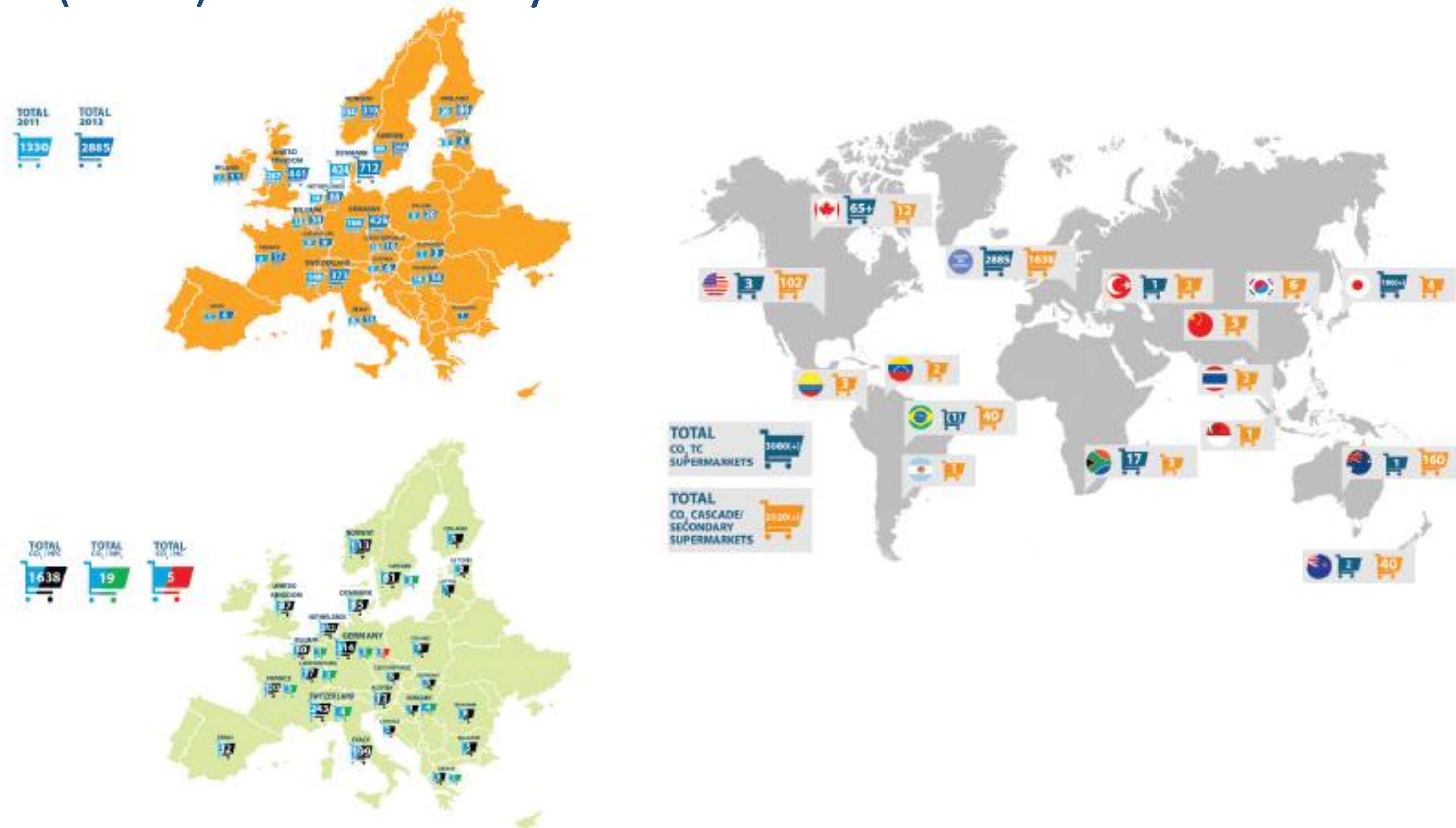


Figure 2: Year 2013 map of CO_2 trans-critical booster systems in Europe (top-left), CO_2 cascade systems in Europe (bottom-left) and CO2 trans-critical and cascade/secondary stores in world (right) (Shecco, 2014)

Supermarket Refrigeration

- CO2 (R744) Transritical System

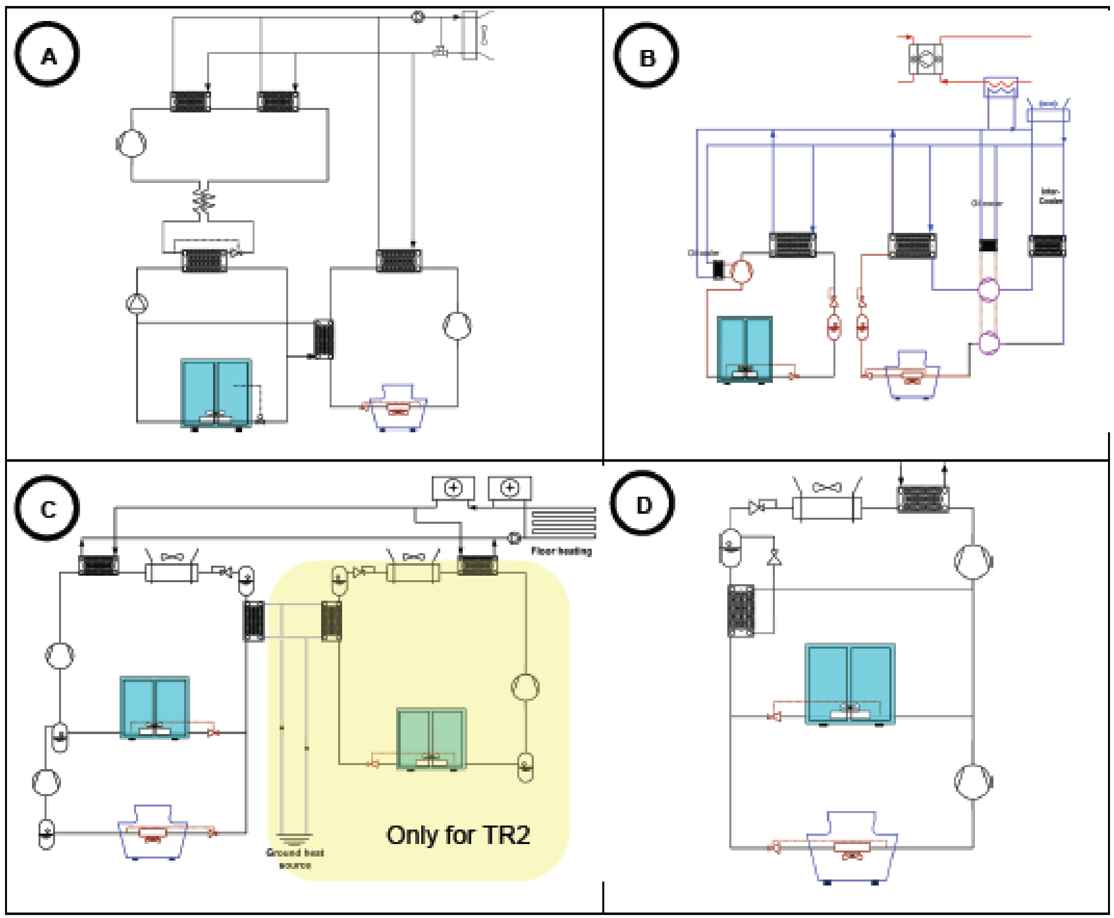


Figure 3: Systems schematics A) HFC reference systems RS1-RS2-RS3. B) TR1-Parallel transcritical. C) TR2-transcritical booster + Parallel medium temperature cycle. TR3- has only transcritical booster units D) TR4 and TR5-transcritical booster with flash gas by-pass.

Supermarket Refrigeration

- CO2 (R744) Transritical System

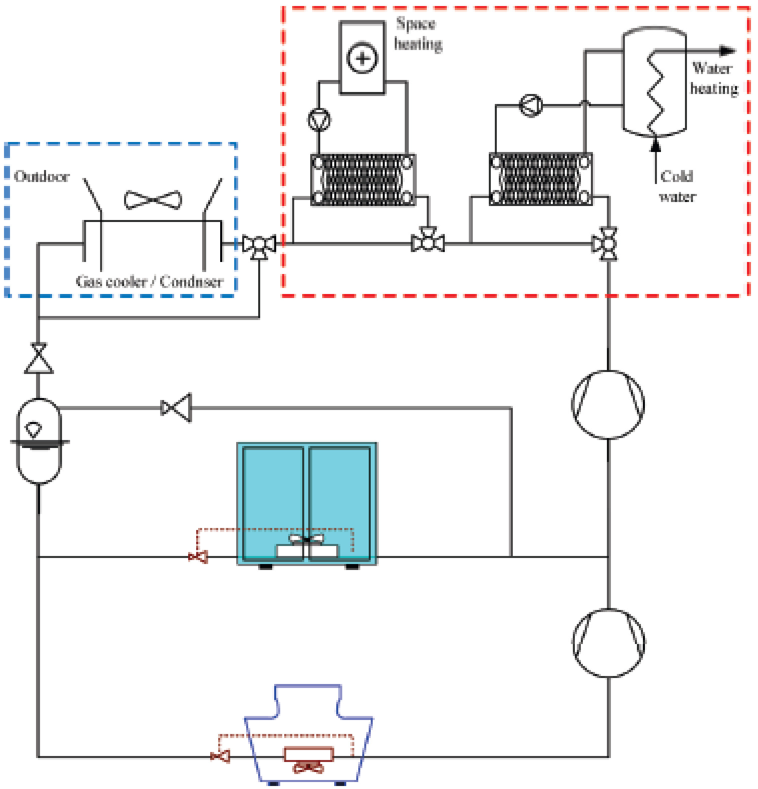
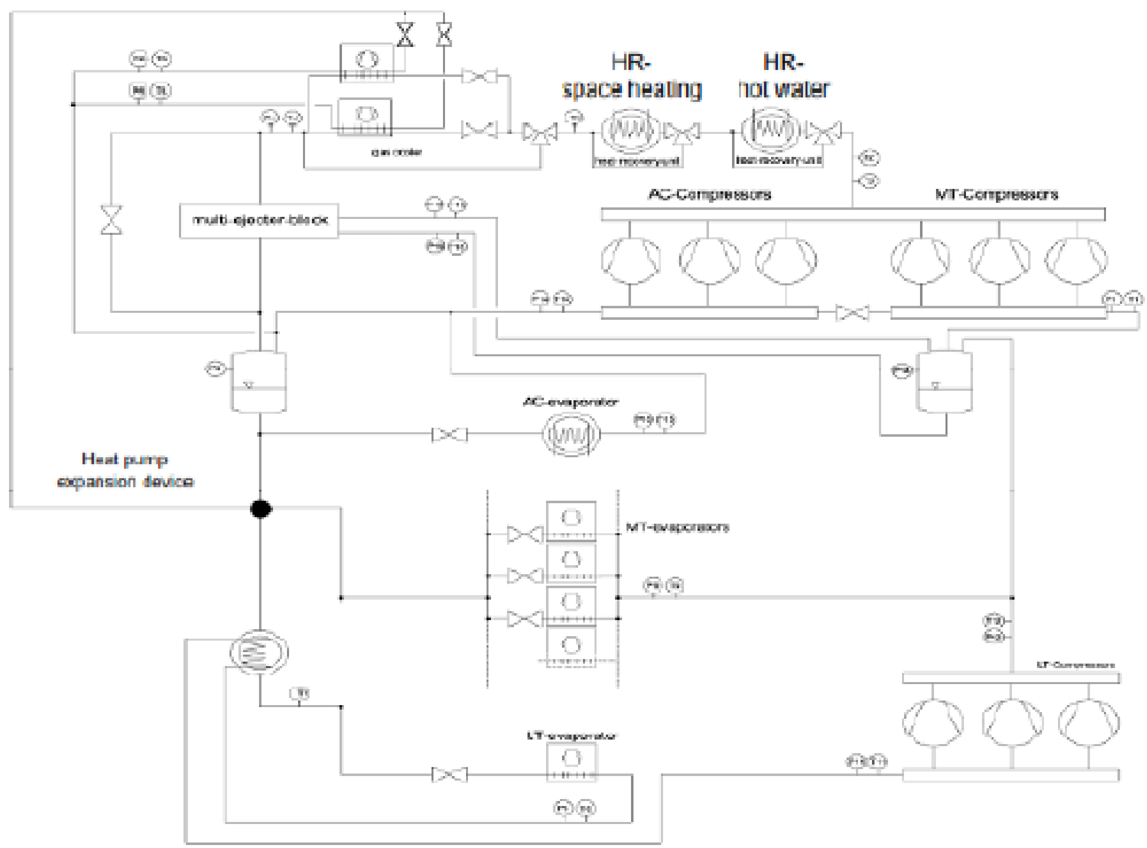


Figure 23: Schematic of a state-of-the-art CO2 trans-critical booster system

Supermarket Refrigeration

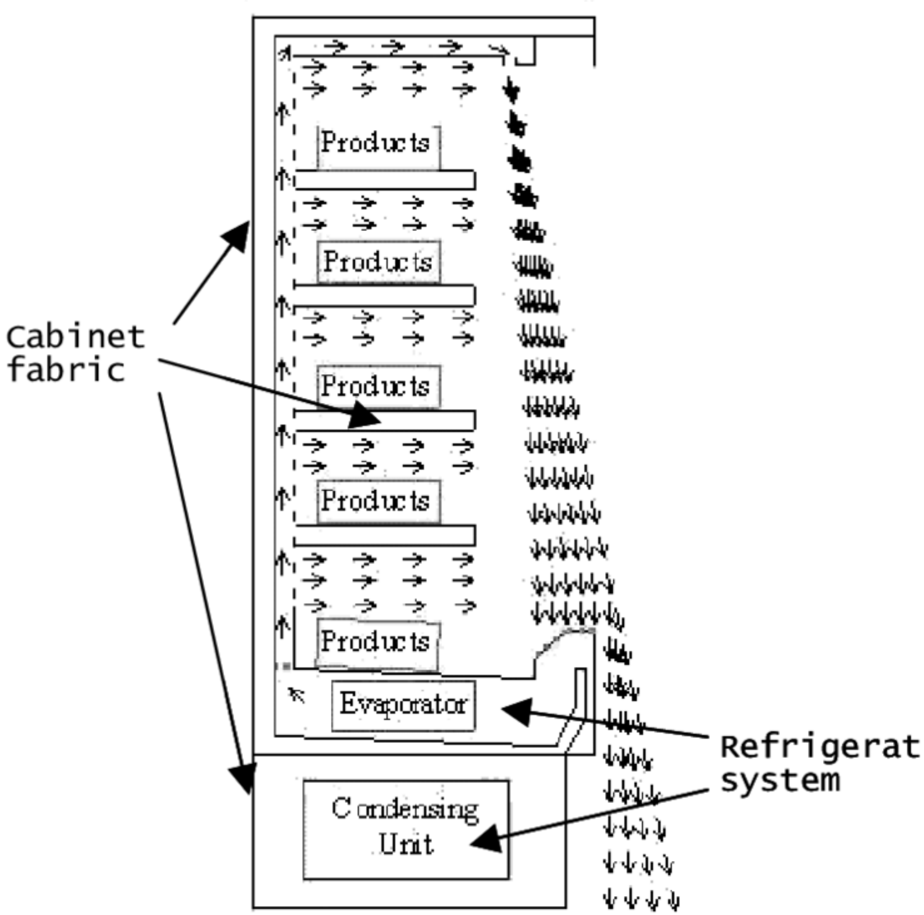
- CO2 (R744) Transritical System

Fig. 17. "All-in-one" transcritical R744 booster supermarket refrigeration system equipped with multi-ejector rack (IESPC unit) (Hafner et al., 2016).



Supermarket Refrigeration

- Self Contained HC Rerigeration System



Supermarket Refrigeration

- Self Contained HC Rerigeration System

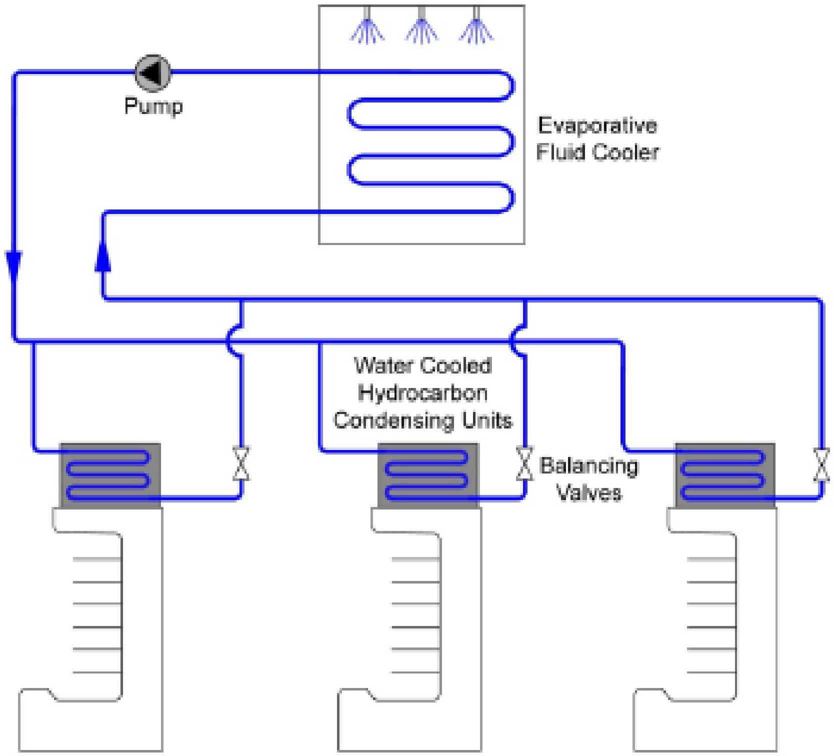


Figure 3-6. Self-contained hydrocarbon condensing units with a hydronic loop

Natural Refrigeration Systems

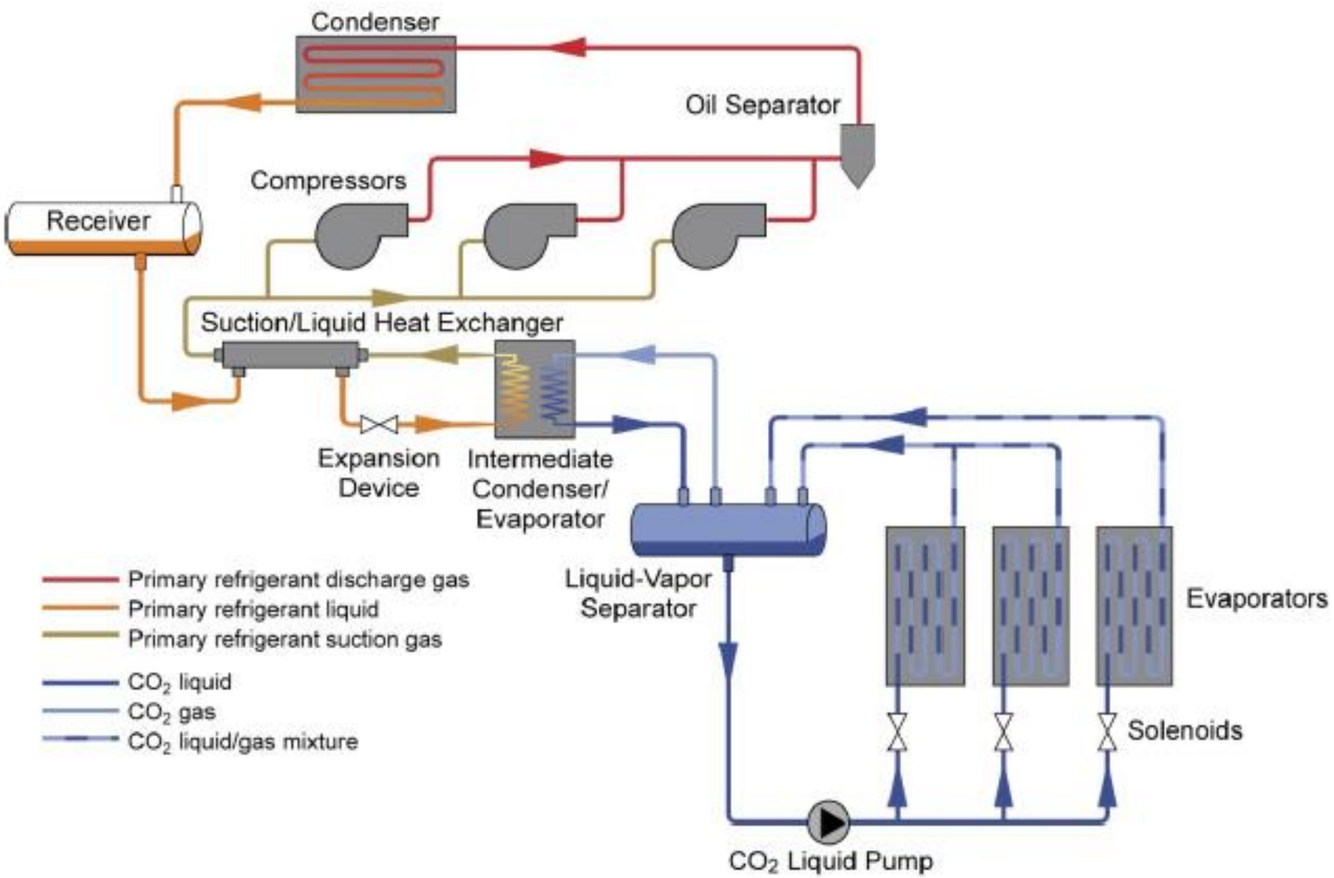


Figure 3-1. LT or MT CO2 overfeed system

Natural Refrigeration Systems

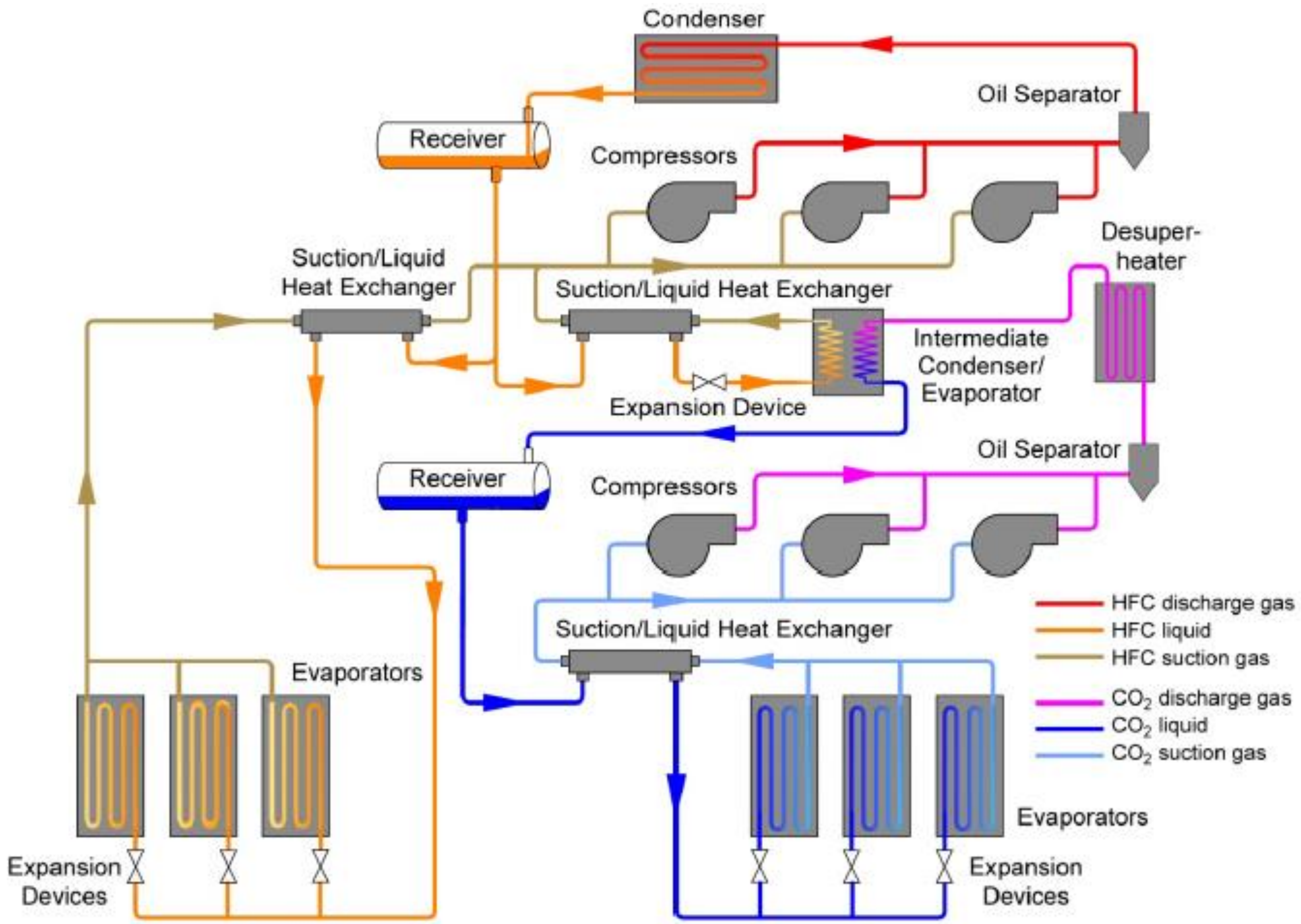


Figure 3-2. MT HFC/LT CO2 DX cascade

Natural Refrigeration Systems

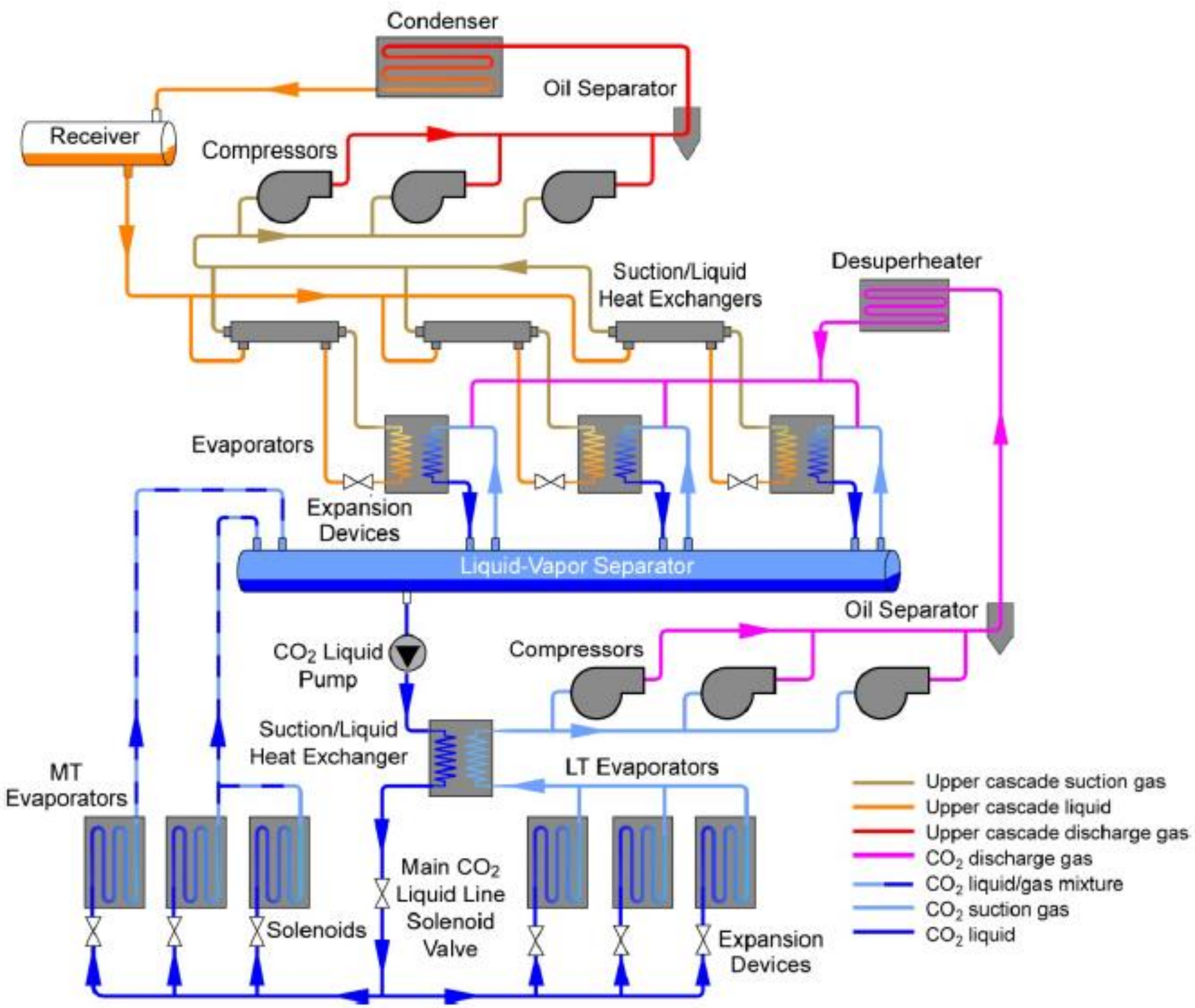


Figure 3-3. Combined MT pumped/LT DX CO_2 cascade system

Natural Refrigeration Systems

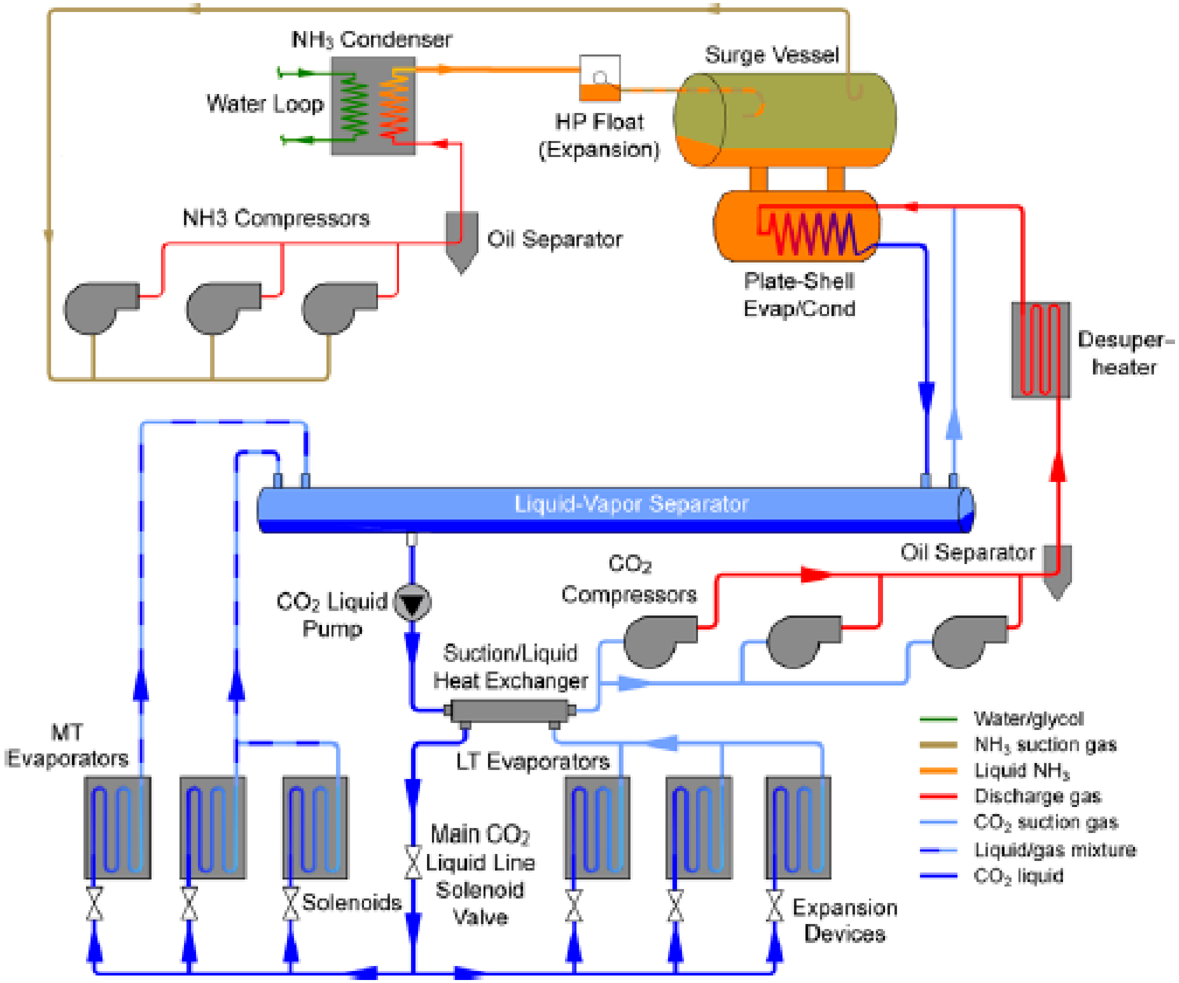


Figure 3-4. Combined MT pumped/LT DX CO_2 cascaded with NH_3-flooded system

THANKS FOR YOUR ATTENTION!