7th Edition

REFCOLD® INDIA

03 – 05 OCTOBER 2024

Biswa Bangla Mela Prangan, Kolkata

ISHRAE® | informa markets

SOUTH ASIA'S PREMIER REFRIGERATION & COLD-CHAIN EXHIBITION

FRESH & HEALTHY PRESERVATION THROUGH INNOVATIVE TECHNOLOGIES

7th Edition REFCOLD INDIA
03 – 05 OCTOBER 2024
Biswa Bangla Mela Prangan, Kolkata

NTNU Norwegian University of Science and Technology | Norwegian Embassy New Delhi | Future Refrigeration India: INDEE+ | ISHRAE | informa markets

KNOWLEDGE SESSION

Theme

Successful Demonstration and Future Scope of Natural Refrigerant Systems in India

Potential for Natural Refrigerant Systems for Refrigeration Applications in India

Challenges and Opportunities

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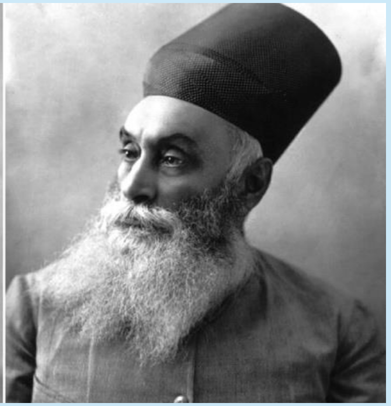
Indian Institute of Science, Bengaluru

DISCLAIMER

The contents of the presentation are personal views based on experience gathered over the past few years of interaction with industry academia and other organizations

Excerpts of the conversation between Swamy Vivekananda and Mr. J. N Tata

A Sea Voyage That Changed India!



The conversation dates back to May 31st, 1893, when these two great Indians met aboard a steamer that sailed from Yokohama to Vancouver.

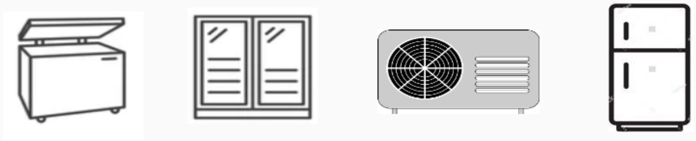
They discussed Japan's phenomenal progress in technology and ***<u>Jamsetji's plan of laying the foundations of the steel industry in India</u>***.

The founder of one of India's largest conglomerates, ***Jamsetji also explained that he was in search of equipment and technology that would help make India a strong industrial nation.***

Vivekananda endorsed the vision with enthusiasm, adding that the ***real hope of India lay in the prosperity and progress of its ordinary millions.***

He also added that instead of importing matches from Japan, Jamsetji should manufacture them in India and help provide a livelihood to the rural poor.

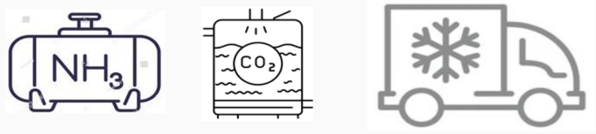
Potential Applications of Natural Refrigerants - *Indian Context*



- *Supermarkets*
- *Deep Freezers*
- *Display Cabinets*
- *Visi coolers*
- *Bulk Milk Chillers*
- *0.5-15 TR units*
- *(R290, R600a, R600)*

(Small Systems, Large Market Share, 3-5 years life, commodity scale cost-sensitive)

Domestic and Commercial



- *Large Capacity Cooling units*
- *Dairy Seafood Processing*
- *Food and Pharma Processing units*
- *Hotel and Hospitals*
- *District Cooling*
- *>100 TR units*
- *R717 (Ammonia) R744 (CO_2)*

(Large Systems, Long Life, Higher Investments, Limited nos.)

Industrial and Transportation

MythBusters about CO_2 Refrigeration Systems

Myth 1: CO_2 is toxic

Fact: ***CO_2 is not toxic***, but CO_2 being heavier than air will displace it. High volumes of CO_2 will cause asphyxiation.

Myth 2: CO_2 systems are not for tropical climates with high ambient temperatures

Fact: CO_2 systems work in transcritical mode (above the critical pressure of 72.8 bar) resulting in ***high discharge temperatures > 90°C*** and hence ***can work at very high ambient temperatures (up to 55 °C)***

Myth 3: CO_2 systems are bulky and unsafe since they operate at high pressures

Fact: CO_2 systems do operate at high pressures and adequate safety must be ensured in design***. However, since CO_2 is much more denser compared to any other refrigerant, it is significantly more compact.***

Myth 4: CO_2 systems are prone to leakages, requiring frequent maintenance

Fact: CO_2 systems have high standstill pressures and require good engineering. ***A well-engineered CO_2 system will never leak and provide you with years of trouble-free performance.***

Misconceptions about CO_2 Refrigeration Systems

Misconception: CO_2 systems have low COP

Reality: ***COP is a single-point measurement***. Theoretically, CO_2 systems have lower COPs compared to other refrigerants. ***The penalty factor for CO_2 across the operating envelope is much lower compared to any other refrigerant- outperforms all other refrigerants***!

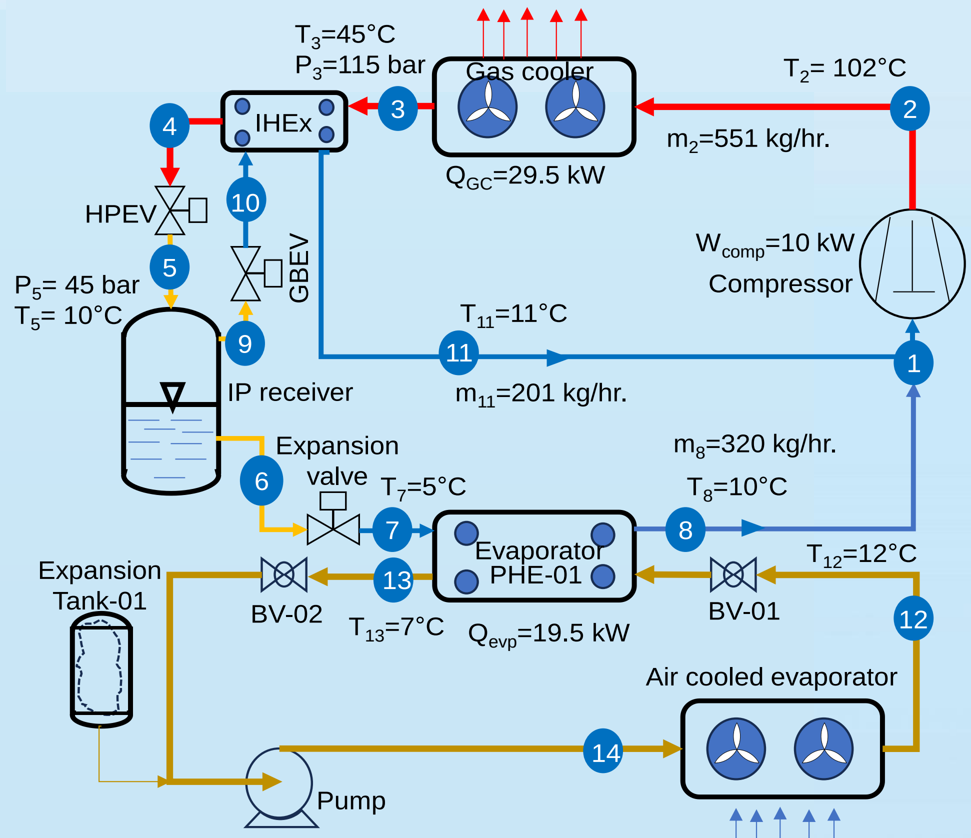
Misconception: CO_2 systems are expensive

Reality: CO_2 systems are expensive due to high component costs…but compared to what? ***CO_2 systems are industrial systems*** and ***should not be compared*** to ***Commercial Systems***- The life of a well-maintained CO_2 system can be as high as 30 years! ***Besides the cost of refrigerant is almost NIL!***

Misconception: CO_2 systems are unreliable and prone to failures

Reality: CO_2 systems do operate at high pressures and adequate safety must be ensured in design***. However, since CO_2 is much more denser compared to any other refrigerant, it is significantly more compact.***

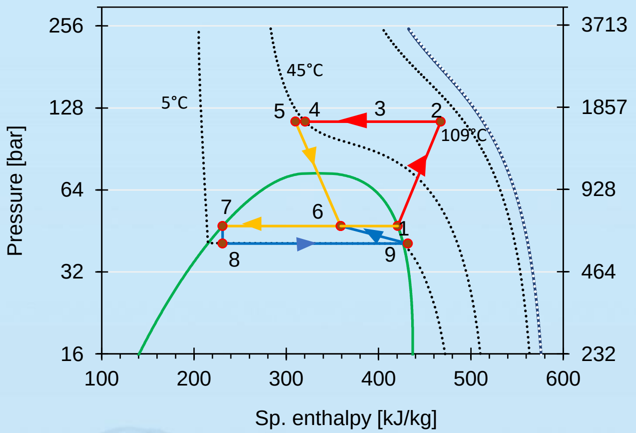
20 kW T-CO_2 System for Cold Rooms

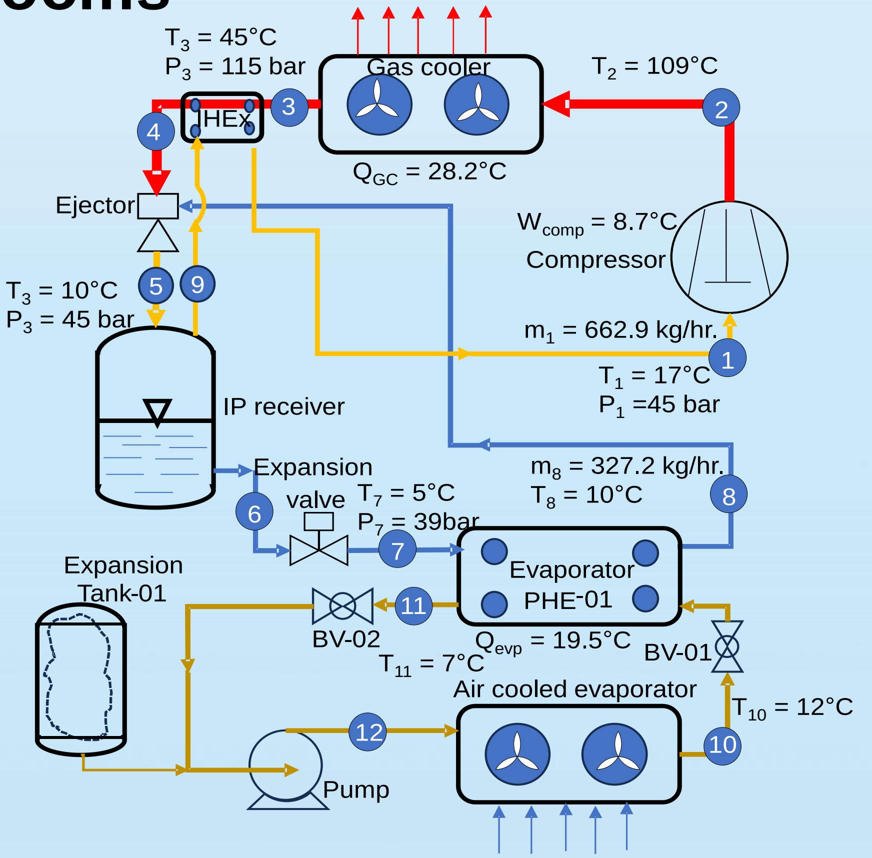


COP=1.95

Simple gas bypass system

Project Funded by
UNIDO, FLCTD
BEE, Danfoss
INDEE+, Alfalaval

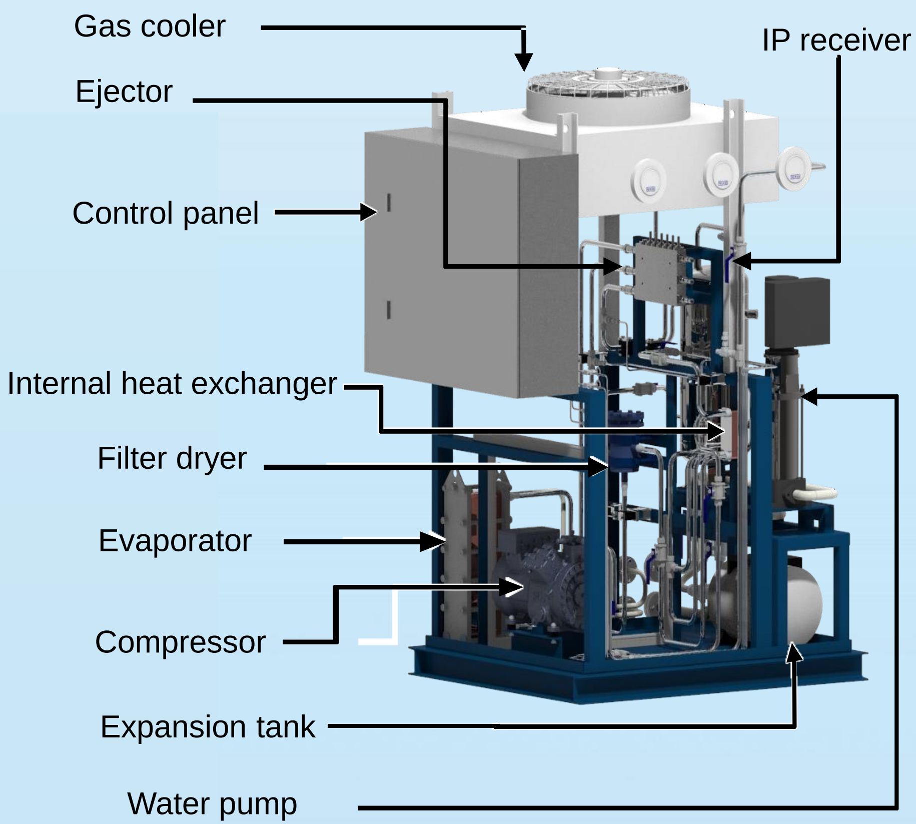


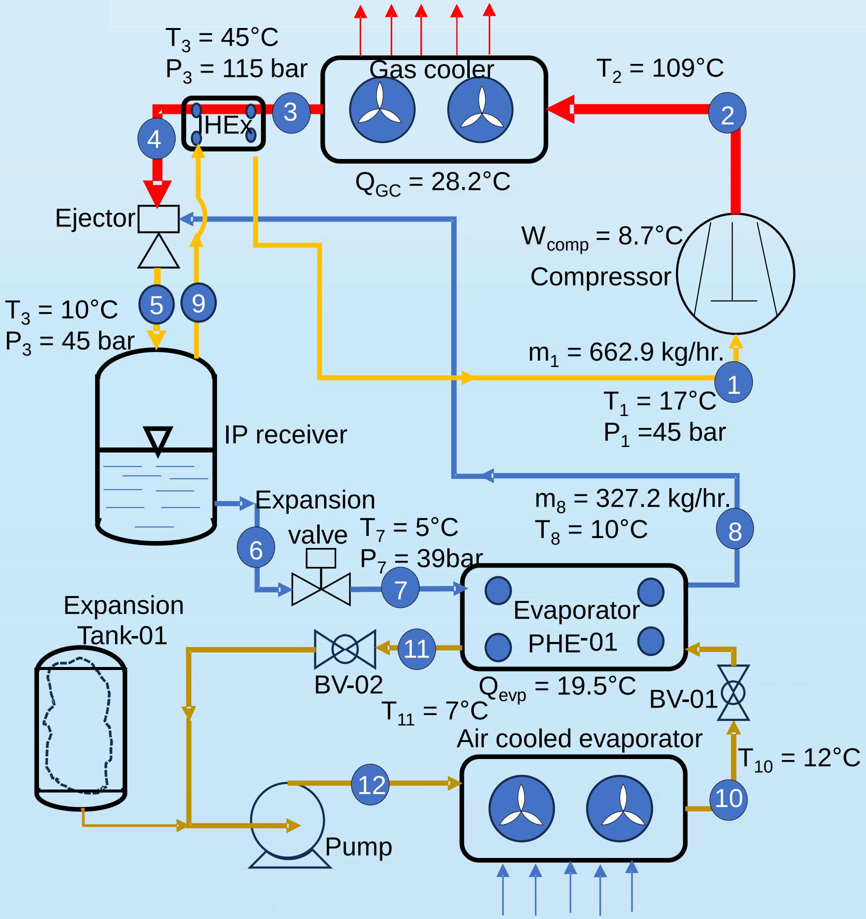


Ejector system

COP=2.24

L×W×H = 1.4m×1.2m×2.3m





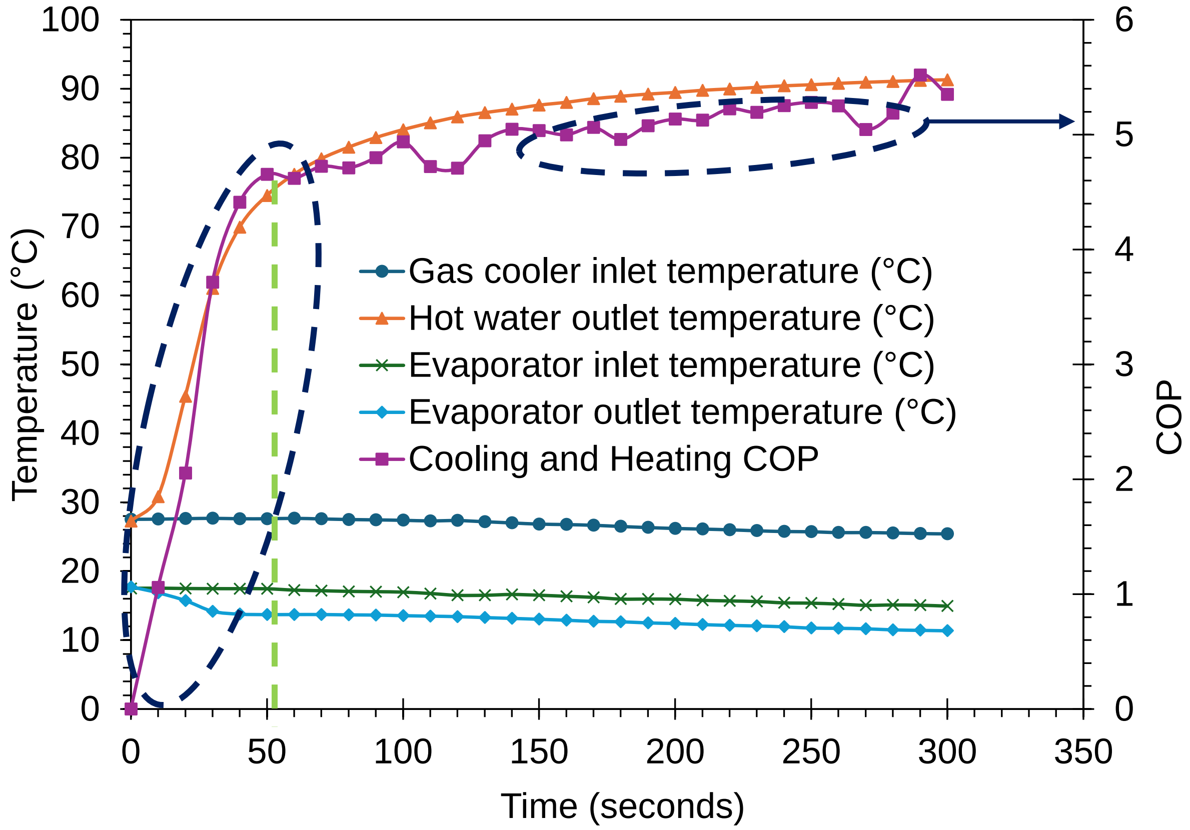
Expected Date of Commissioning at Snowman Logistics, Bengaluru

Jan 2025

140 kW Transcritical CO_2 Heat Pump For Mondelez India

Compact footprint of 1.5x1.2x2.4 m^3 (LxWxH)

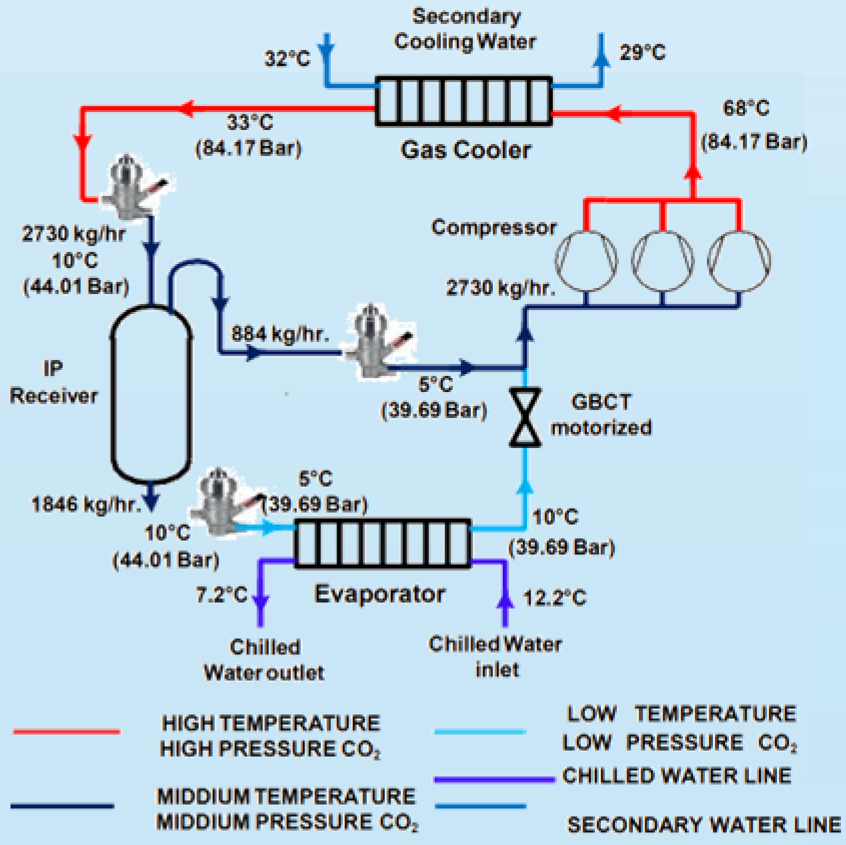
140 hours of testing over the entire operating range including 72 hours of endurance test completed at IISc Bengaluru



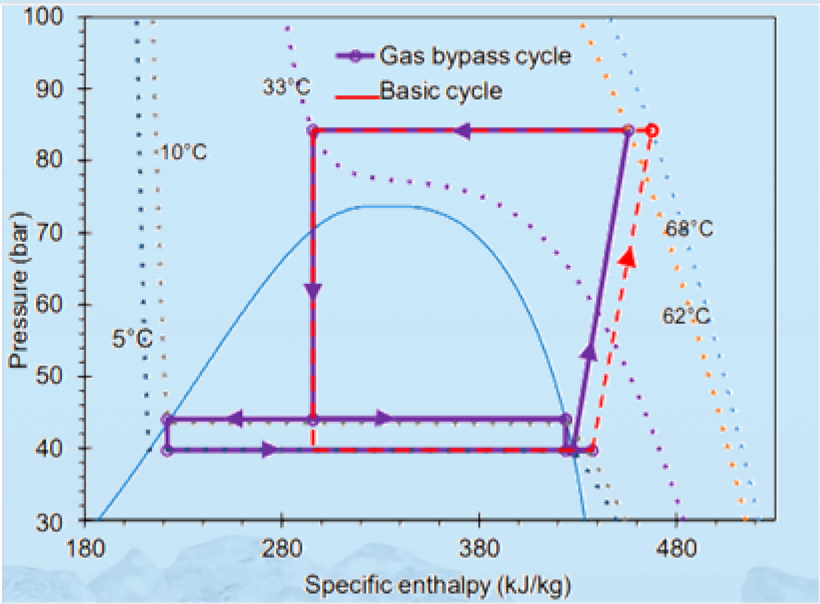
Hot water from 24°C to 85°C in 53s!

100 kW Transcritical CO_2 Chiller for Indian Navy

- *Cooling capacity: 30TR*
- Maximum Pressure: 120 bar
- Maximum Discharge Temperature: 85°C
- Material of Construction : SS316 (CO_2 side)
  : Titanium (Water side)
- Gas Cooler Temperatures (Ambient) : 18-40 °C

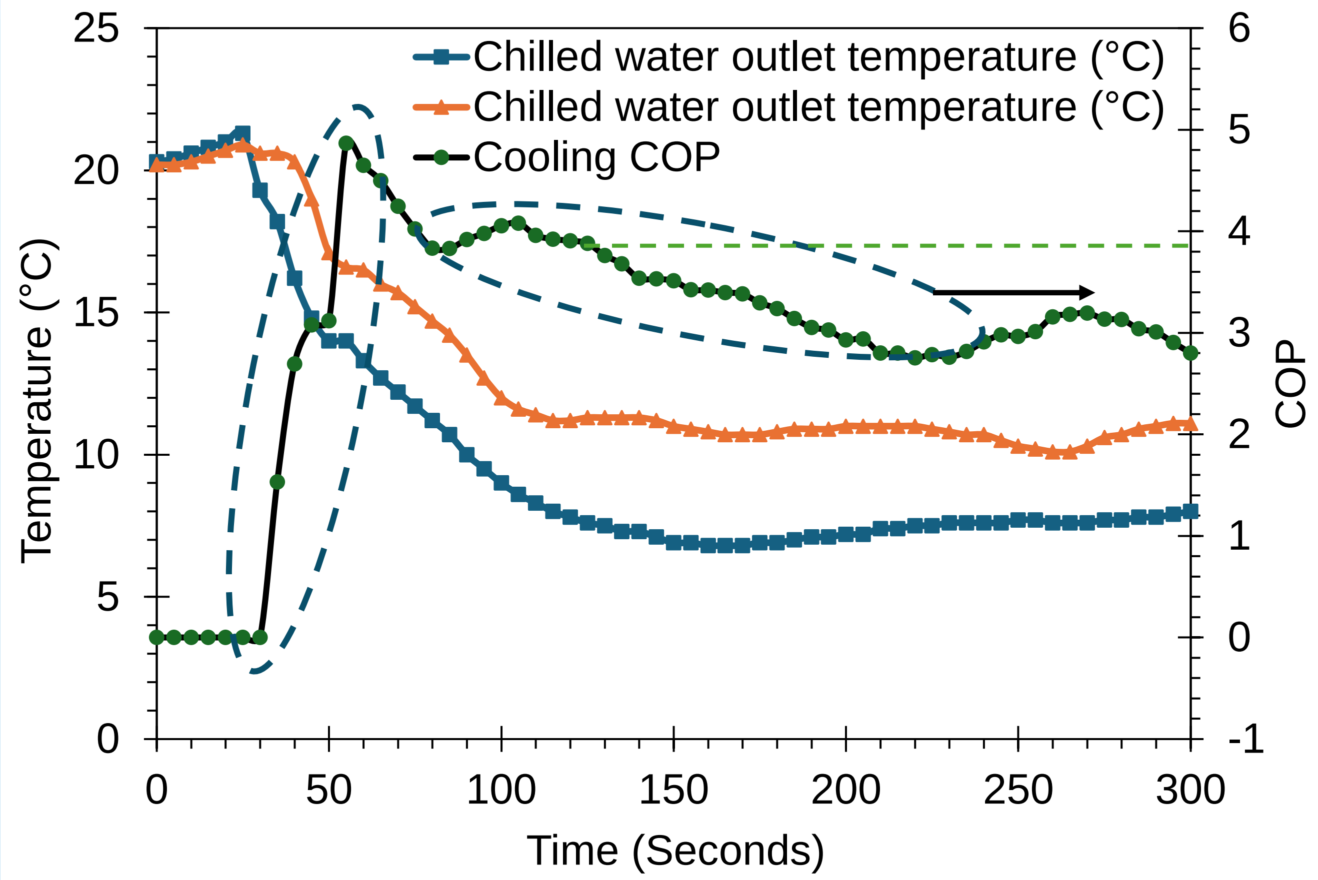


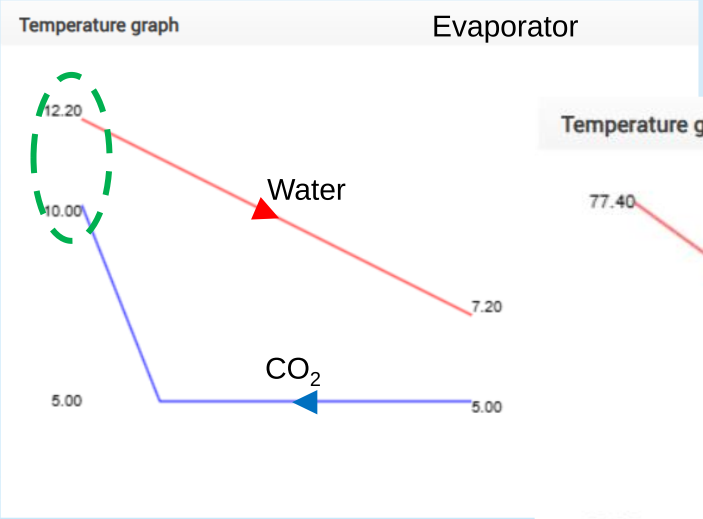
Schematic of T-CO_2 Cooling System

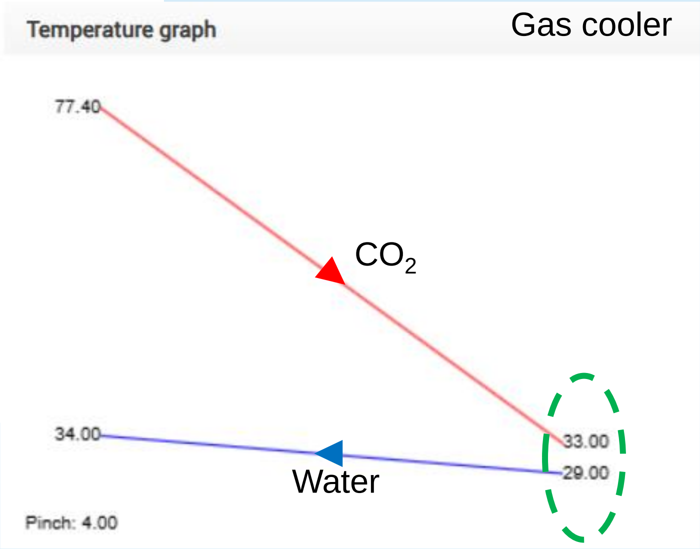


p-h diagram of T-CO_2 Cooling System

Transcritical CO_2 Chiller for Indian Navy- Performance Data



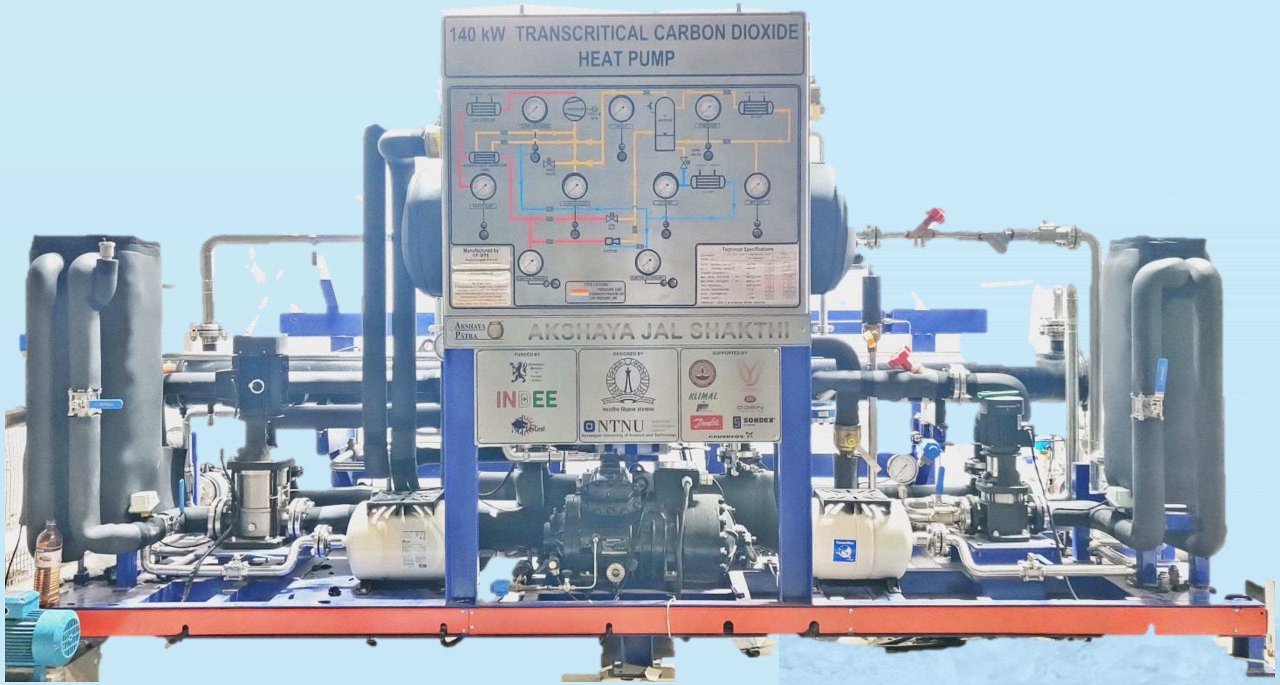




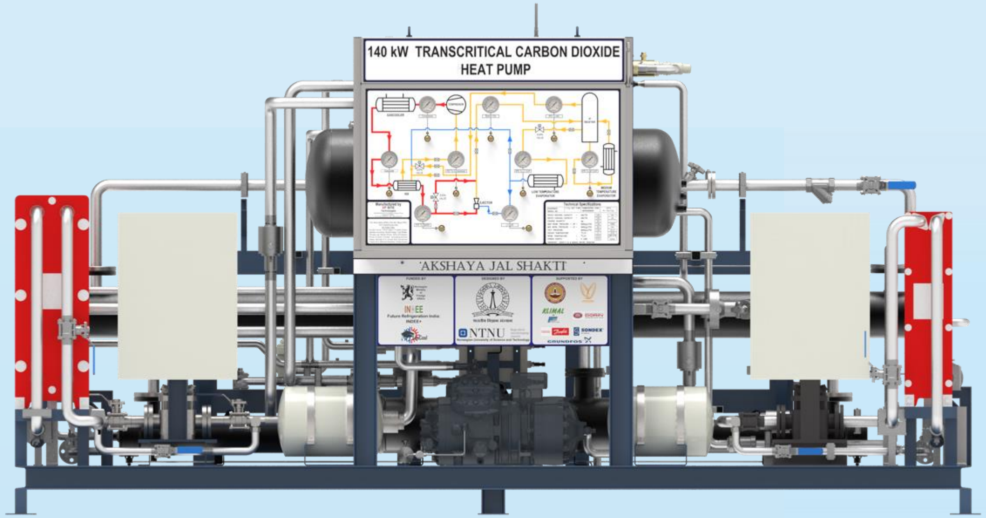
Extremely low temperature splits (pinch) possible with CO_2 in both evaporator and gas cooler

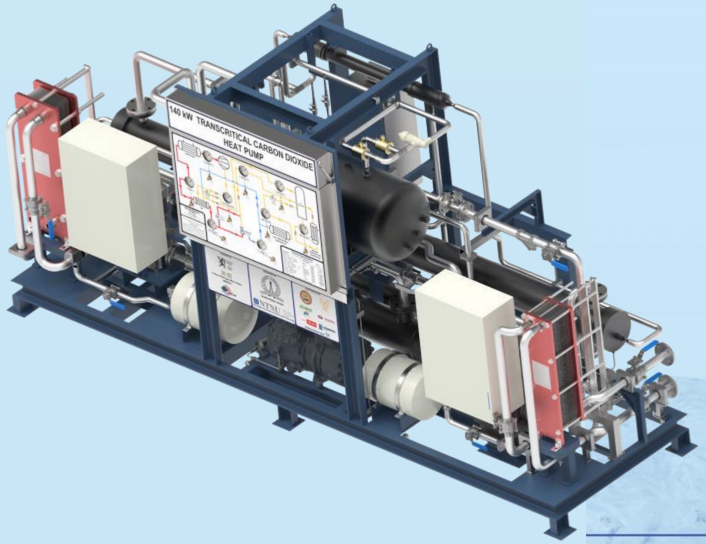
The system has been operational since 2022 and has clocked over 2600 hrs

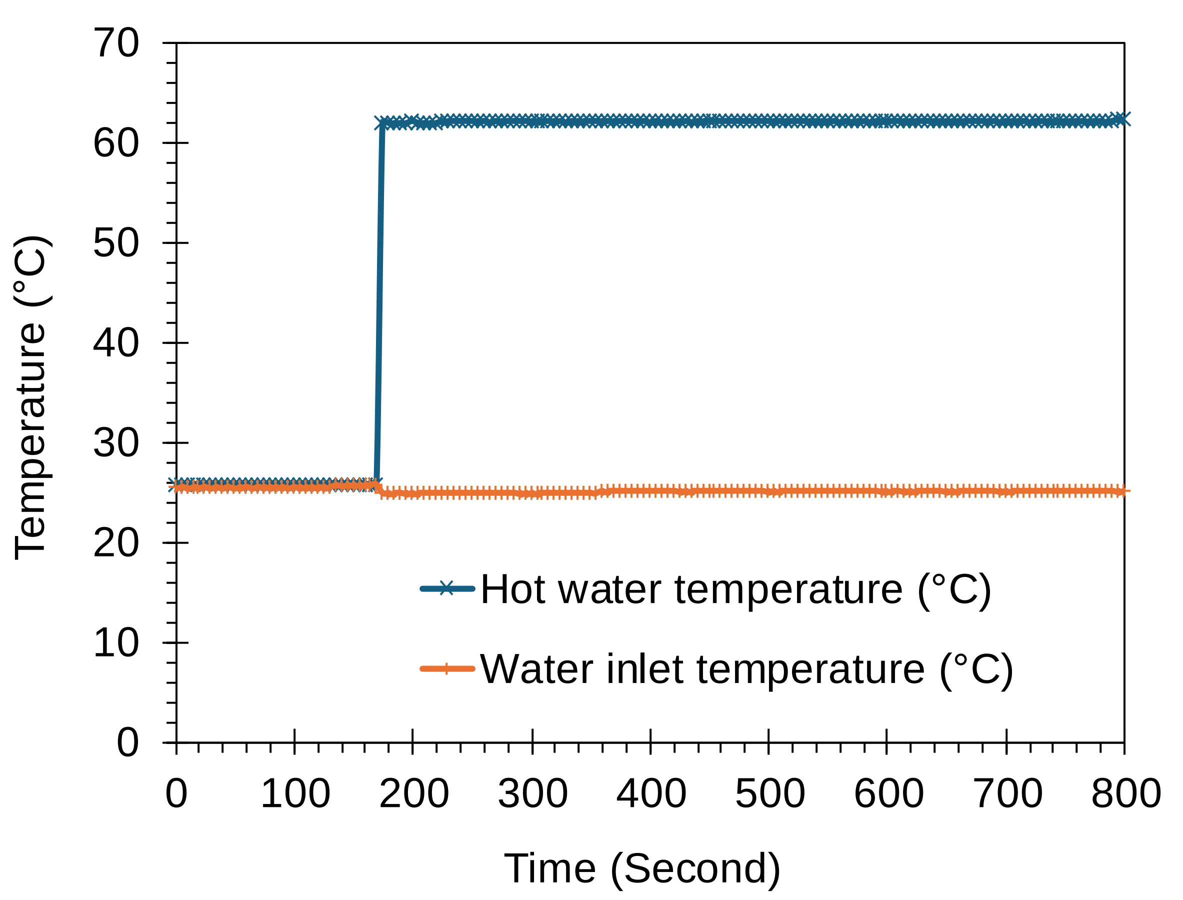
Transcritical CO_2 Heat Pump for Akshaya Patra Foundation



Tentative ROI Calculation		Units
Requirement	20,000	LPD
Initial feed water temp	25	°C
Obtained Water temp	87	° C
Differential Temp	62	° C
Hot water through Heat Pump		
Input Power required	40	kW
COP of Heat Pump	3.62	
No of operation hours required	13	hours
Total Heat load generated	1,882.40	kWh
No of units consumed for heat Pump	520	kWh
No of units consumed for circulation pump	29.09	kWh
No of units consumed for kitchen circulation pump during 4 hours of operation	6.71	kWh
Total no of units consumed for Hot water system	555.81	kWh
Unit Rate of kWh	11	Rs/kWh
Operation cost of the Hot Water system per day	**6,113.88**	**Rupees**
Operation cost of the Hot Water system for 25 Days	**1,52,847.20**	**Rupees**


140 kW TRANSCRITICAL CARBON DIOXIDE HEAT PUMP
"AKSHAYA JAL SHAKTI"




70
60
50
40
30
20
10
0
Temperature (°C)
0
100
200
300
400
500
600
700
800
Time (Second)
Hot water temperature (°C)
Water inlet temperature (°C)

Potential for Transcritical CO_2 Systems in India

1) ***Heat Pumps:***
   Process Industries like Dairy, Pharma, Food Processing
2) ***Combined heating and cooling applications***
   Pharma, resorts, cabin cooling, beverage industries
3) ***On-demand heating and cooling***
   Hotels, Hospitals, Oil and gas, pasteurization, ice-making
4) ***Transient Operations***
   Transportation, short time intervals like fisheries, and shipping vessels, where both space and time matter
5) ***Low-temperature deep-freezing***
   Transport of medicines, cascade systems propane+CO_2, NH_3+CO_2
6) ***High Temperature Booster Heat Pumps***
   Cascade Heat Pumps- Isobutane+CO_2, Pentane+ CO_2 (70-130°C), flash steam generation, preheating to steam compressor










Challenges in Designing Transcritical CO_2 Systems for tropical climates

1) ***Transcritical Cycles***

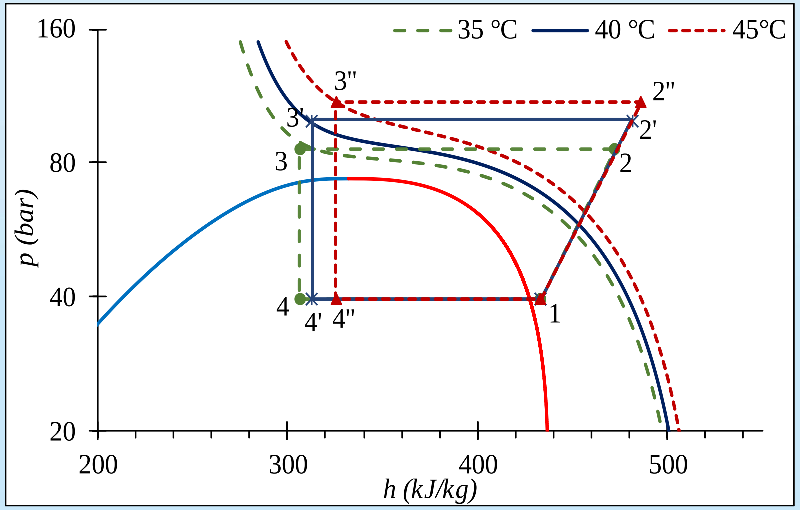
Conventional Ref. cycle knowledge is not sufficient to design transcritical CO_2 cycles

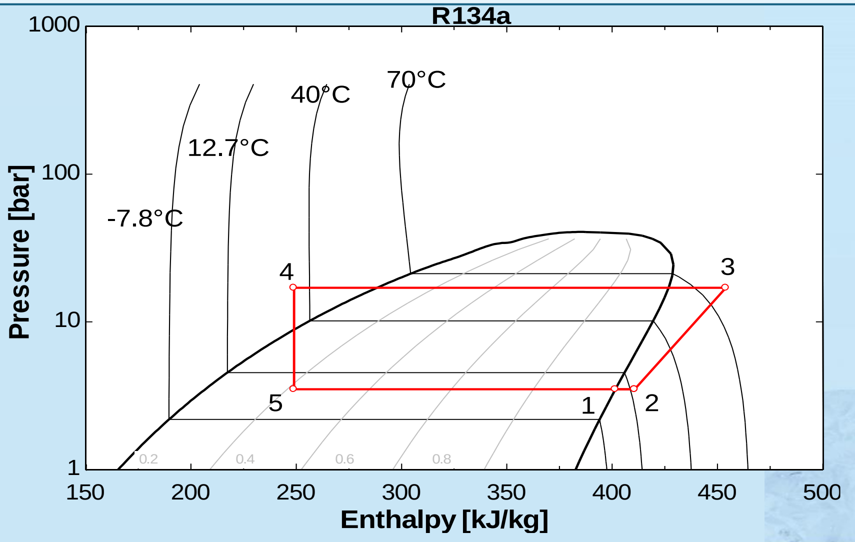
2) ***Tailored application-specific CO_2 cycles***

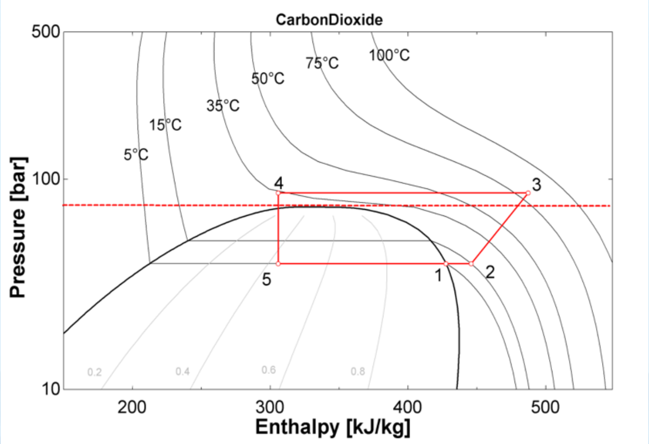
Each application requires a different cycle optimized for the application

3) ***Component selection plays an important role***

Significant drop in efficiency due to incorrect sizing







Pressure-enthalpy diagram of CO_2

Single Phase "Gas Cooler"
Pressure and Temperature can be independently varied

Challenges in Designing Transcritical CO_2 Systems

4. ***Lack of Support from suppliers, system designers, manufacturing***

   CO_2 cycles are new and require highly skilled manpower and advanced machines

5. ***Industrial Systems need handshaking with other equipment***

   Most control systems are closed and do not communicate with BMS or SCADA systems

6. ***Components are expensive and still developing***

   Controls are most expensive part ***(Compressors-20%, Heat Exchagners-25%, Skid Piping and Instrumentation- 25%, Controls- 30%)***

7. ***Initial investments are high for manufacturing***

   Leak detection tools, precision welding etc

Mandatory Equipment

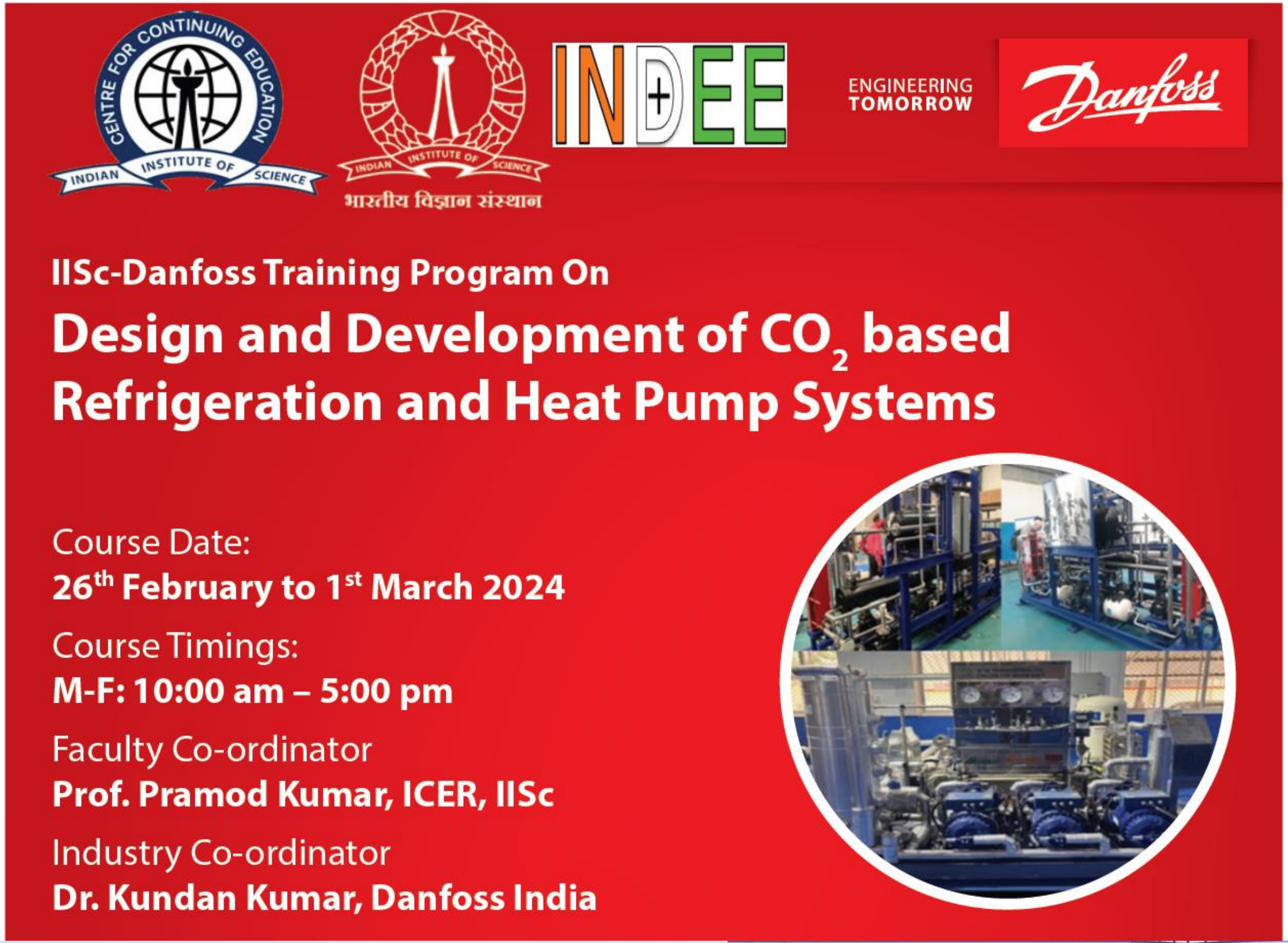
Leak Detectors

Booster Pump

Vacuum Pump

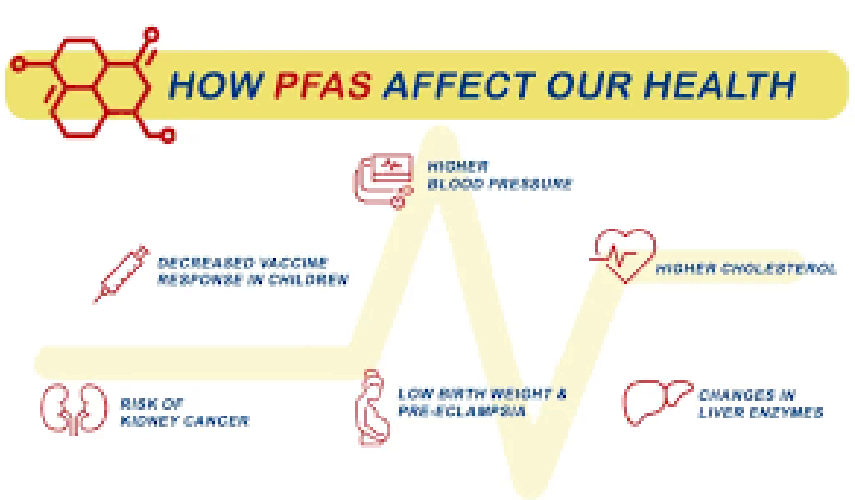
Oil Pump

Transcritical CO_2 Controls



Five-Day Training Program for Industry Participants

5 reasons why we should shift to Natural Refrigerants at the earliest?



1) ***Refrigerant Reclamation and Storage is a futile effort-*** *No OEM recommends reuse of old refrigerants*

2) *There are* ***no known mechanisms for safe disposal of used refrigerants*** *– Nobody knows it! Not even the manufacturer!*

3) ***Nobody knows the long-term harmful effects of these refrigerants -*** *The chemicals used for manufacturing refrigerants are destroying the water, soil environment, and everything that surrounds us!*

4) ***Synthetic Refrigerants are Expensive and are a proprietary product!***

5) *There are* ***no holistic studies that prove that energy saved using synthetic refrigerants during their lifetime*** *exceeds the energy used in manufacturing, storing, transporting, and safely disposing of them!*

Thermodynamics suggests that the energy needed to produce synthetic refrigerants can be nearly twice of what one would get by burning them!

India-Norway Collaboration 2021-2024

INDEE

Future Refrigeration India:
INDEE+

Acknowledgements

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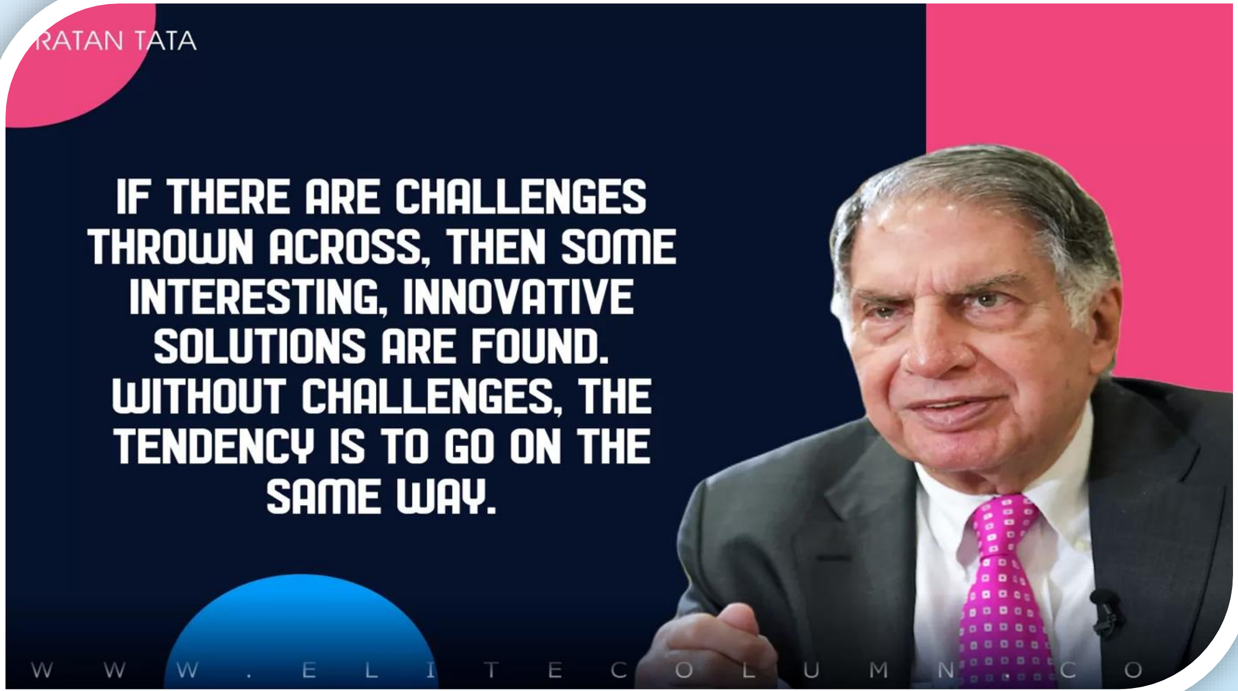
NTNU SINTEF IIF IIR ECOrefTEC CEEW

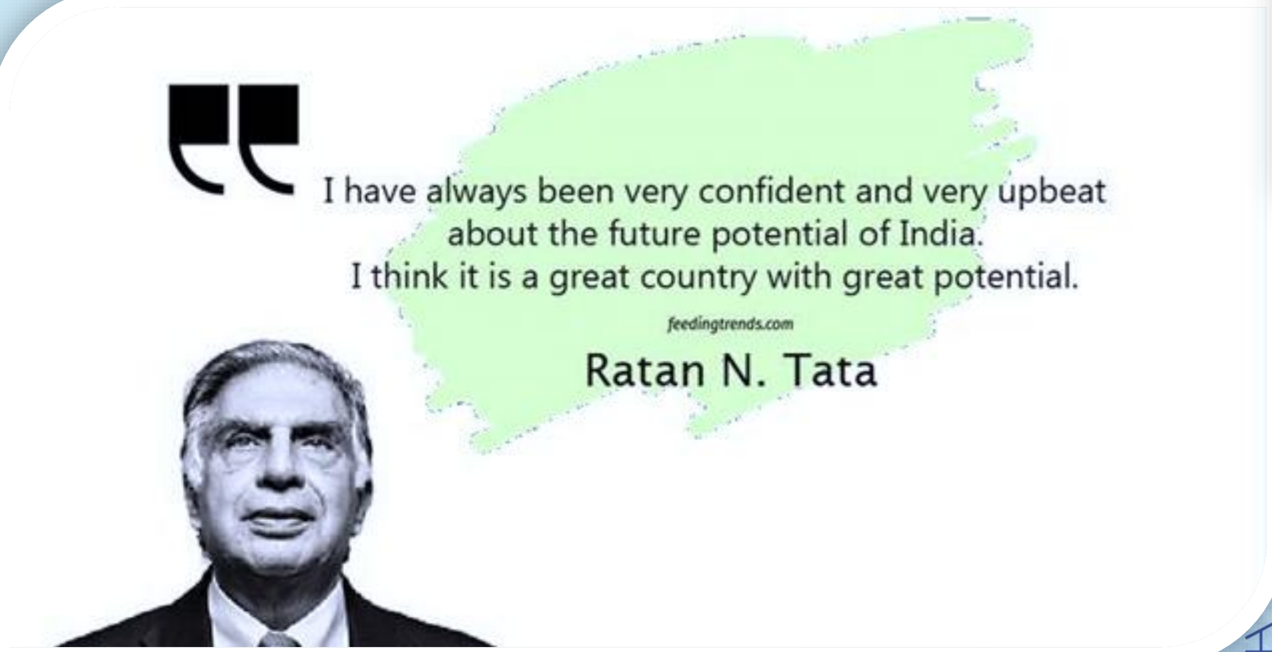
Norwegian Embassy New Delhi

INDEE+

updates:

Questions?





THANK YOU!

INDEE

Future Refrigeration India: INDEE+

India - Norway Collaboration (2021 – 2024)

Outcomes and Contributions to Indian cooling applications

Dr. Sarun Kumar KOCHUNNI & **Prof. Dr. Armin HAFNER**
NTNU

Funded by:

Norwegian Embassy
New Delhi

Coordinated by:

NTNU
Norwegian University of Science and Technology

Go Natural and apply Clean Cooling/Heating Systems

SINTEF
NORWEGIAN ENVIRONMENT AGENCY
IIF IIR
CEEW THE COUNCIL

- Hands on **Demonstrators** and **Educational Units**
- Team with a **common goal and spirit**
- **Vision** that refrigeration sector can support society keeping **growth** and increase **profits**

INDEE+ Demonstration Sites & Educational Units

INDEE

Area of Application	System and purpose	Leading Institutes	Vendor	End User
Hotel	CO_2 HP: 480 kW cooling capacity (Hot water and air conditioning)	NTNU	Medors Renewable Energy MEDORS	Antarim
Hotel	CO_2 HP: 290 kW heating capacity. Hot water and air conditioning*	IIT Madras, NTNU	Koshyma Engineering Pvt Ltd KOSHYMA Equipment Fabricators	
School Kitchen	CO_2 HP: Hot water and air conditioning	IISc, IIT Madras, NTNU	aspiration energy	Akshaya Pātra Unlimited food for education
Industrial processes (Boiler feed water heating)	CO_2 HP: 200 kW heating capacity. Hot water and air conditioning*	IISc, SINTEF, NTNU		
Maritime	150 kW NH_3/CO_2 cascade system. Low temperature tunnel/blast freezer	CIFT, SINTEF, NTNU	Cochin Food Tech Private Limited (CF Tech) CF TECH	Bell Foods Group
Maritime	350 kW NH_3/CO_2 cascade system. Low temperature tunnel/blast freezer	CIFT, SINTEF, NTNU	Cochin Food Tech Private Limited (CF Tech)	
Maritime	13 kW propane-based flake Ice maker for boats	BITS Pilani, SINTEF, NTNU	Mech Air Industries MECH-AIR	

* Under negotiation

IISc Bangalore:
Supermarket refrigeration

BITS Pilani:
Dairy Industry

CIFT Kochi:
Refrigerated Sea Water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NEA


Marco Bless
SINTEF Energy


Jan Bengsch
SINTEF Ocean


Lukas Köster
SINTEF Ocean


Didier Coulomb
IIR

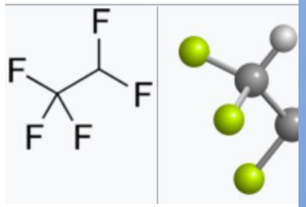
The INDEE Team

Artificial Refrigerants

PFAS

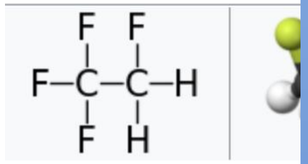
R-125

Pentafluoroethane



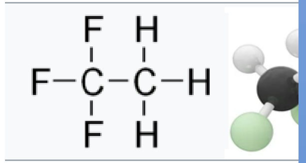
R-134a

1,1,1,2-Tetrafluoro



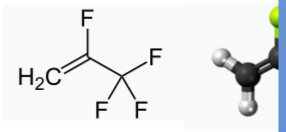
R-143a

1,1,1-Trifluoroetha



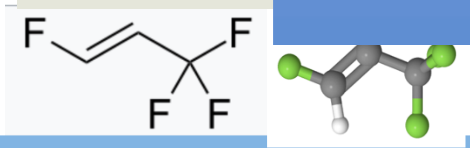
R-1234yf

2,3,3,3-Tetrafluoropr



R-1234ze

1,3,3,3-Tetrafluoropro

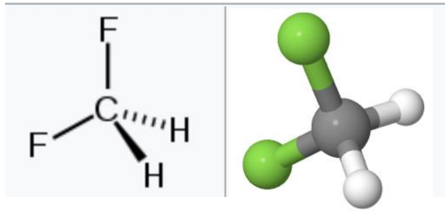


R450,R452,R454, R455, R456, R459, R469, R473, R508, R513, R514, R515, R472A, R454C, R468, R466A, +++

GWP

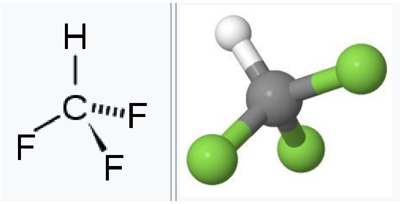
WP 675]

Difluoromethane



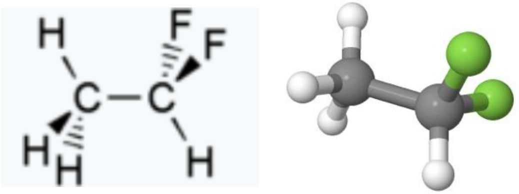
WP 18 400]

Trifluoromethane



[GWP 124]

1,1-Difluoroethane



Not:
fully fluorinated methyl, except R23 –> has H on it

The chemical scope of the PFAS restriction

The restriction proposal by ECHA is defined as: **Any substance** that contains at least:

- one fully fluorinated methyl (**CF_3-**) or
- methylene (**-CF_2-**) carbon atom (without any H/Cl/Br/I attached to it).

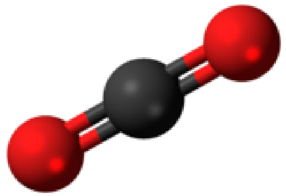
- A substance that only contains the following structural elements is excluded from the scope of the restriction: CF_3-X or X-CF_2-X',

RESTRICTION:

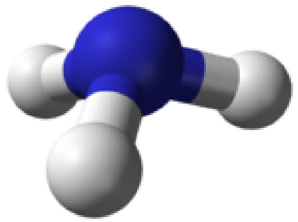
1. **Shall not be manufactured**, **used or placed on the market** as substances on their own;
2. Shall not be placed on the market in:
   a. another substance, as a constituent;
   b. a mixture,
   c. an article

Natural Refrigerants

Carbon Dioxide / CO_2 / R744



Hot water heat pumps,
Commercial- / low temp. industrial refrigeration
Heat pump chillers, low temperature freezing

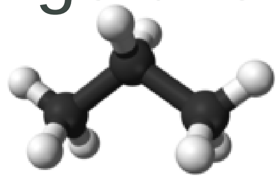


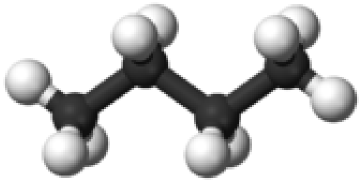
Ammonia NH_3 / R717

Industrial refrigeration and heat pumps

Hydrocarbons (Propane, Butane, etc.) / R290, R600

Residential AC split units, Light commercial refrigeration
Home appliances (fridges and freezers)
High temperature heat pumps





Take home message/question

INDEE

Is your customer able to invest twice in equipment the coming years?

- Implementing a non-natural working fluid system in the next years represents a bad asset for decades
- Sustainability reporting will be a key for successful business
  - -PFAS assets are not sustainable

Future Refrigeration India: INDEE

Contact us:

https://www.ntnu.edu/indee

THANK YOU!!!

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Go Natural and apply Clean Cooling/Heating Systems

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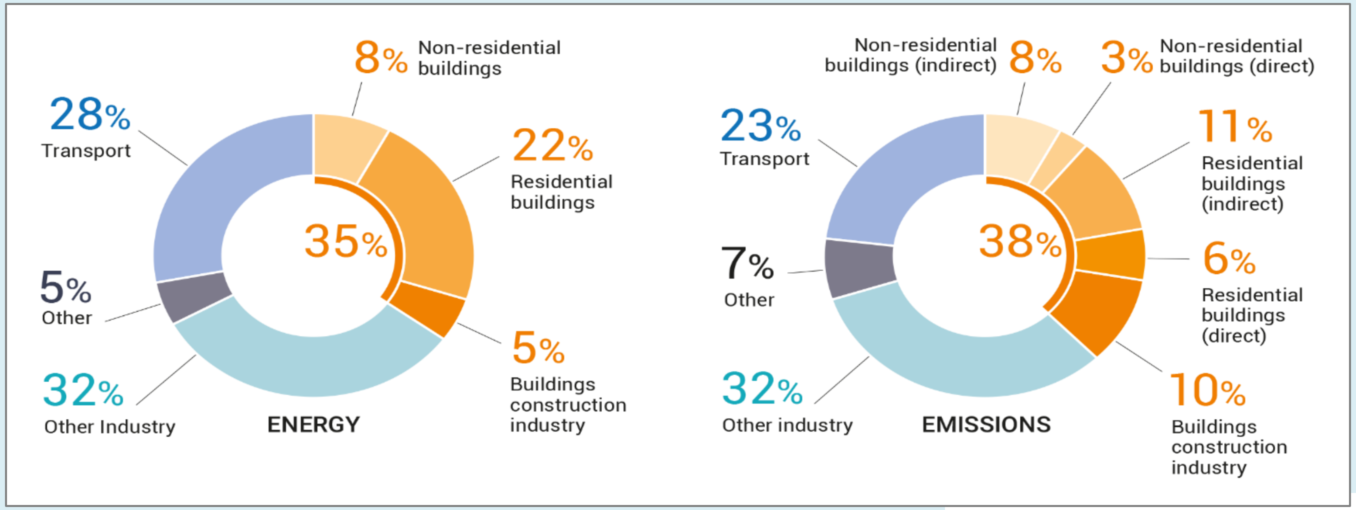
Potential of CO_2 Heat Pump for Hospital Application

Dr. Y. Siva Kumar Reddy
Post Doctoral Fellow
Indian Institute of Technology Madras, Chennai, India

Presentation outline

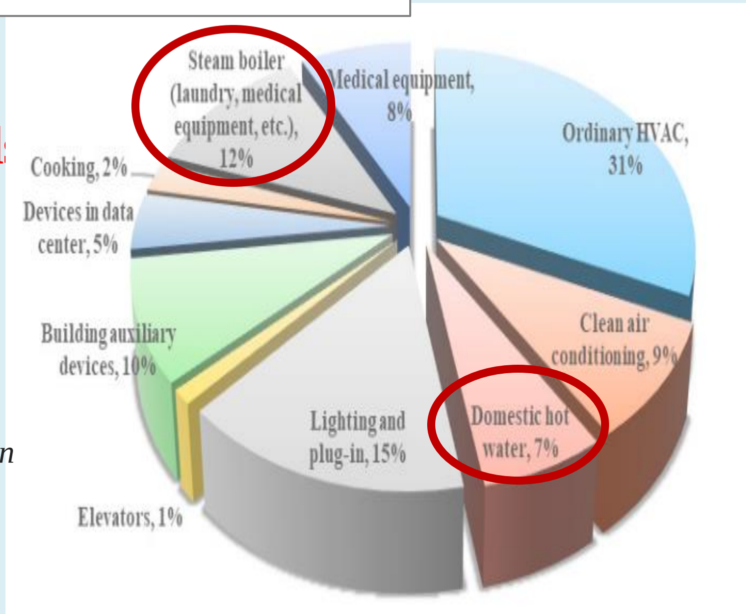
- World Energy Statistics and Energy breakdown for hospitals
- Existing heating system and parameters for hospital
- Proposed CO_2 heat pump chiller
- Sizing of CO_2 heat pump chiller
- Operating parameters, operating cost savings and ROI
- Concluding remarks

World Energy Statistics

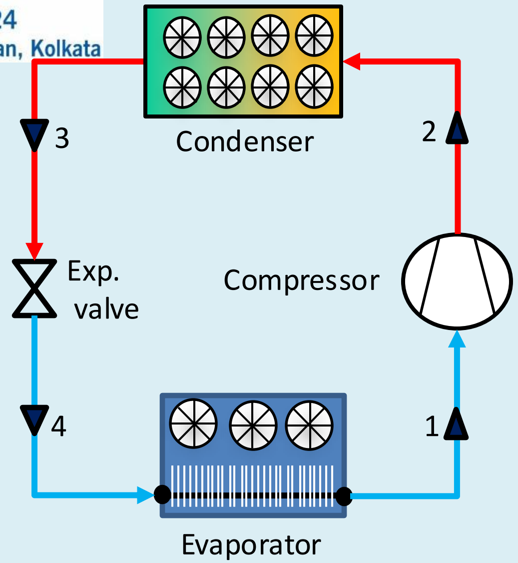


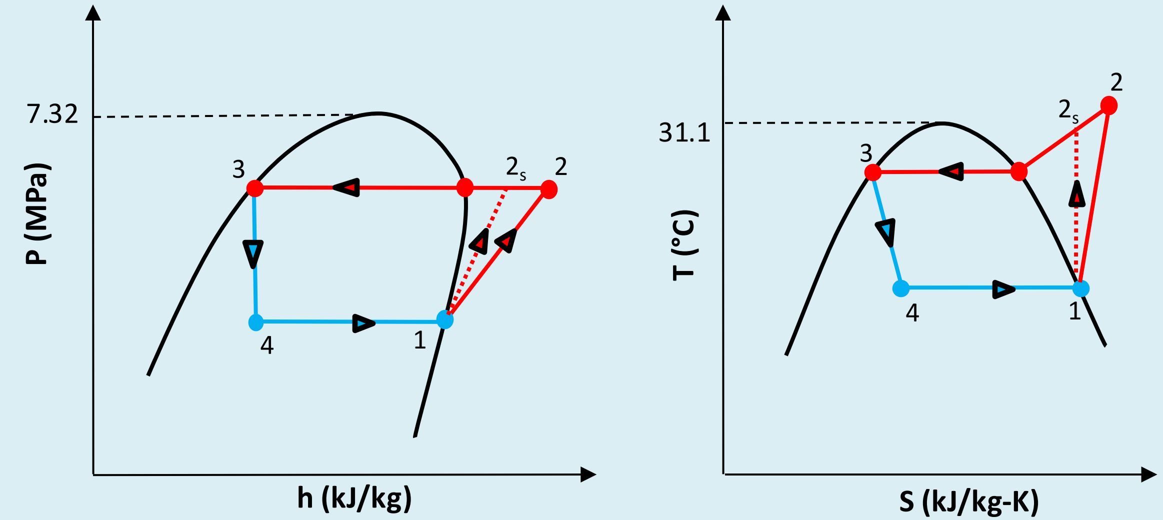
United Nations Environment Programme 2019 Global Status Report.

Energy breakdown structure for hospitals

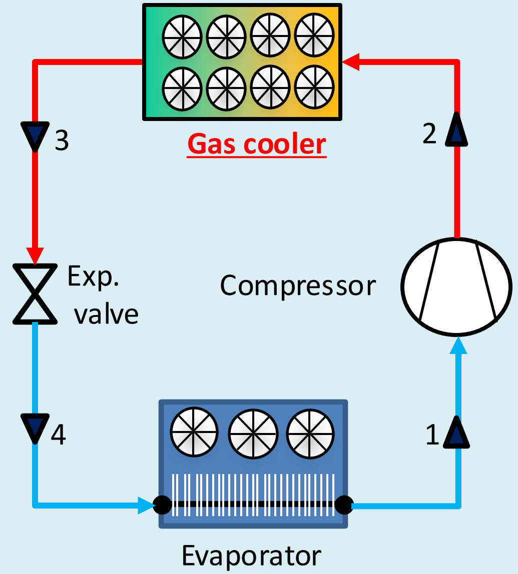


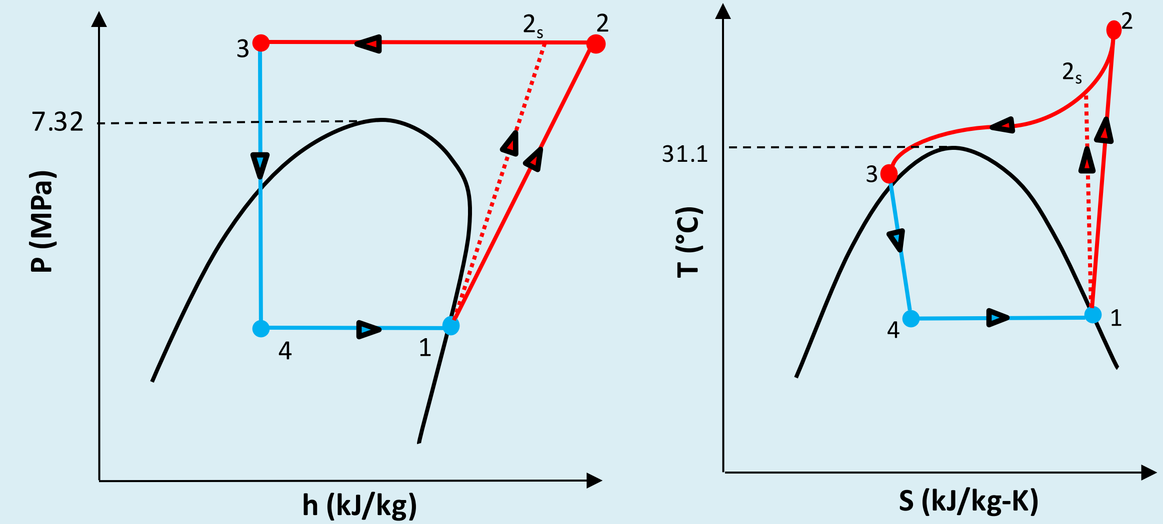
Shen, Chenyao, et al. "Analysis of building energy consumption in a hospital in the hot summer and cold winter area." Energy Procedia 158 (2019): 3735-3740.





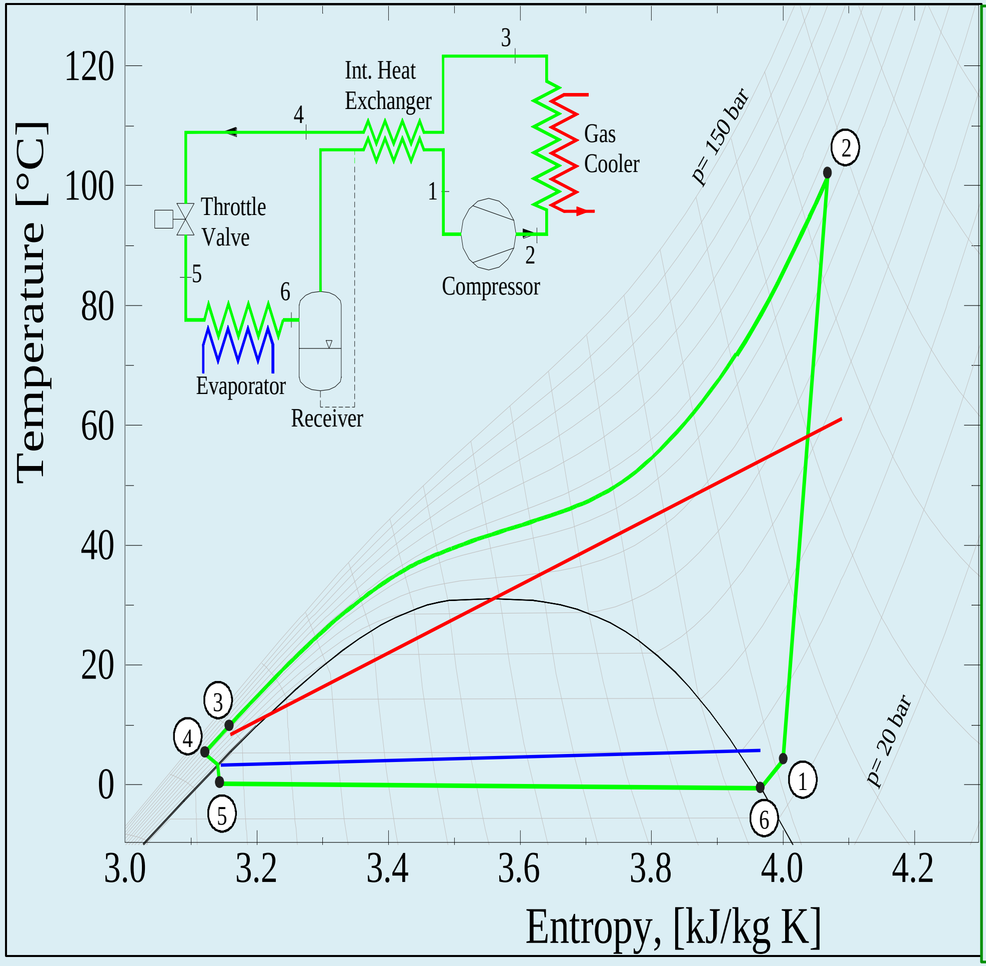
Simple VCR system





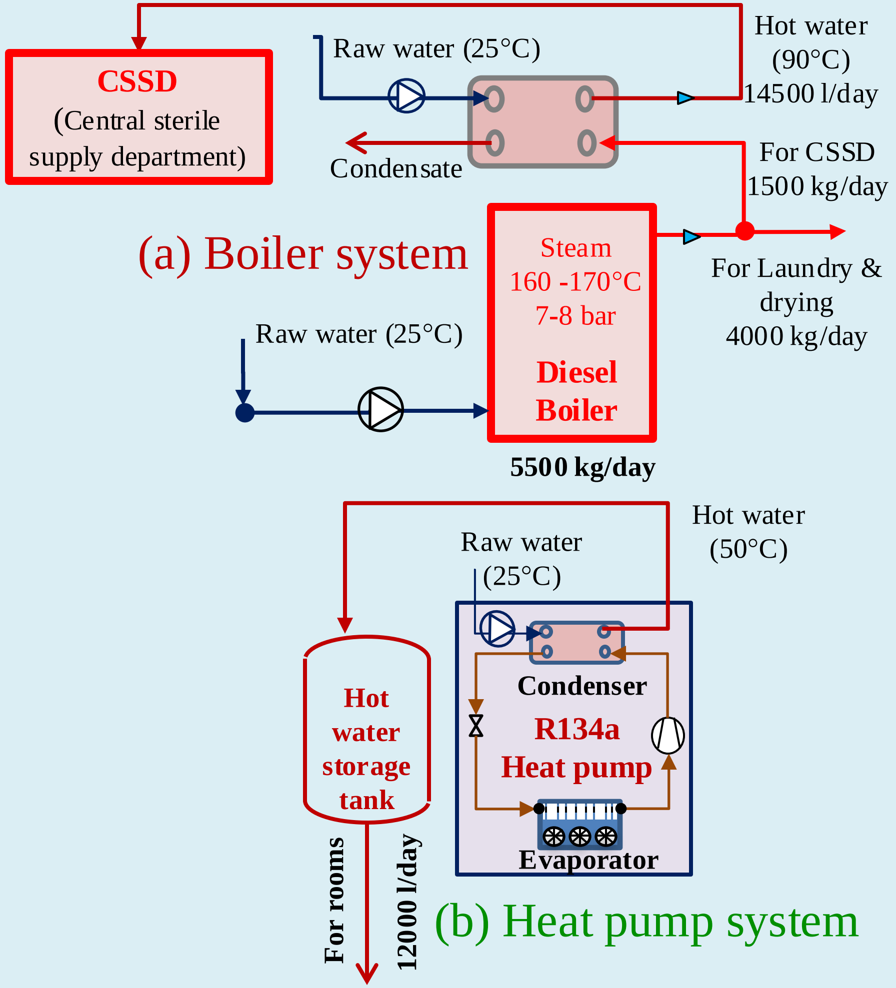
Trans-critical CO_2 VCR system

ONCE-FLOW THROUGH WATER "HEAT AND USE" IS A PERFECT APPLICATION FOR CO2 SYSTEM TO UTILIZE THE HEAT EFFICIENTLY



- **Sensible heat is available in the hot discharge CO2 gas at a temperature exceeding 120°C.**
- **The gas temperature drops as it rejects heat.**
- **If this thermal energy is utilized to sensibly heat any fluid matching the temperature gradient, then thermo-dynamically, there is no exergy loss.**
- **This concept can be used to efficiently heat the water from room temperature to nearly boiling temperature.**
- **Thus, Transcritical CO2 systems are well-suited for simultaneous cooling and once-flow through water heating.**

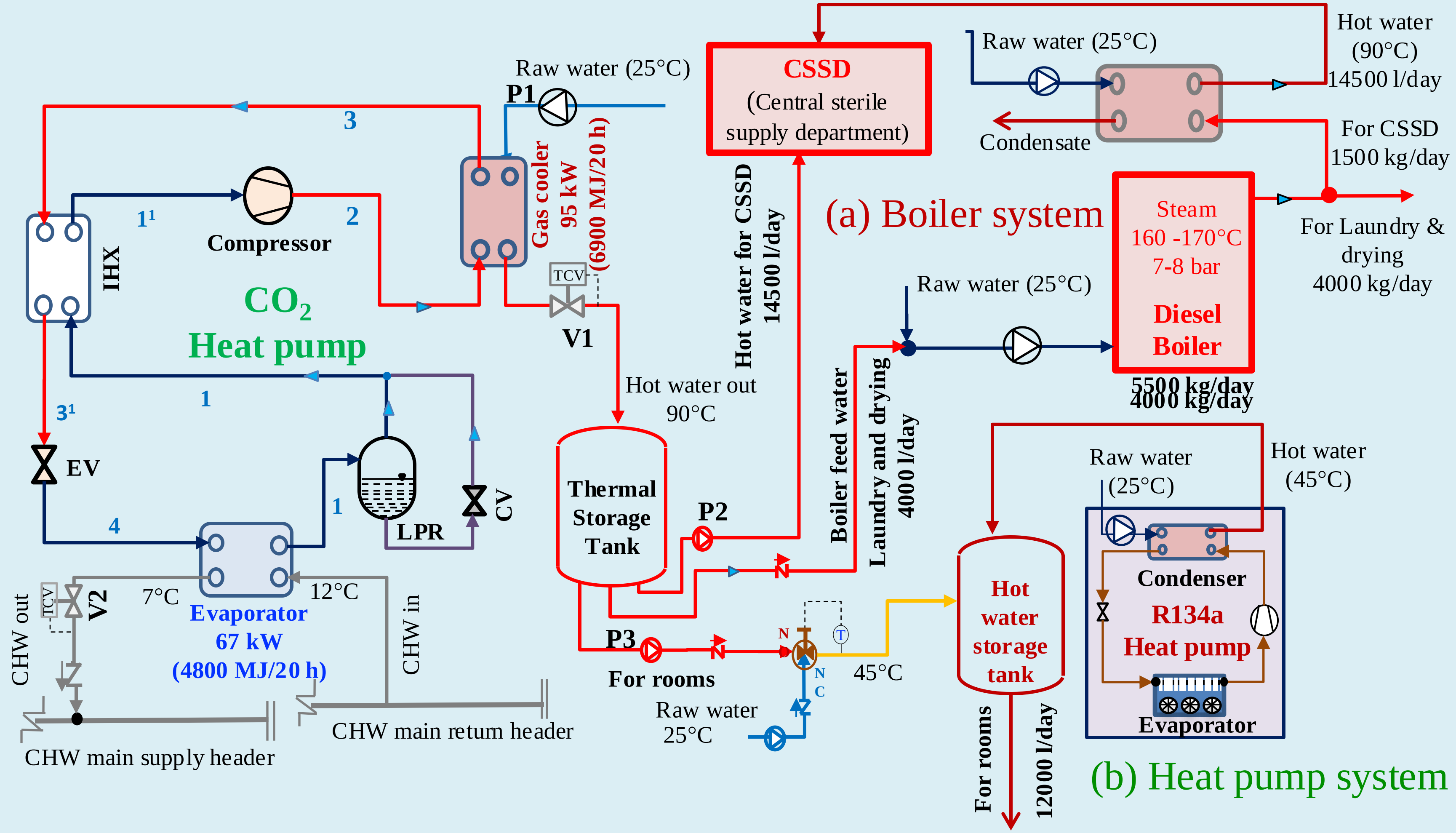
Existing heating systems for a 400-bed multi-speciality hospital



Operating cost of existing systems

S. No.	Parameters	Value	Unit
	R134a heat pump operating cost		
1	Hot water consumption for rooms per day at 45°C	12	kl/day
2	Temperature lift from 25 to 45°C	20	°C
3	Heating requirement for rooms per day	10,05,000	kJ/day
4	Operating hours of R134a per day	10	hours
5	R134a heat pump capacity	28.0	kW
6	Power consumption with COP_h = 5.7	6.2	kW
7	Annual operating cost with 12 INR/kWh, (C_1)	2,72,000	INR/year
	Diesel boiler operating Cost		
8	Steam required per day	5550	kg/day
9	Steam required pressure	7.5	bar
10	Total heat required	1,87,00,000	kJ/day
11	Diesel consumption per day	700	l/day
12	Boiler efficiency	70%	
13	Boiler operational hours	10	hours
14	Annual boiler operating cost with fuel price 94 INR/l, (C_2)	2,40,17,000	INR/year
	Existing chiller data		
15	Existing chiller operating load	2000	TR
16	Input Power	0.57	kW/TR

Proposed CO_2 heat pump chiller for the hospital



Sizing of CO_2 heat pump

- **Heat that can be provided by CO_2 heat pump in a hospital:**

1. All the heat required for CSSD: $Q_{CSSD}=m_{st,CSSD}*(h_{st}-h_{cond})$

($m_{st,CSSD}$ - steam required for CSSD per day, h_{st} – steam enthalpy & h_{cond} – enthalpy of condensate)

2. Partial amount of heat required for laundry and drying: ($Q_{(l+d),p}$) : $Q_{(l+d),p} = m_{st,(l+d)} *(h_{TST}-h_{w,amb})$ ($m_{st,(l+d)}$ - steam for laundry & drying per day, h_{TST} - enthalpy of hot water stored in TST (90°C)

3. All the heat required for rooms: $Q_{DHW}=m_{DHW}*c_{p,w}*(T_{DHW}-T_{w,amb})$

- **The heating capacity of CO_2 HP: $\dot{Q}_{HP} =(Q_{CSSD} + Q_{(l+d),p} + Q_{DHW})/(t_{HP,day})$**

($t_{HP,day}$ - operating time (20 h) of heat pump per day) **(95 kW Heating, 67 kW Cooling)**

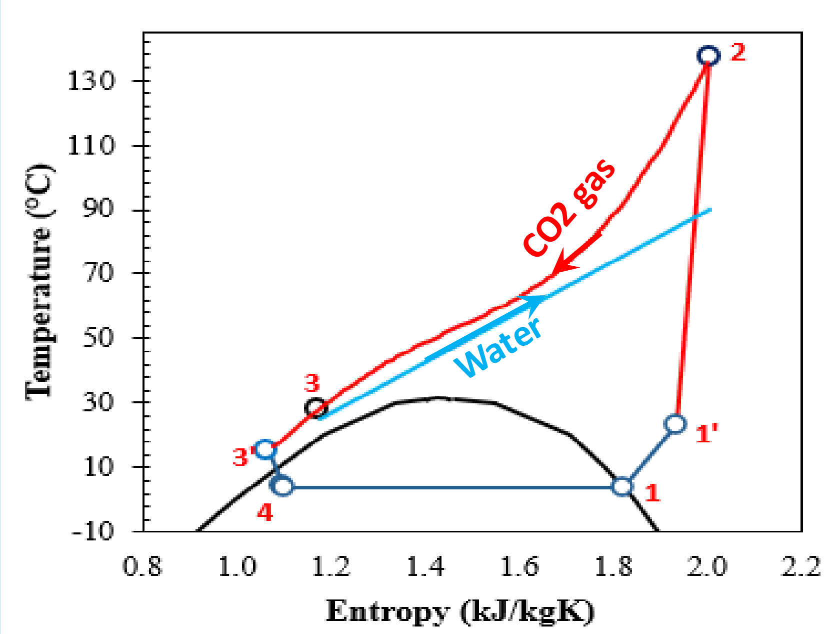
- **Heat to be provided by diesel boiler in a hospital:**

The diesel boiler has to provide the remaining heat, $Q_{db} = (m_{st,(l+d)})*(h_{st}-h_{TST})$

i.e., heating the boiler to feed water from 90°C to steam at 165°C (enthalpy h_{st})

CO_2 Heat Pump Operating Parameters

S.No.	Parameters	Value	Unit
1.	CO_2 HP heating capacity, (Q_{HP})	95	kW
2.	Evaporator temperature (T_e)	4	°C
3.	Effectiveness of IHX (ε_{IHX})	0.8	-
4.	Inlet water temperature to gas cooler ($T_{w,amb}$)	25	°C
5.	Outlet water temperature of gas cooler (T_{TST})	90	°C
6.	Gas cooler approach temperature	3	°C



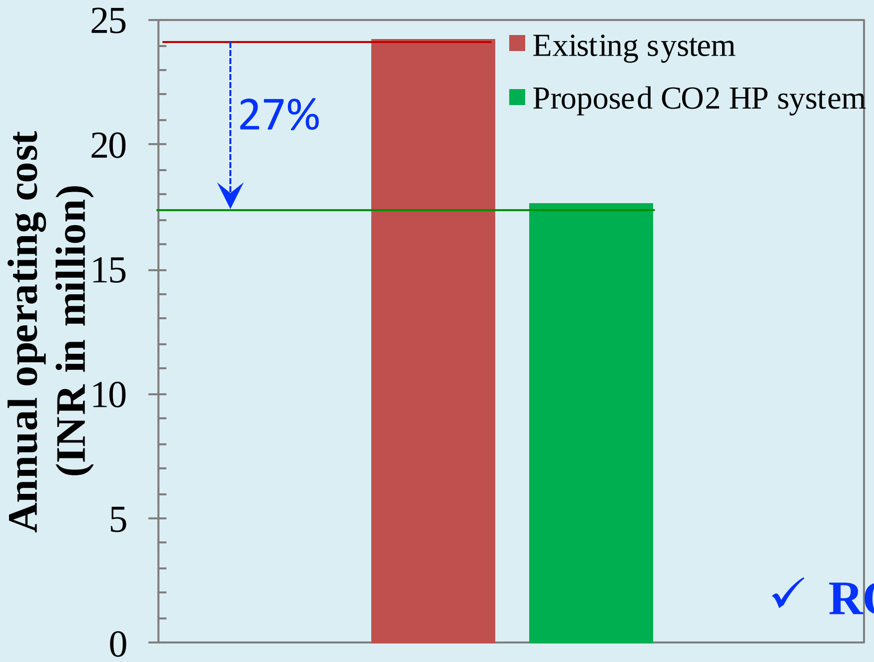
The cooling capacity of CO_2 HP: $Q_{cc} = \dot{m}_{CO2} * (h_1 - h_4)$

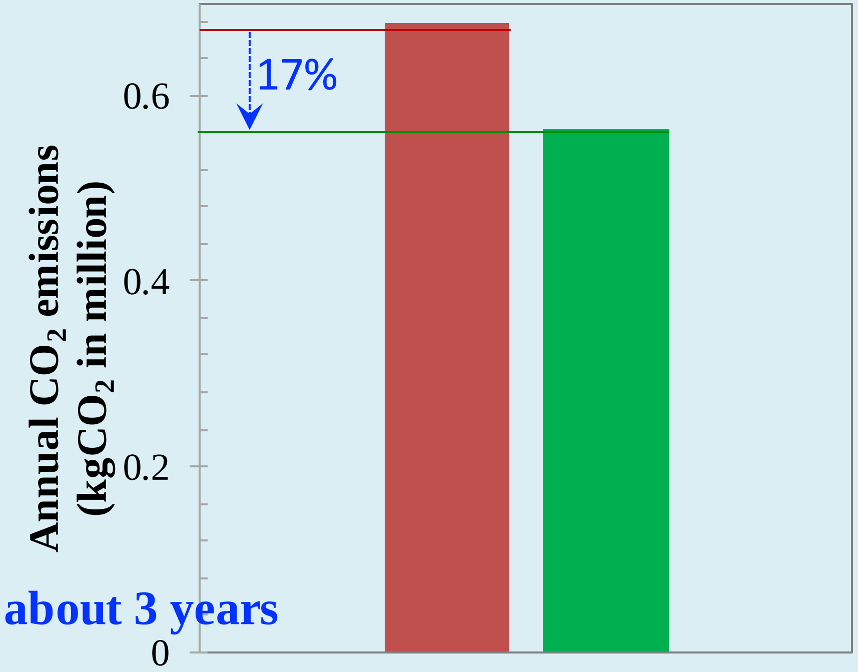
The compressor input power of CO_2 HP: $w_{comp} = \dot{m}_{CO2} * (h_2 - h_1{}^1)$

Annual operating cost savings and ROI

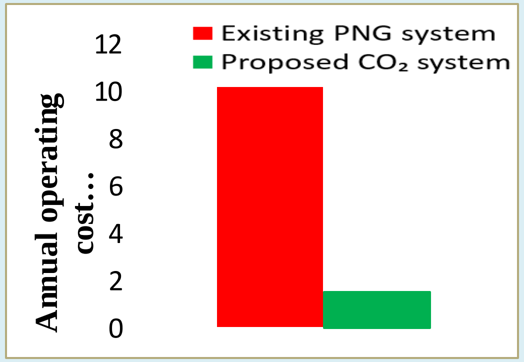
S.No.	Parameters	Value	Unit
	CO_2 HP operating cost		
1.	Maximum heat demand CO_2 HP could meet, Q_{HP}	68,65,000	kJ/day
2.	Required CO_2 HP capacity, Q_{HP} (for 20 hour operation/day)	95	kW
3.	Input power for CO_2 HP compressor, w_{comp}	28	kW
4.	Total power required including proposed pumps (P1, P2, and P3)	32	kW
5.	CO_2 HP operating hours in a day, $t_{HP,day}$	20	hour/day
6.	Price of electrical energy per kWh	12	INR/unit
7.	Annual CO_2 HP operating cost (C_3)	28,29,000	INR/year
	Chilling benefit from CO_2 HP		
8.	Free chilling capacity produced by CO_2 HP, Q_{cc}	67	kW
9.	Power rating for existing chiller	0.57	kW/TR
10.	Electrical Input Power Required for producing free chilling (1 TR = 3.5 kW)	11	kW
11.	Annual electricity operating cost savings by free chilling (C_4)	9,64,000	INR
	Existing diesel boiler operating cost to meet remaining heat (Q_{rem})		
12.	Remaining heat to be taken care by diesel boiler per day, Q_{rem}	1,23,95,000	kJ
13.	Diesel quantity required per day to meet Q_{rem}	460	l
14.	Annual operating cost of diesel to meet Q_{rem} (C_5)	1,58,17,000	INR
	Savings & ROI		
15.	Annual Cost savings (C_1+C_2-C_3+C_4-C_5)	6,600,000	INR
16.	Present building cost of the proposed CO2 heat pump in India	20,000,000	INR
17.	Return on investment (ROI)	~3	Years

Reduction in the operating cost and CO_2 emissions for Hospitals





✓ **ROI about 3 years**

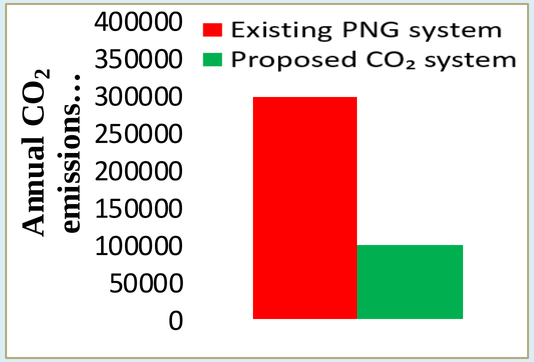


Compare with Hotels

Reduction in the operating cost and CO_2 emissions for Hotels

✓ ROI less than 2 years

Hotels don't need steam



CO2 heat pump integrated thermal storage for DHW in hotels. Journal of Building Engineering (2024). https://doi.org/10.1016/j.jobe.2024.109270.

Concluding Remarks

- The application of natural refrigerants is crucial.
- India's cooling and heating demands will grow exponentially.
- Transcritical CO_2 systems are well-suited for simultaneous cooling and once-flow through water heating.
- This study is focused on examining the feasibility of a CO_2 heat pump chiller for hospitals in India to meet heating demands.
- The potential for significant reductions in operating costs and CO_2 emissions, estimated at 27 and 17%, underscores the value of CO_2 heat pump chillers.
- ROI is about three years at the estimated cost of CO_2 HP installation in India.
- CO_2 system integrated with TST can be adopted as a viable, efficient, and clean solution for hospital heating needs.

Acknowledgments

Thank You

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Clean cooling solution to meet the heating and cooling demand in milk processing

SOUTH ASIA'S PREMIER REFRIGERATION & COLD-CHAIN EXHIBITION

FRESH & HEALTHY PRESERVATION THROUGH INNOVATIVE TECHNOLOGIES

Presented by:
Prof. M S Dasgupta
BITS, Pilani, India

India aiming for White revolution 2

5 year Target:

- Food and Nutritional security
- To set up 56000 new multi purpose Dairy cooperatives
- Strengthen 46500 existing dairy cooperatives
- Technology intervention at all level

What's unique about Indian Dairy sector

Operation Flood launched in 1970

- Worlds largest producer of milk with a wide margin.
- ~25% of global milk production (236.35 MMT in 2023-24)
- Only ~0.01% milk product exported, earning $272.64 million (2023-24)
- Dairy market is largest single agricultural item, ~22% of total agriculture value and 5% of GDP
- Steady rise in milk production and demand, 6.4% CAGR
- ~80 million rural households engaged in dairying and 71% are women
- 70% production come from dairy firm raising less than 10 animals – most common 2/3 animals
- Excellent example of cooperative type model implementation

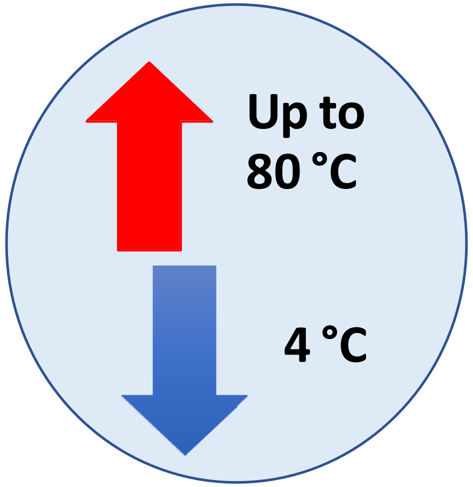
Indian Dairy sector

- Productivity low
- Methane emission is high due to low digestibility of fodder
- Carbon foot print estimated between 1.45 -1.81 kg CO_2 eq. per kg of milk
- 40 kWh/MT electrical and 60000 kCal/MT thermal energy input estimated

- Dairy sector has significant demand of both heating and cooling
- Use of natural refrigerants in Refrigeration and Heat pump application
- The Bureau of Indian Standards (BIS) adopted safety standards for natural refrigerants in 2020: IEC 60335-2-40:2018
- Technology intervention is a distinct focus of White Revolution 2

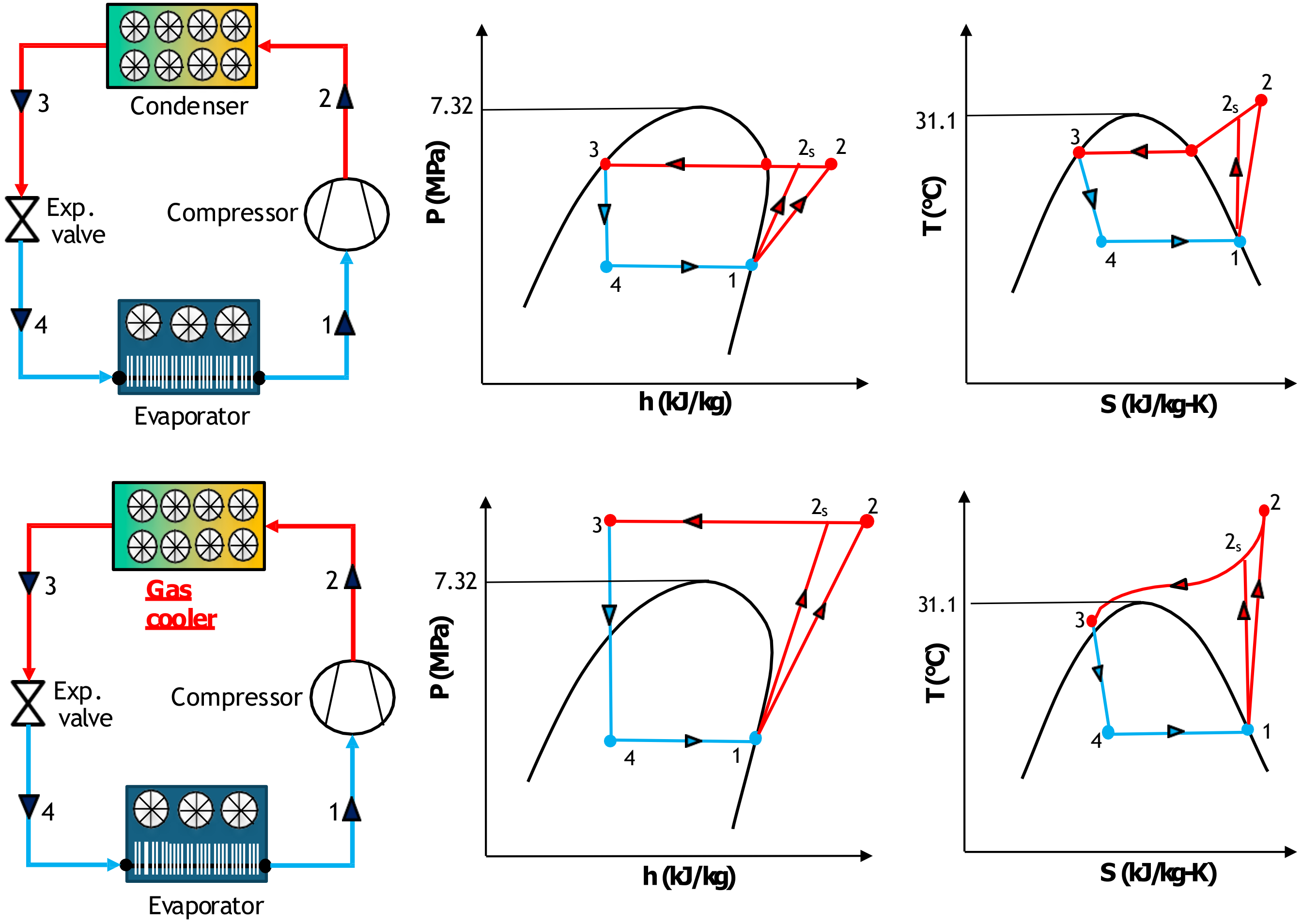
Heating and cooling requirement in dairy Industry

- Cooling:
  - Chilling of milk (4 °C)
  - Cold storage
- Heating:
  - Pasteurization of milk (72 °C)
  - Clean In Place (CIP)



- Conventional Systems:
  - **Cooling**: NH_3, R134a, R407c, R22… Vapour Compression system
  - **Heating**: Boilers, Solar thermal, Electric, Gas, Heatpump

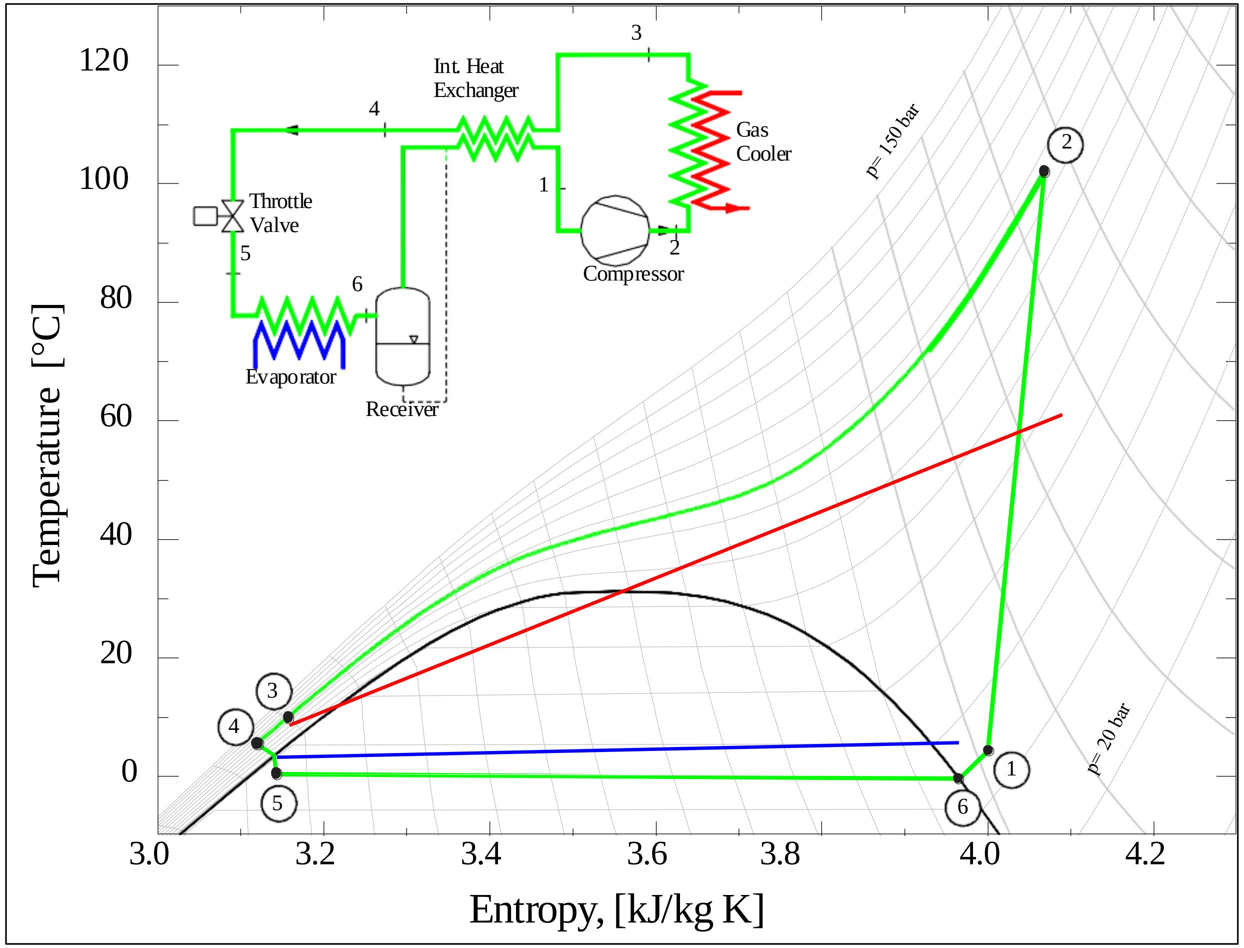
Advantage of Trans-critical CO2 over other VCR systems



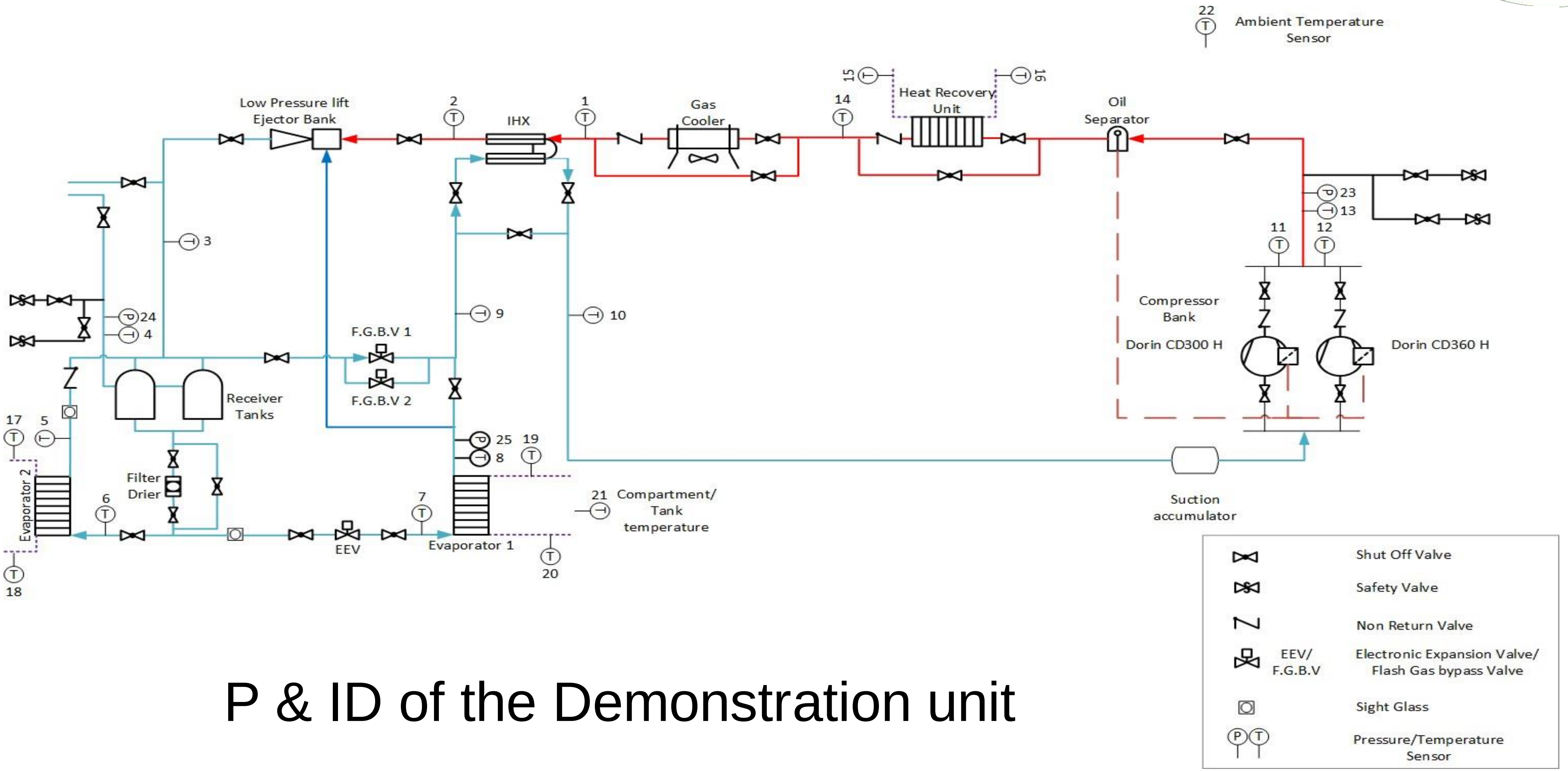
The transcritical cycle operation provides a large continuous temperature glide.

The lack of condensing or phase changing allows for a water profile that follows the CO2.

CO2 for simultaneous heating and cooling application

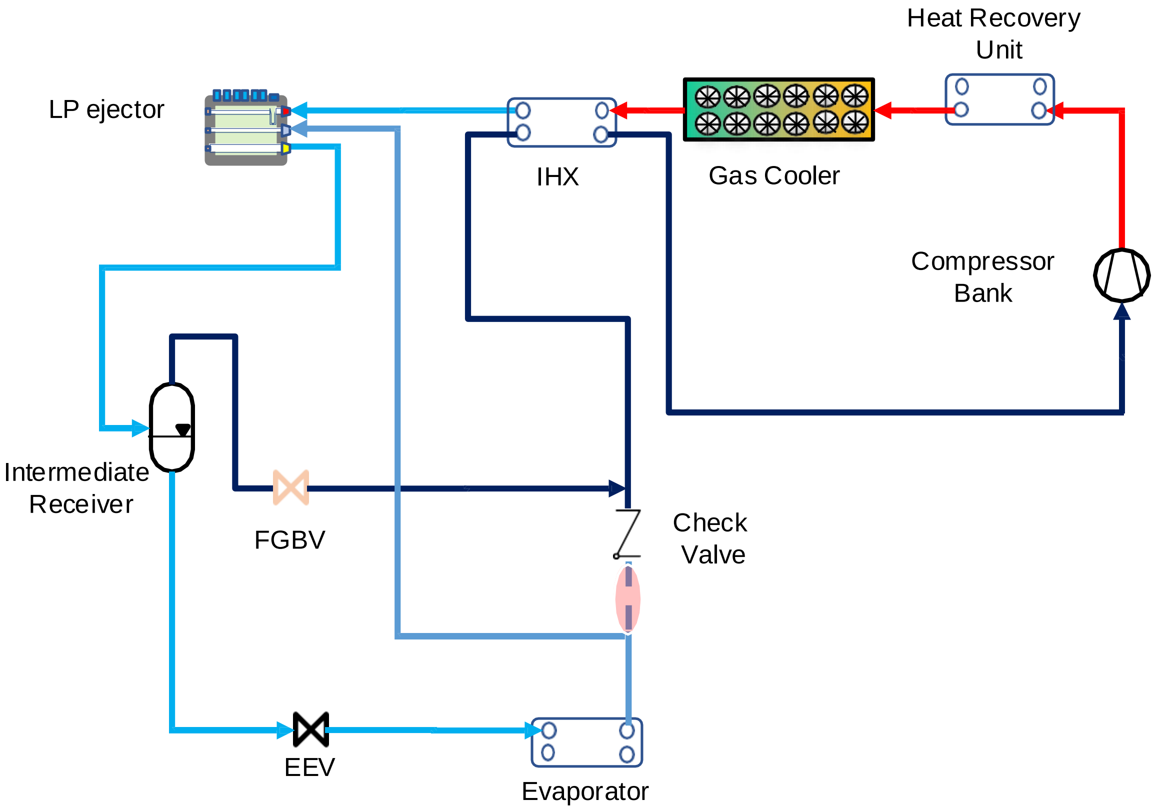


- Sensible heat available in the hot discharge CO_2 gas at a temperature exceeding 120 °C.
- Can be used to efficiently heat the water from room temperature to nearly boiling temperature.
- Reduce exergy loss

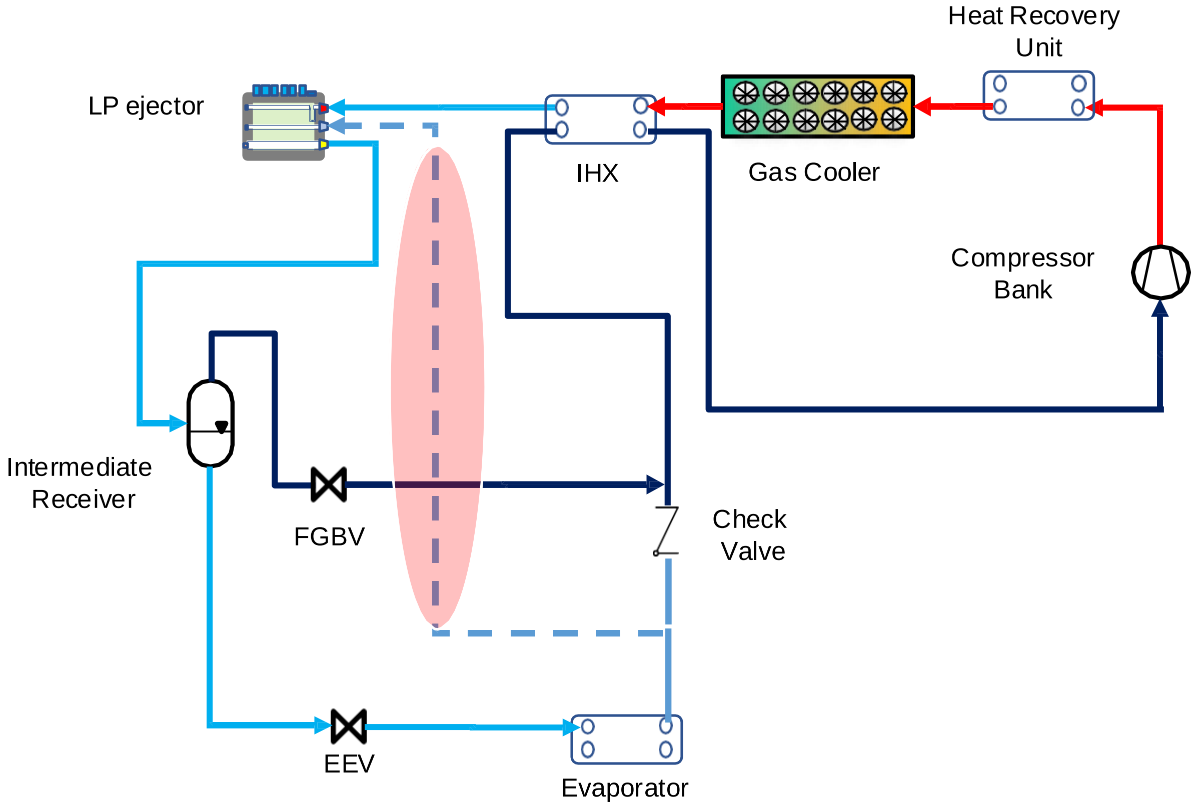


P & ID of the Demonstration unit

Summer Operation



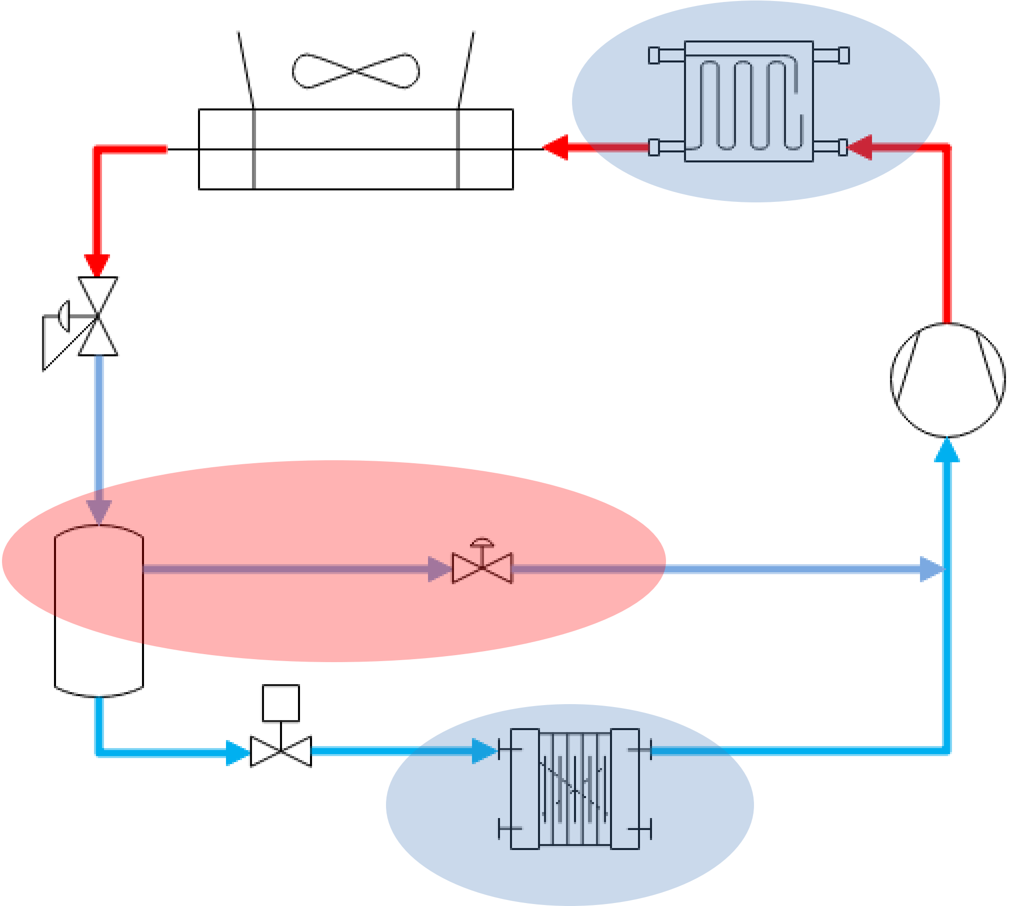
Winter Operation



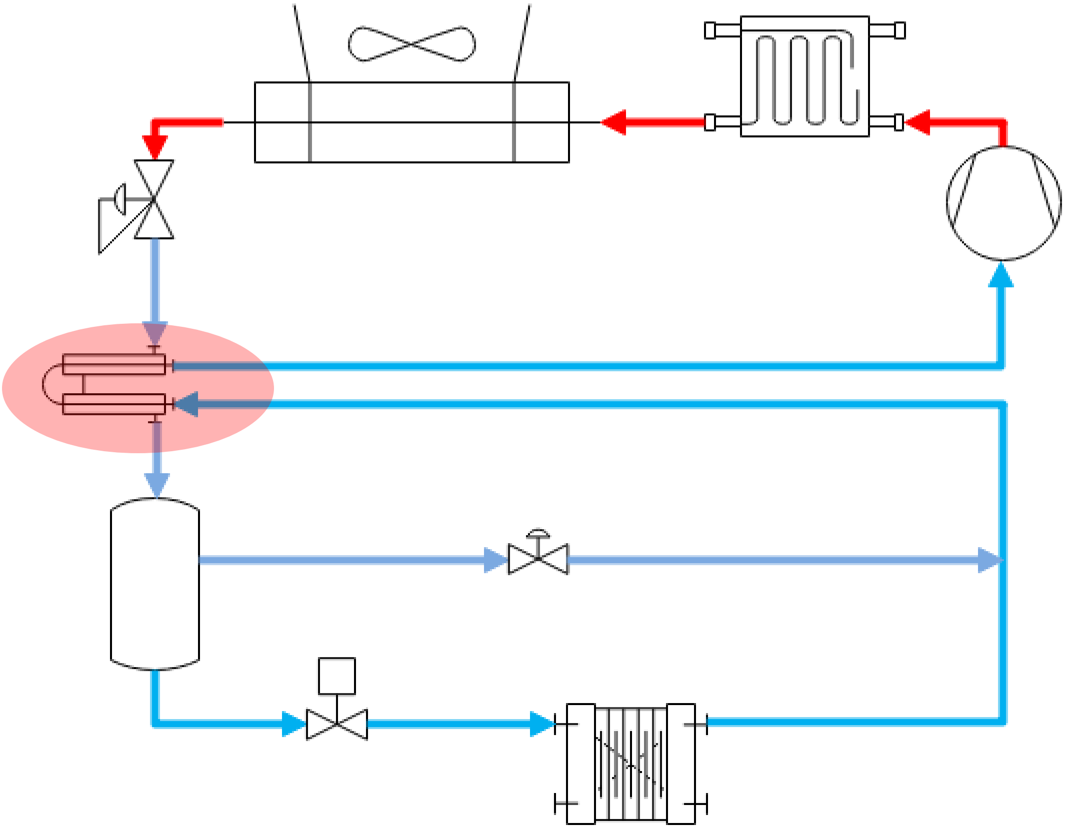
*A simplified image is shown

Summer & Winter Operation

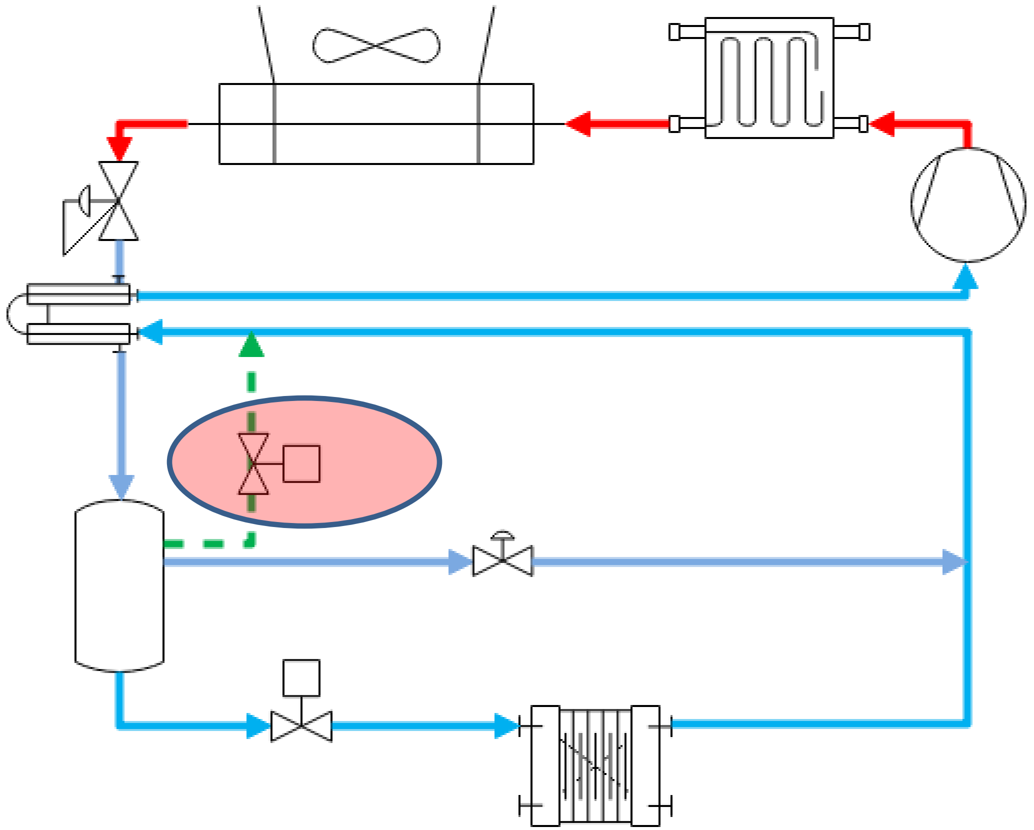
- Simultaneous heating and cooling application
- FGB to improve refrigerant quality



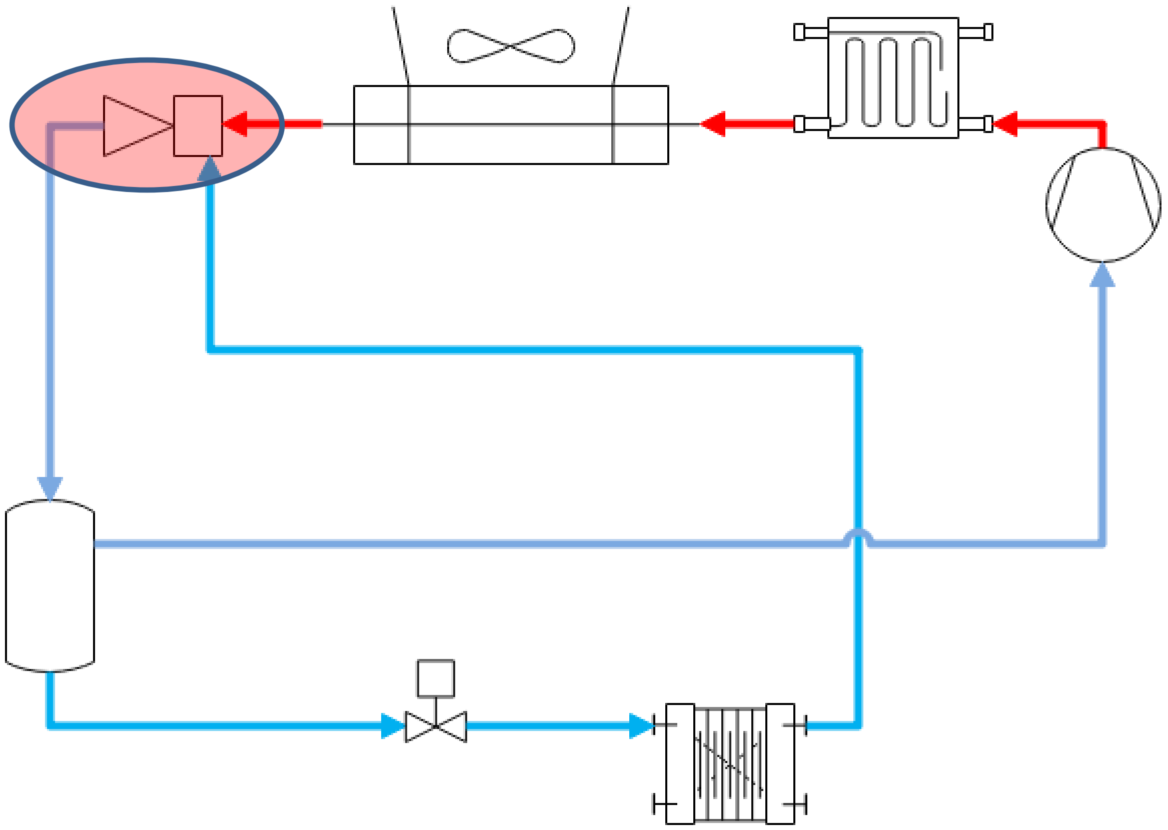
- IHX to provide subcooling
- Compressor superheat



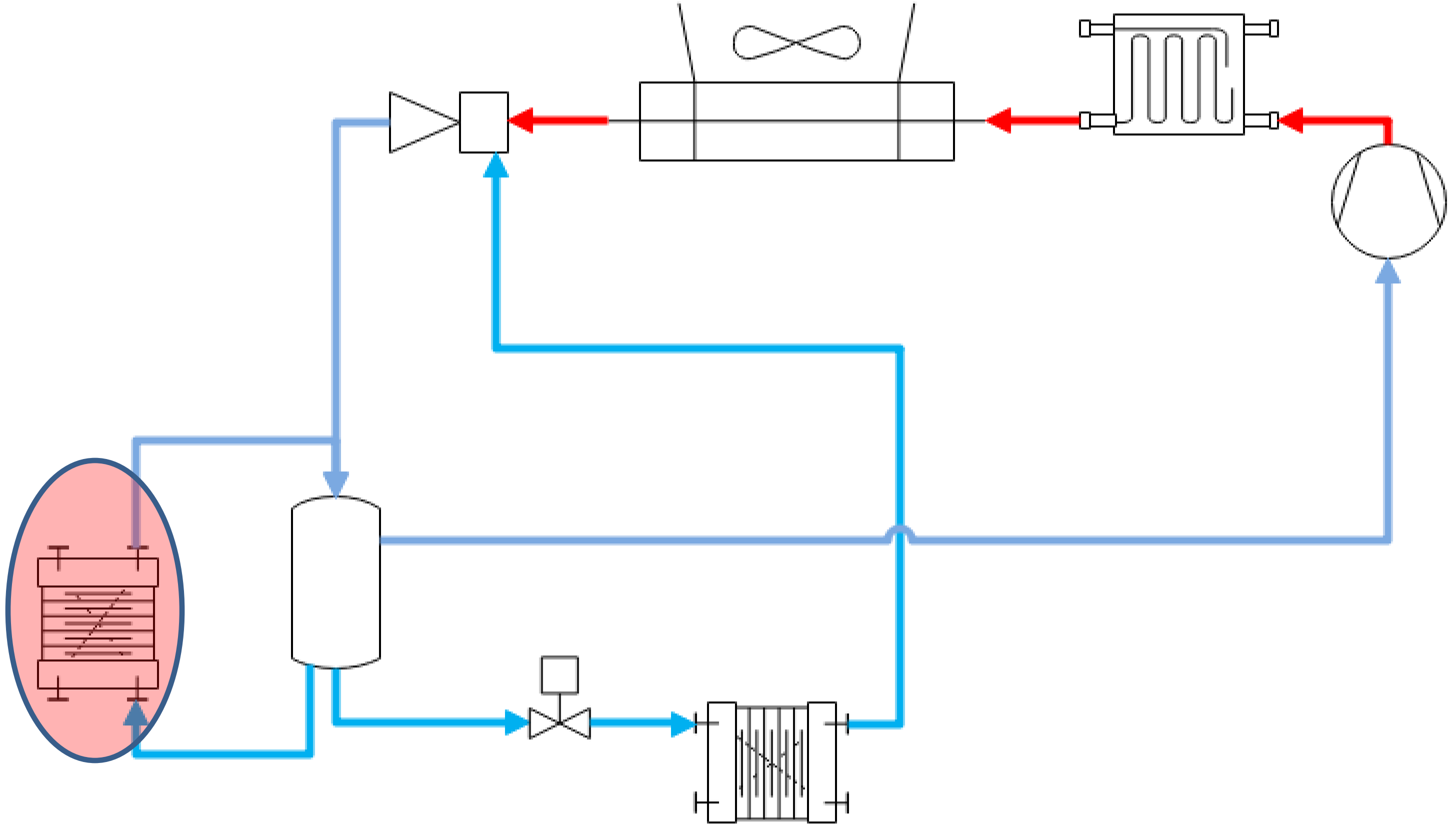
- **Liquid injection** to control superheat and compressor safety

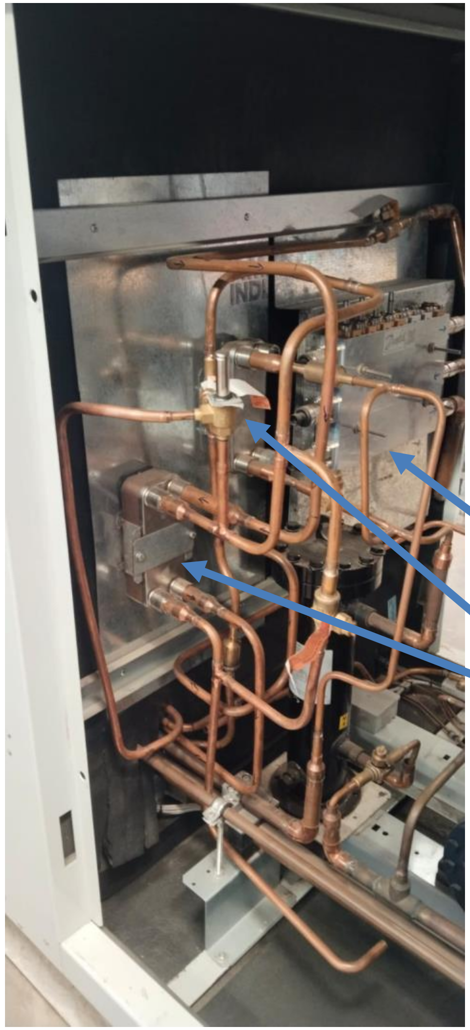


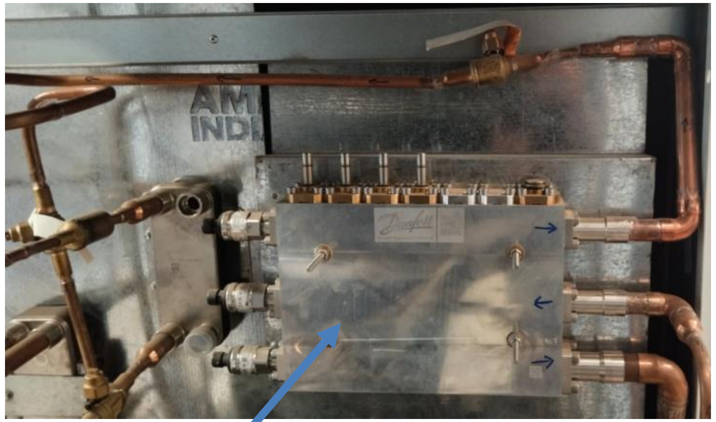
- **Ejector** to recover high throttle loss
- Act as a back pressure control valve



- Gravity-fed evaporator for additional cooling effect
- Ideal for chiller application







Ejector

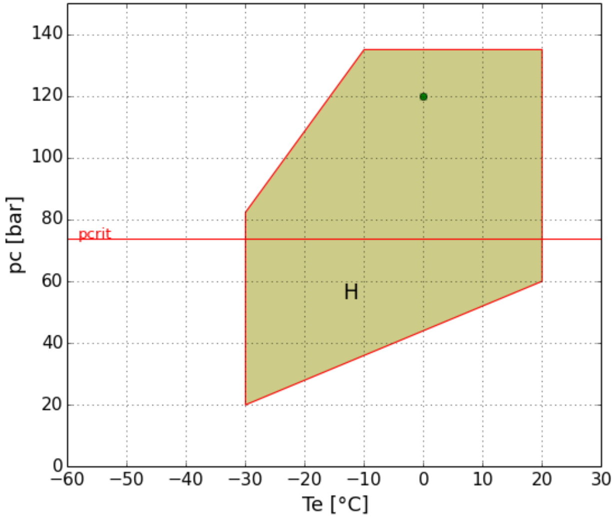
IHX

Heat recovery unit

Electric panel

Compressor Rack

1. Dorin CD300H: 1.46 m^3/hr @ 50 Hz
2. Dorin CD360H: 2.39 m^3/hr @ 50 Hz



Compressor Operating Envelope

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INDEE

Birla Institute of Technology & Science, Pilani

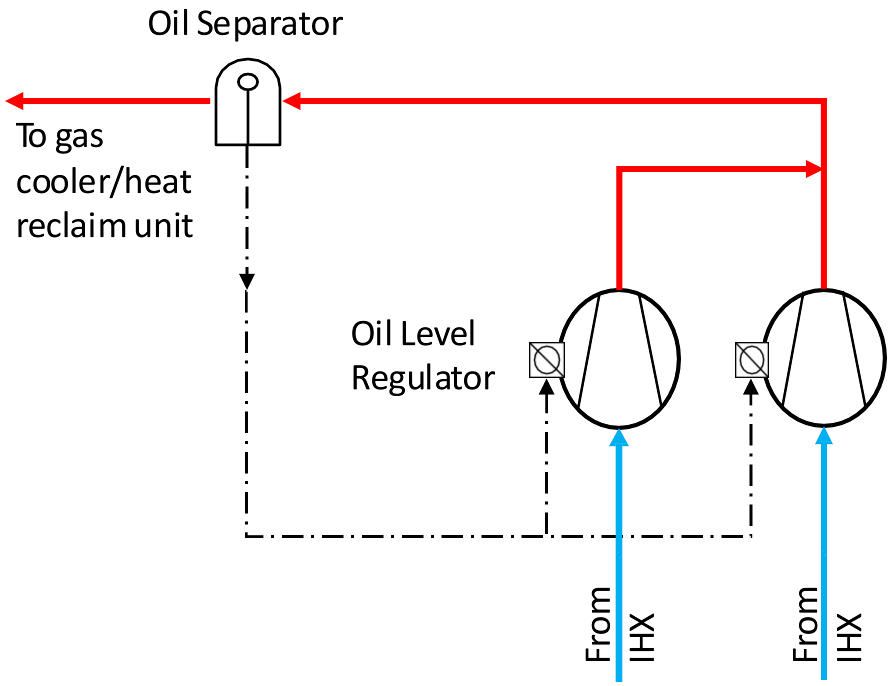
Theme

Successful Demonstration and Future Scope of Natural Refrigerant Systems in India

This work is a part of the Indo-Norwegian project INDEE+, Future Refrigeration India, sponsored by MFA, Government of Norway and coordinated by NTNU Norway

Major Component Make/Models

Component	Make/Model
Compressors	Dorin: CD300H and CD360H
Heat Exchangers	Alfa Laval: AXP14 & AXP82
LP Ejectors and Controllers	Danfoss: Multi Ejector LP 935
Oil Management System	Tecnac (Oil separator) Teklab (Oil level sensor)



Oil Management System

Collaborators

Danfoss

ENGINEERING TOMORROW

ALFA LAVAL

MECH-AIR INDUSTRIES

Frascold®
Blue is better

Current Status and Path Forward

1. Design and selection of components
2. Procurement of components
3. Modification and testing of the unit at Vadodara, Gujarat
4. Educational/ Training activities at Vadodara, Gujarat
5. Educational/ Training activities at BITS-Pilani, Rajasthan

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On-Board Refrigeration in Small Fish Boats with R290

SOUTH ASIA'S PREMIER REFRIGERATION & COLD-CHAIN EXHIBITION

FRESH & HEALTHY PRESERVATION THROUGH INNOVATIVE TECHNOLOGIES

Birla Institute of Technology & Science, Pilani (BITS Pilani)
Rajasthan

Presented by:
Prosenjit Singha

Indian scenario

- **Coastline >8000 km**
- **Exclusive Economic Zone ~2.02 million sq. km**
- **~70,000 Mechanical Motorised boat**
- **Estimated 13.7 million metric tons fish (2021)**
- **1.37 million metric tons of fish & product exported (2022)**
- **7.76 billion USD earned in export (2022)**

*** Third largest fish producer * Second largest aquaculture producer * Fourth largest seafood producer in the world**

– and there is room for growth

The Challenge

Challenge

No on-board refrigeration

Indian fishing scenario is dominated by motorized & mechanized Purse seiner that carries crushed ice from coast.

Proposal: On-board & Transport Refrigeration

On-board & Transport Refrigeration

R-290 based system

- **Onboard ice making unit, on-demand ice production.**
- **Simple and maintainable system architecture focusing on mechanical components rather than sensitive electronic parts.**
- **Powered directly from the boat's engine via a belt.**
- **Auxiliary system powered by cost-effective 150Ah battery.**

Why Propane (R290) as refrigerant

- Propane (R290) is natural refrigerant, inexpensive, offers great thermal performance, and is compatible with common structural materials and standard lubricants

- **Better performance for stated application & temperature range**

- Commonly used polyolester oil in compressors, is suitable for R290 with an adjusted viscosity

- **Low acute toxicity according to ASHRAE standards**

- Updated regulation of the European Union, the allowed R290 charge has been lifted from 150g to 500g of

Overall heat transfer coefficient (W/m^2K)

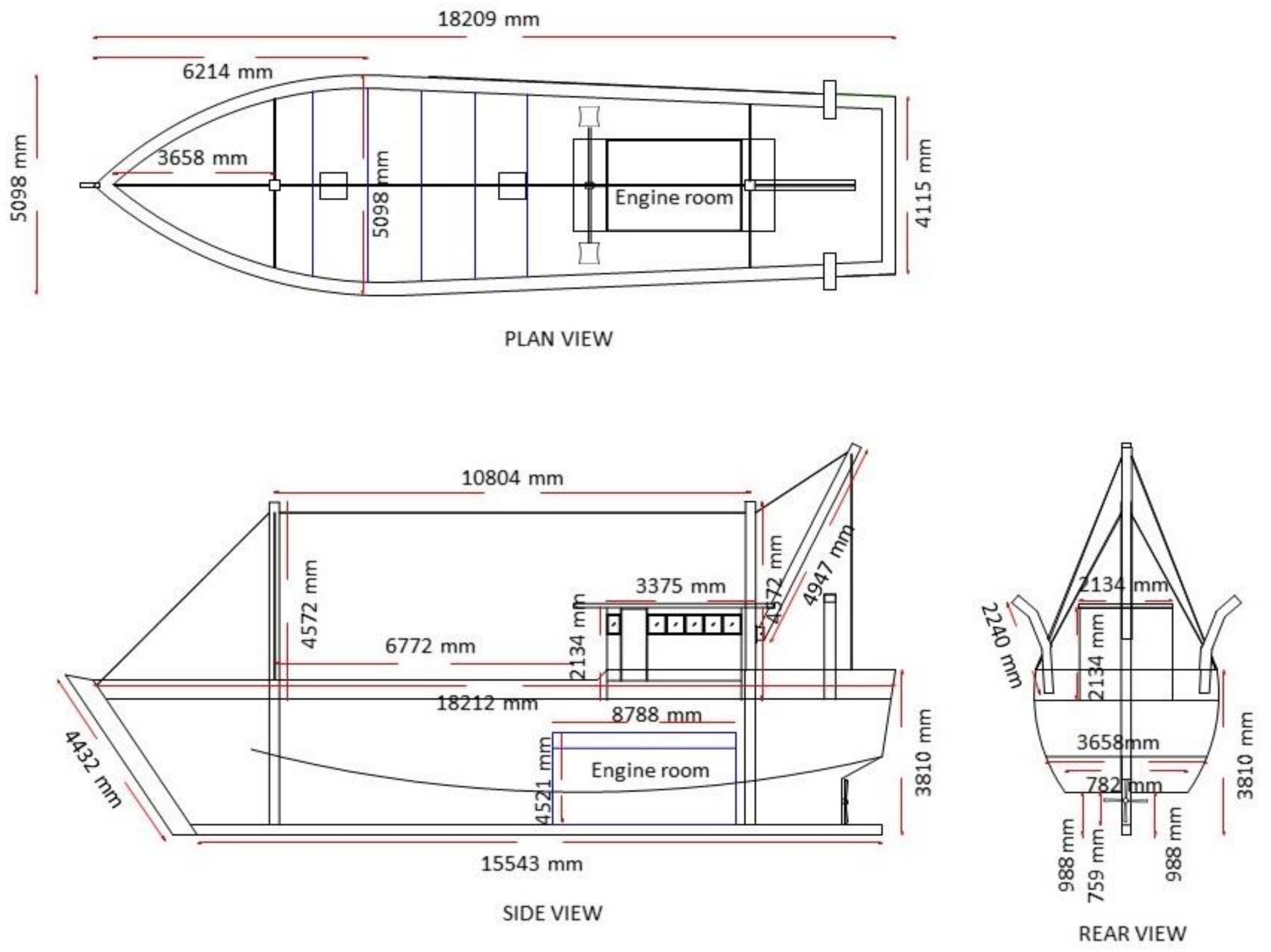
Evaporative drum side

R744/Water	1141.9
R134A/Water	803.7
R404A/Water	1133.6
R290/Water	1322.5

Cascade heat exchanger

R744/R290	1486.7
R744/R404A	1028.9
R744/R134A	915.5

Small boats come in many variety!



Mumbai coast: RSW system, Demand: Cooling load 3.5 kW, intermittent running, 50% support.

Gujarat coast: Flake ice system Demand:100 kg ice per hour for 10 hr. daily, 50% support.

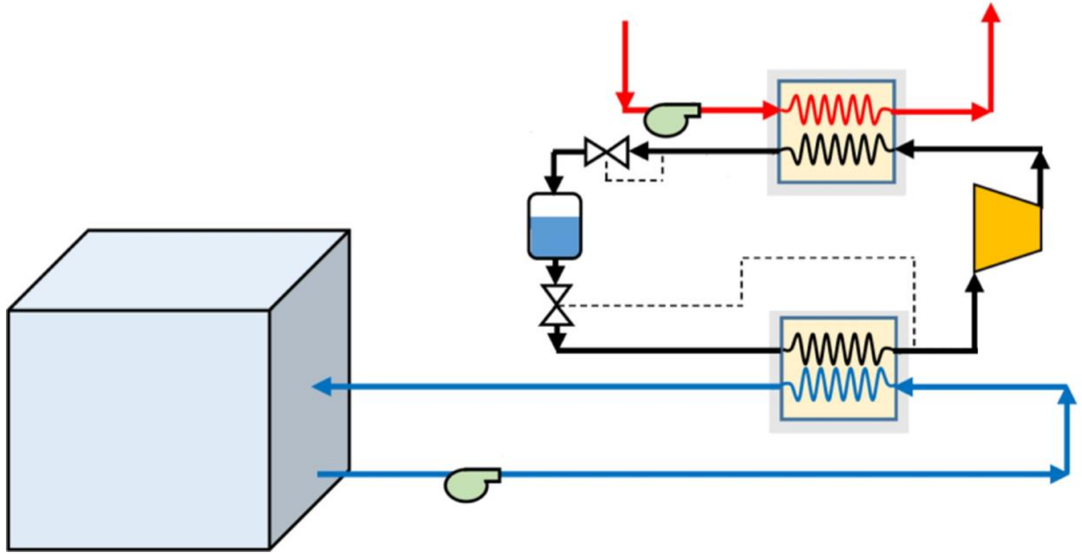
Kerala coast: block ice system 24 hours of compressor running, 50% support.

Proposed RSW system

Cooling load calculation

Equipment	Value
Average catch size	8 tonnes
Compartment dimensions	1.22 × 1.22 × 1.9 m^3
No of compartment	10
Specific heat (C_p) of fish	3.13 – 3.38 kJ/kgK
Latent heat (L) of ice	334 kJ/kgK
Sea water temperature	26.5 °C to 31.5 °C

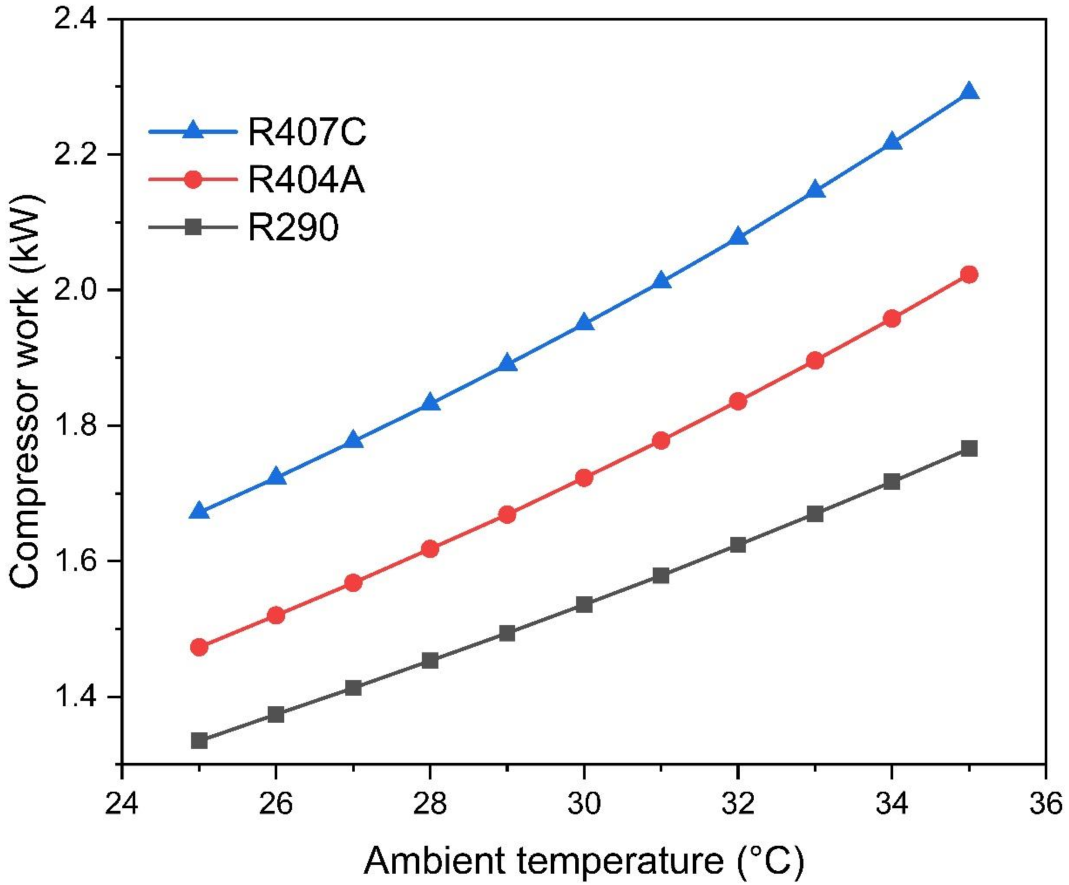
Cooling load unit 3.5 kW



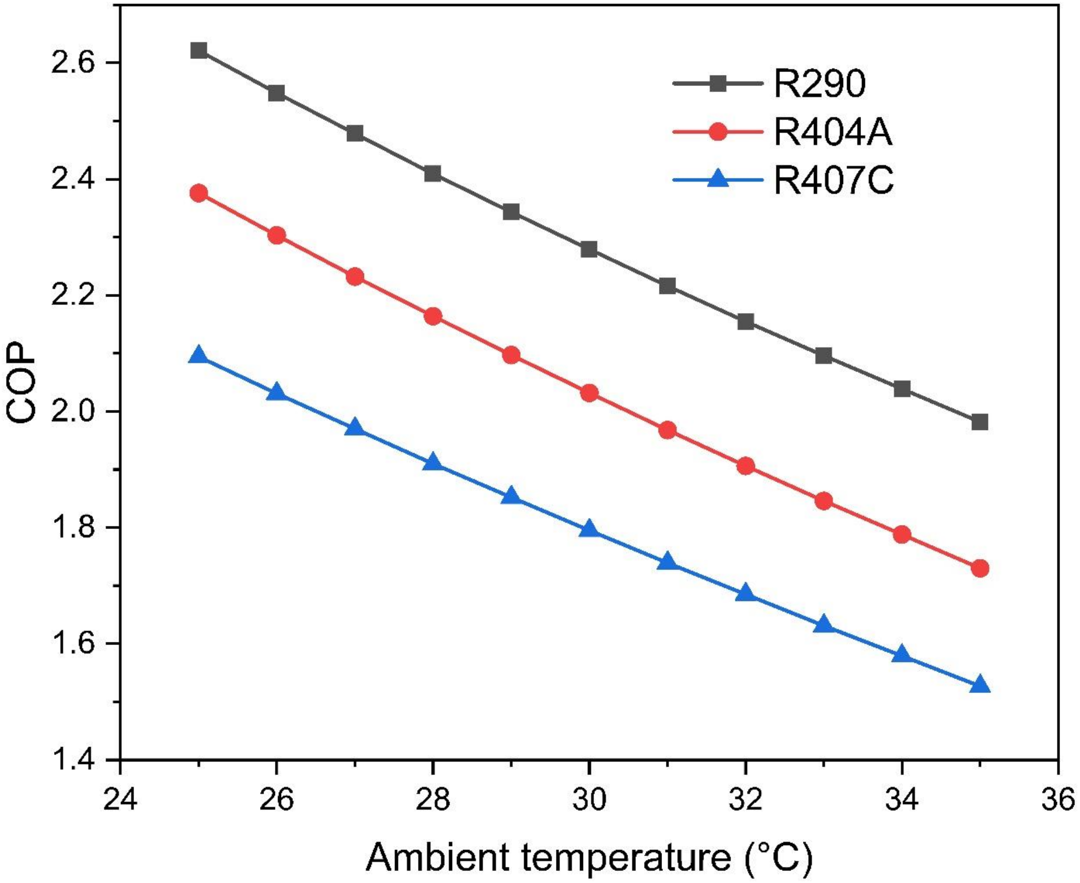
Insulating material

Factors	Values
Fiber glass	0.036 kJ/kgK
PUF	0.048 kJ/kgK
Air	0.024 kJ/kgK
HT coefficient for moving air	34.05 kJ/kgK
Heat transfer coefficient of still air	9.3 kJ/kgK
Heat transfer coefficient of ice	598.5 kJ/kgK

Results (RSW unit)



Reduction in compression work upto 13% and 23% found when compared to R404A and R407C

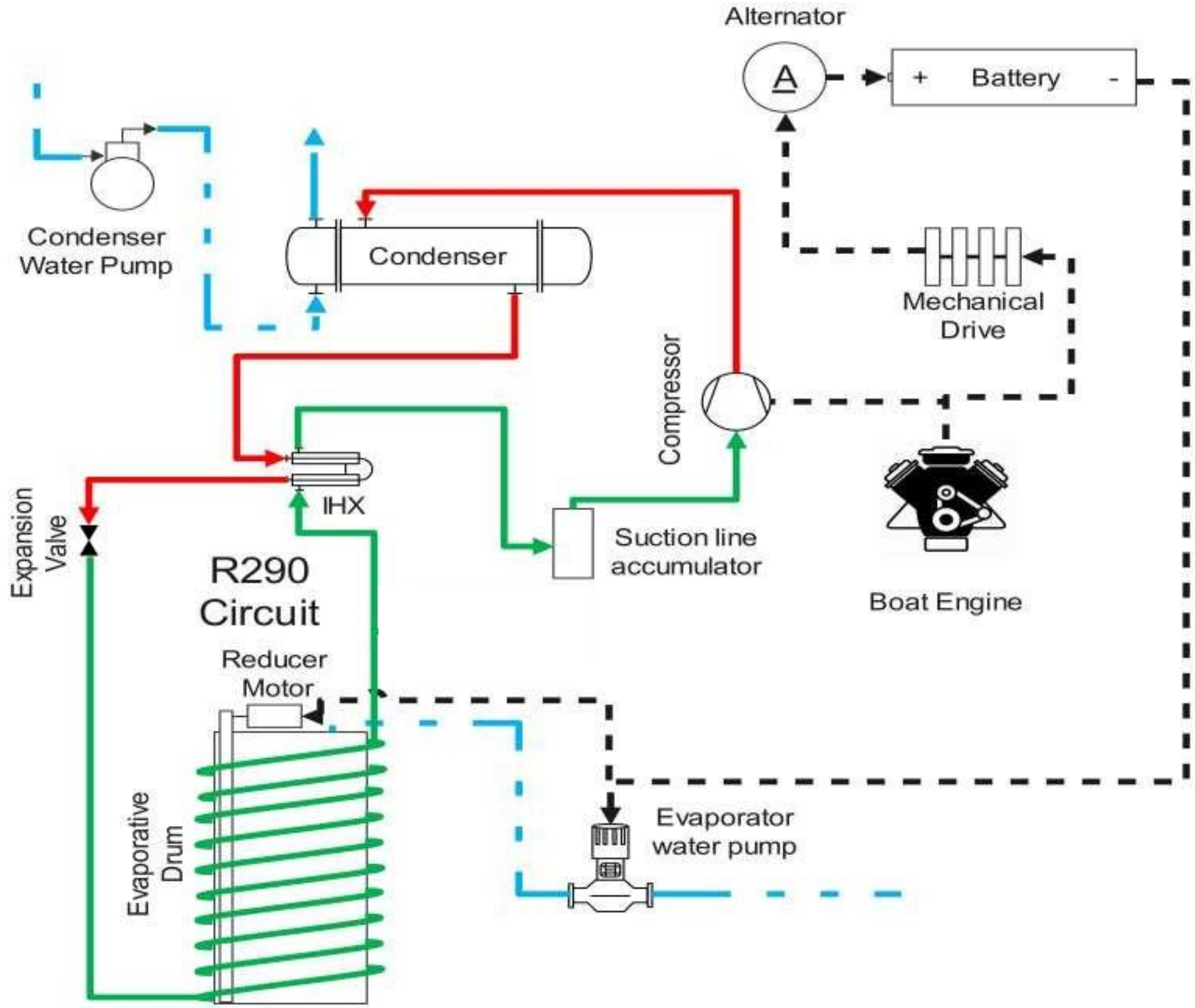


Improvement in COP upto 14% and 30% found when compared to R404A and R407C

Proposed Flake Ice system

Direct loop
R290 system
configuration

Cooling Load 30 kW



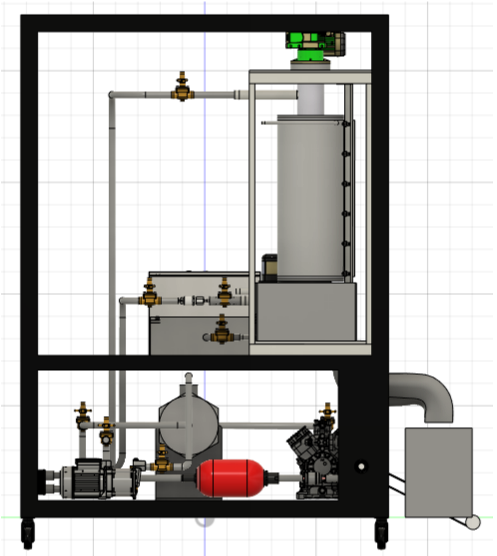
Flake Ice system with various refrigerants

Parameter	(°C)
Evaporator temperature	-25
Condensing temperature	40

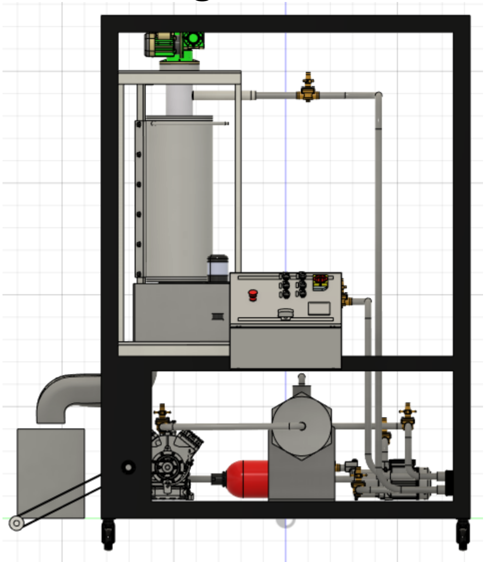
Refrigerant	Compressor Selected	Type	Nominal speed (RPM)	Displacement at nominal speed (m^3/hr)
R404A	FVR-L-30-120	Open type screw compressor	2900	120
R407A	FVR-L-30-120	Open type screw compressor	2900	120
Propane	FVR-L-30-120AX	Open type screw compressor	2900	120

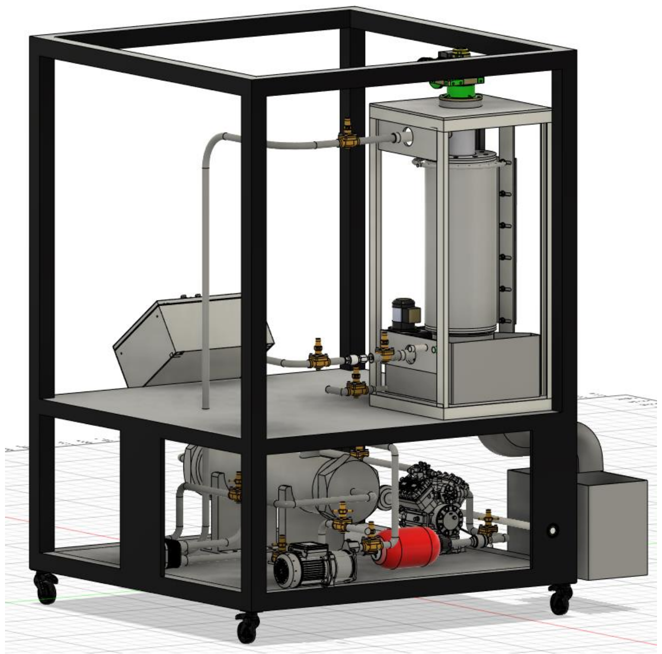
3D drawing of flake ice system

Left side view



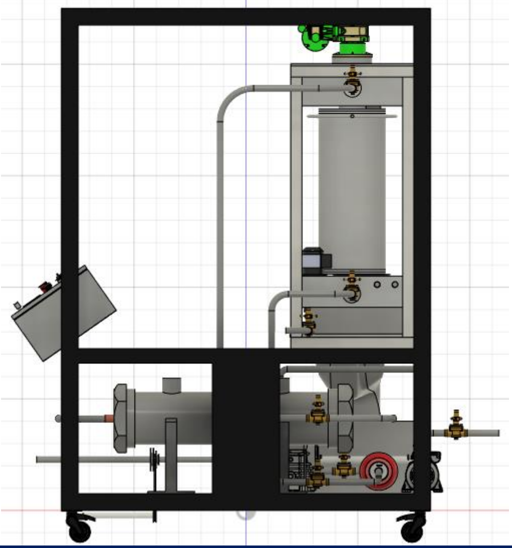
Right side view



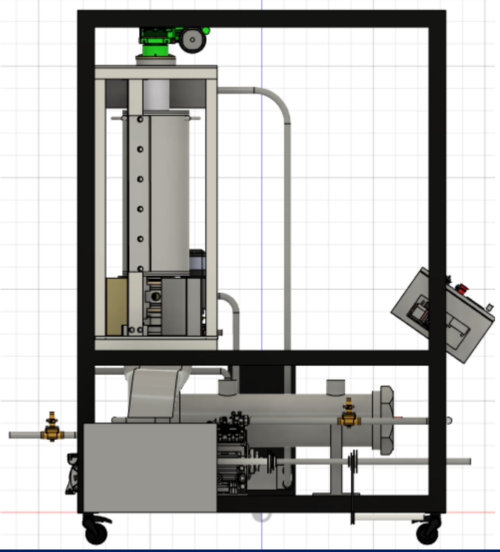


Isometric view

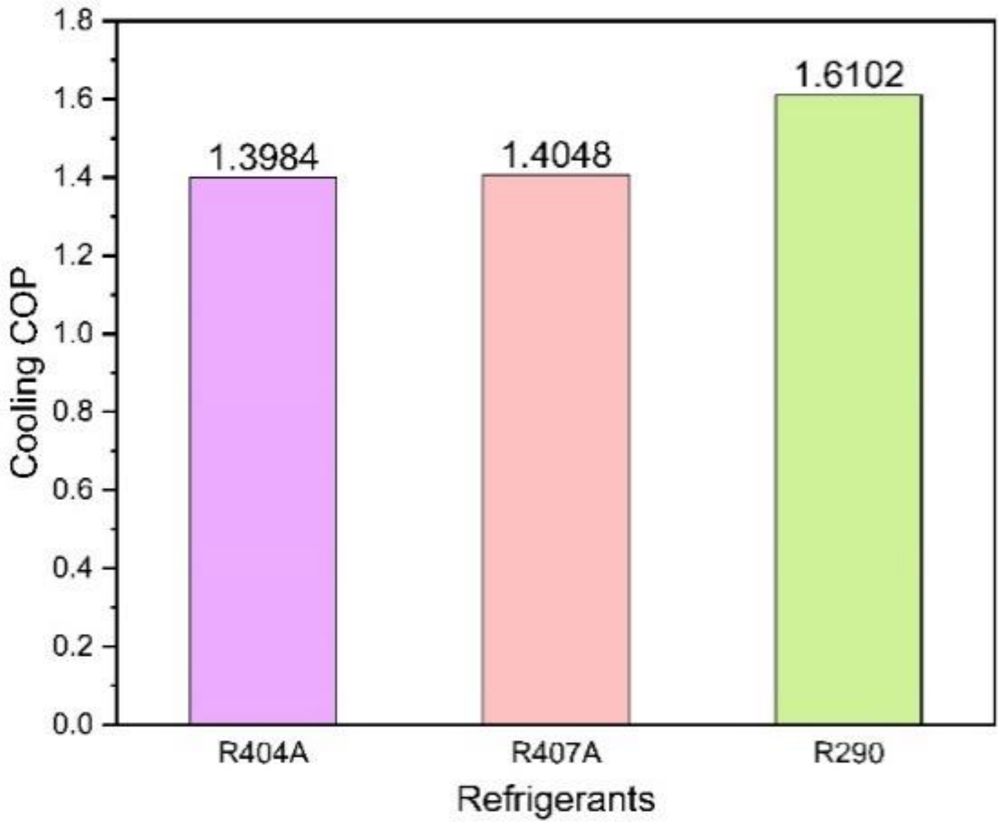
Rear view



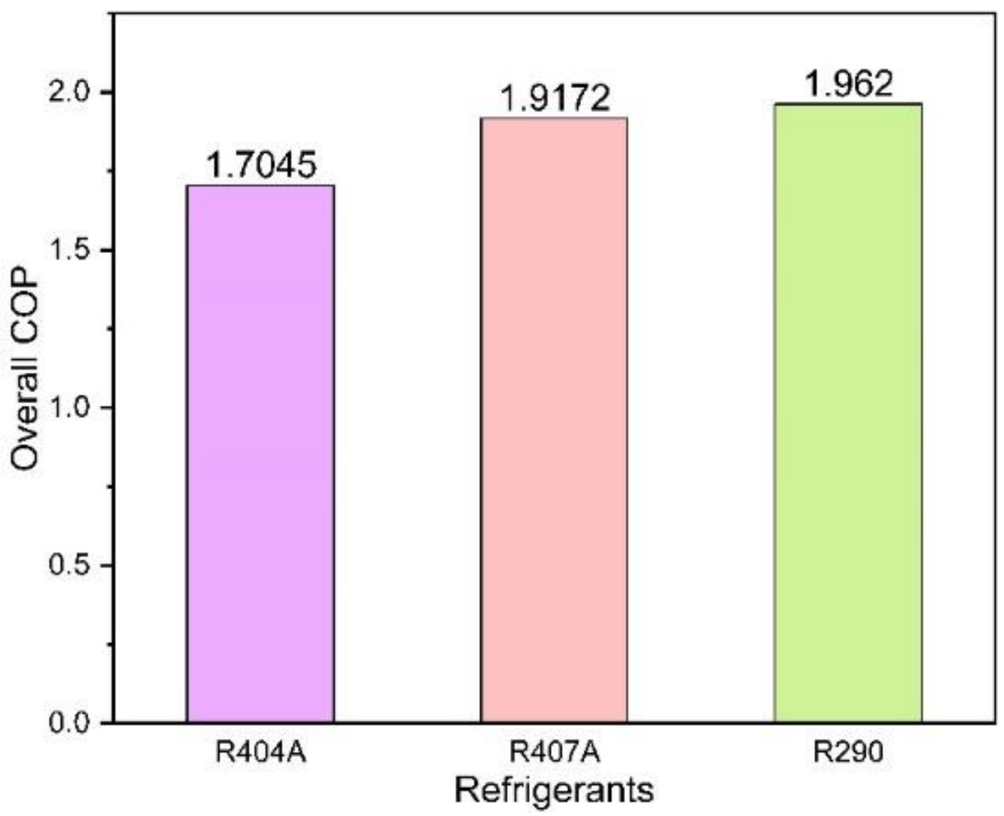
Front view



Results (Flake ice unit)



15.13% and 14.6% higher cooling COP.

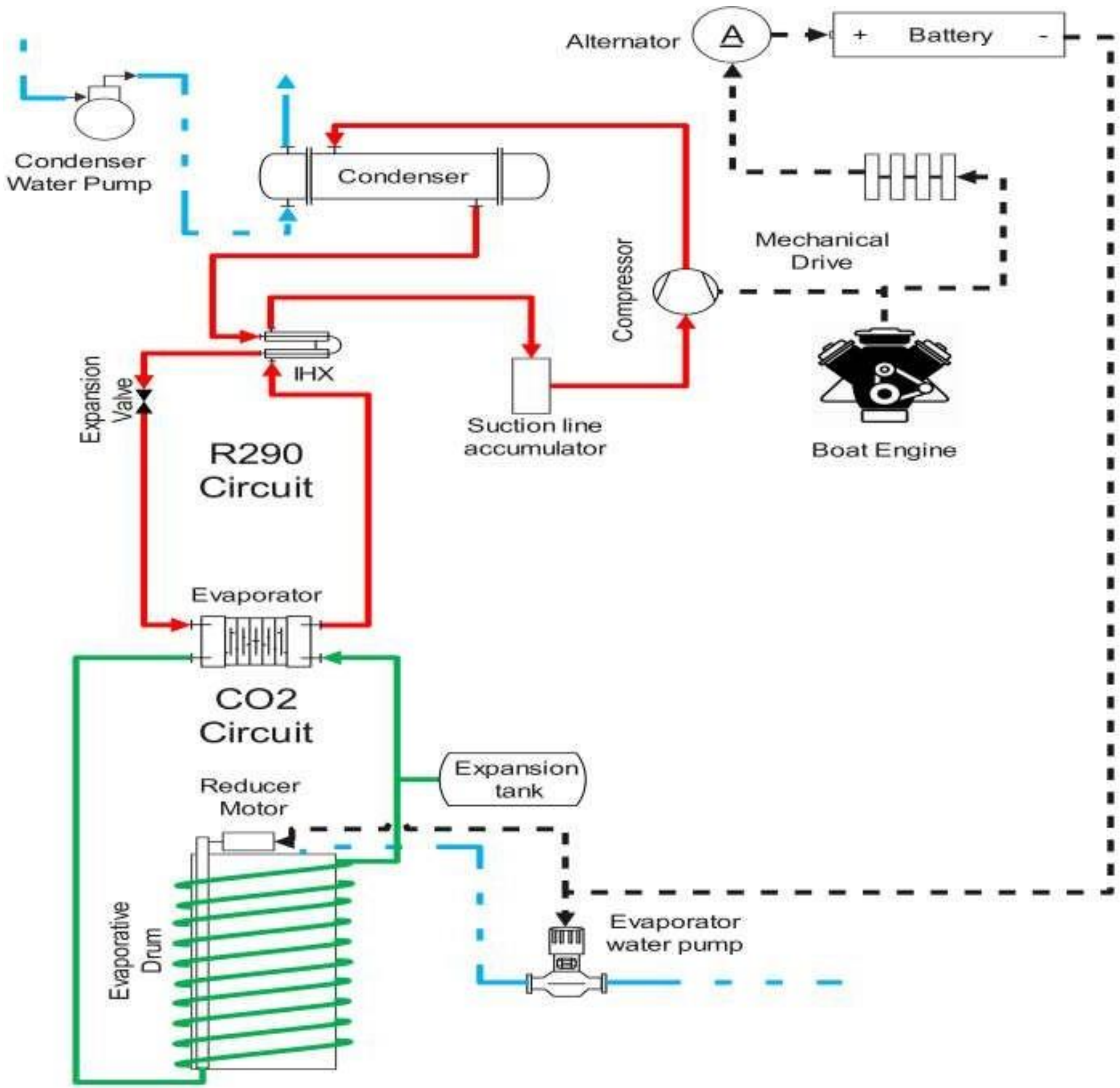


15.4% and 2.2% higher overall COP

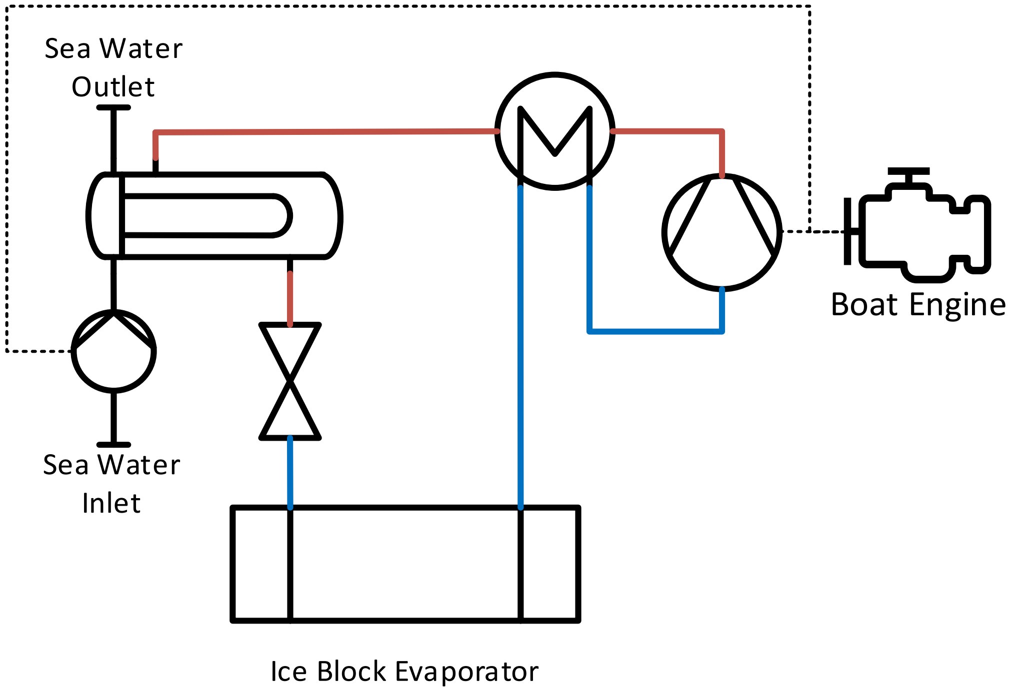
Alternate system with CO_2 in secondary loop

Proposed indirect loop R-290, R-744 configuration

Cooling Load 30 kW



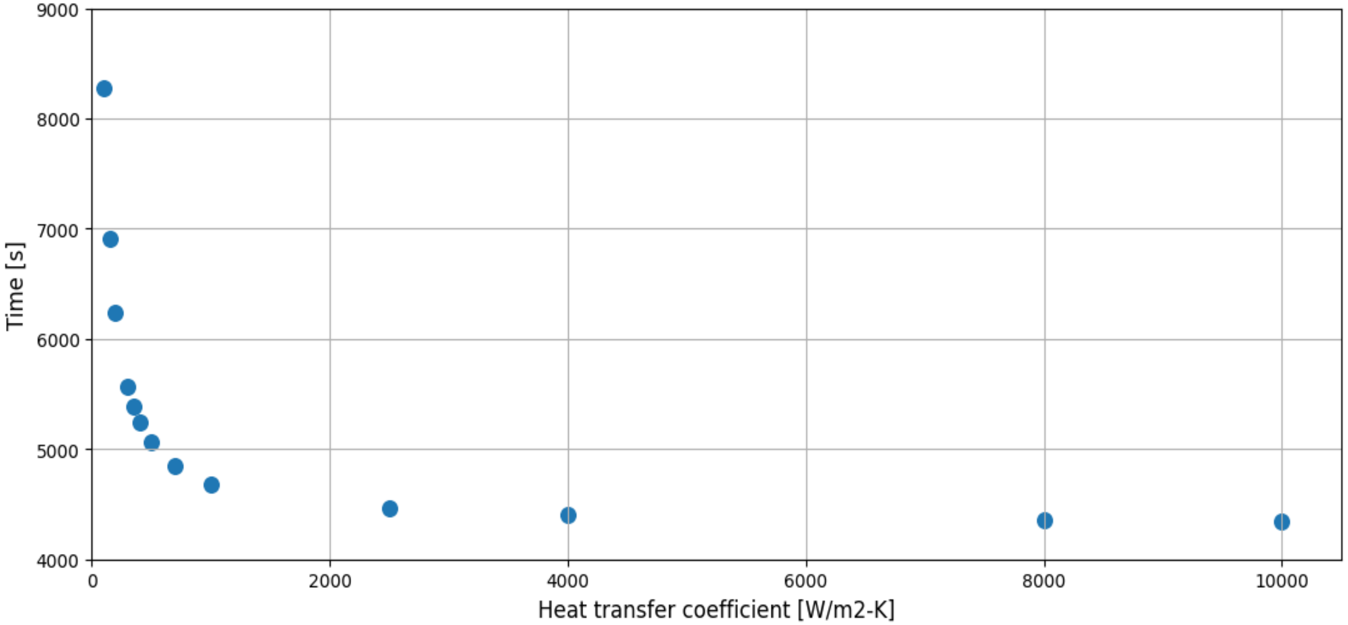
Alternate block ice system



Cooling load 13 kW for block ice application

Geometry	Value
Combined height [m]	3.31
Single cell height for 5 parallel plates [m]	0.66
Width [m]	0.03
length [m]	1.1
Plate spacing [m]	0.002

Performance



Geometry	Value
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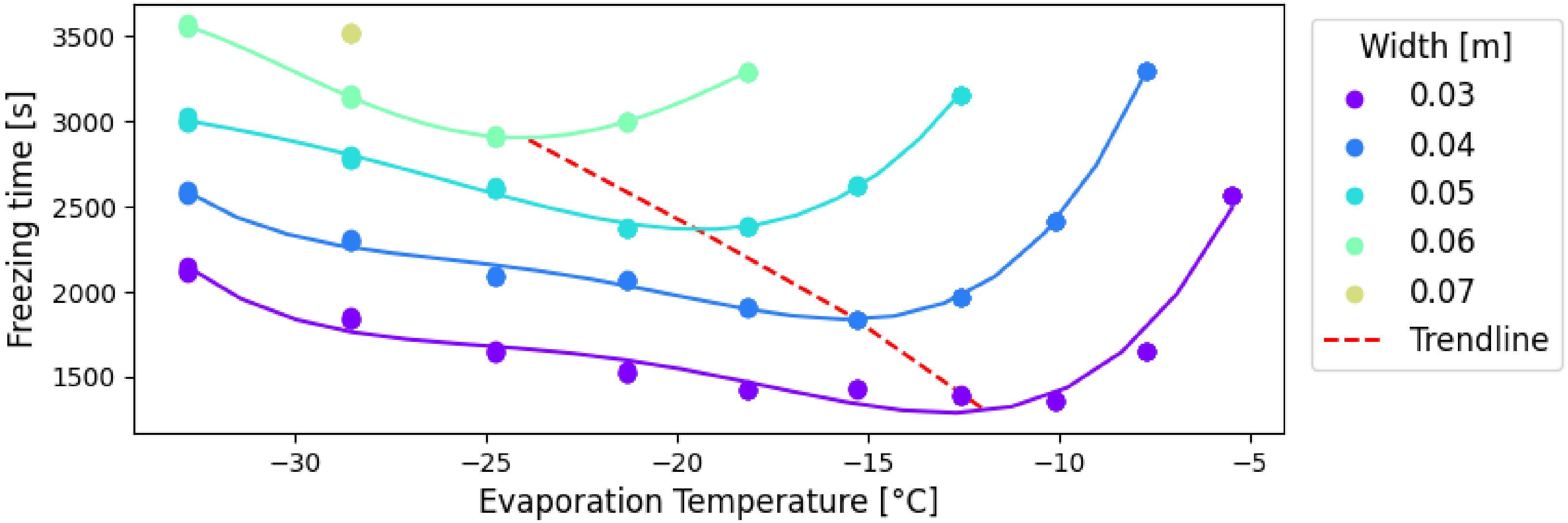

Environmental analysis

Items	Carbon footprint (CFP) *
Fish	0.25-0.3 kg/ kg of fish
Diesel	3.1 kg/kg of diesel burning

* Tan, R., Culaba, A., 2009. Estimating the carbon footprint of tuna fisheries. WWF Bin. Item 1–14.

Results and discussion (CFP)

Reduction of CFP
- Due to reduction in ice carried (8000 kg)
- Due reduction in fish wasted (315 kg)

Increment of CFP
- Due to machine weight (1120 kg)
- Due to operation of machine (470 kg)

Net reduction in carbon foot-print = 6725 kg CO_2 equivalent per trip

Results and discussion (ROI)

Items	Cost saving
Cost saving in terms of diesel	$2848 USD
Reduced cost of crushed ice	$96 USD
Profit due to the better fish quality	$378 USD
Cost of On-board refrigeration system	$11868 USD
Increase in expanse due to diesel consumption for	$ 602 USD
ROI: ~ 4 trips	

Conclusion

- The reduced compressor work leads to less power supply from the boat engine, resulting lesser fuel consumption
- The cooling COP of propane system is 15.1% and 14.6% higher when compared to R404A and R407A systems for RSW unit
- Improvement in COP upto 14% and 30% found when compared to R404A and R407C
- In addition of using of natural refrigerant, the on-board refrigeration system can reduce CFP upto 6725 kg of CO_2
- The ROI for installing the on-board refrigeration system is found around four trips

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KNOWLEDGE SESSION

Norwegian Ministry of Foreign Affairs

INDEE

Birla Institute of Technology & Science, Pilani

Theme

Successful Demonstration and Future Scope of Natural Refrigerant Systems in India

This work is a part of the Indo-Norwegian project INDEE+, Future Refrigeration India, sponsored by MFA, Government of Norway and coordinated by NTNU Norway

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Hotel Decarbonisation using R744 heat pump/chiller in India

Theme

Successful Demonstration and Future Scope of Natural Refrigerant Systems in India

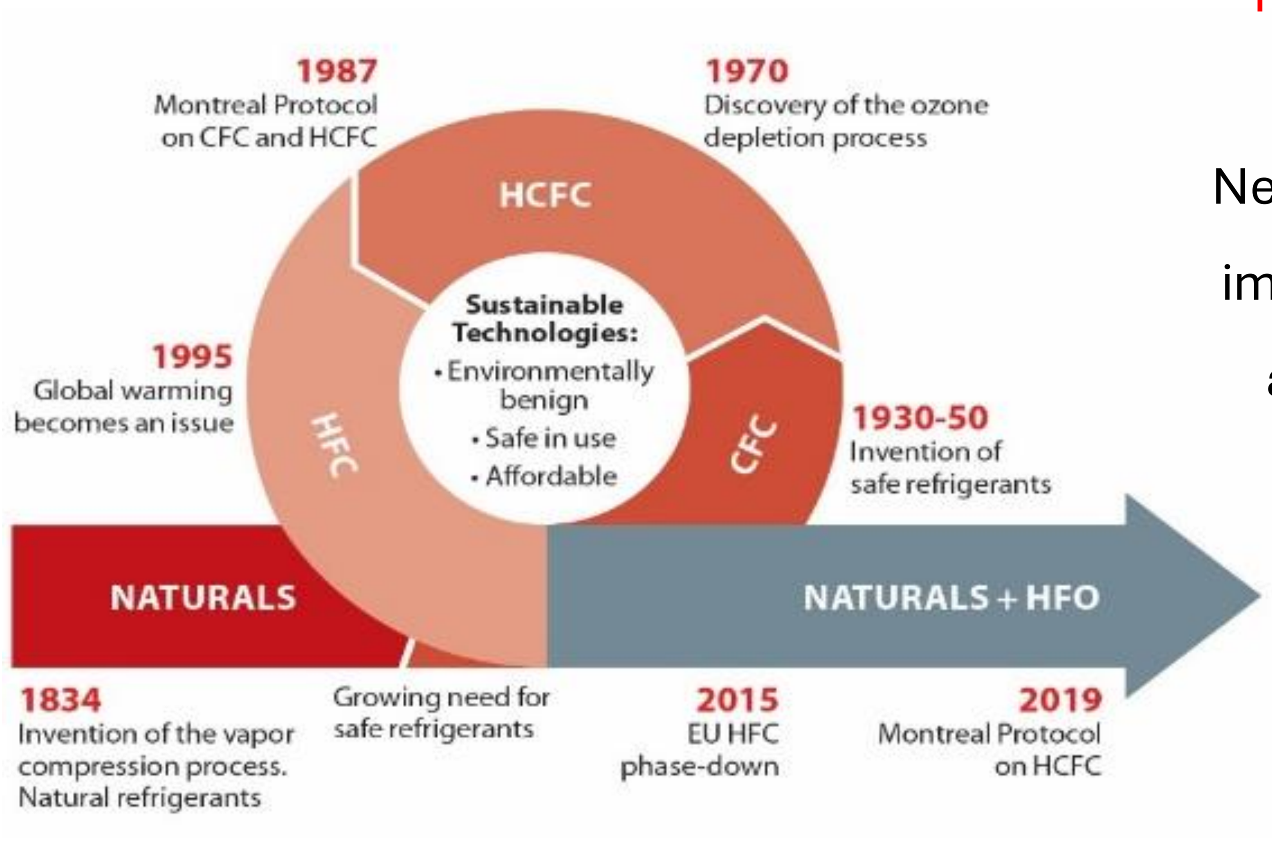
Dr. Simarpreet SINGH
Researcher
NTNU Norway

simarleo89@gmail.com

CONTENTS

Primary Objectives

- Coordinate various actions
  - Design
  - Deliver training programs
  - Transfer knowledge to the various stakeholders.
- Extensive support
  - To develop R&D programs, manufacture in India
  - Implement demonstration sites in real environments.
- Knowledge Transfer
  - R744 refrigeration systems
  - Troubleshooting and maintenance of these systems will be provided.
- Technology transfer
  - Suppliers and manufacturers.

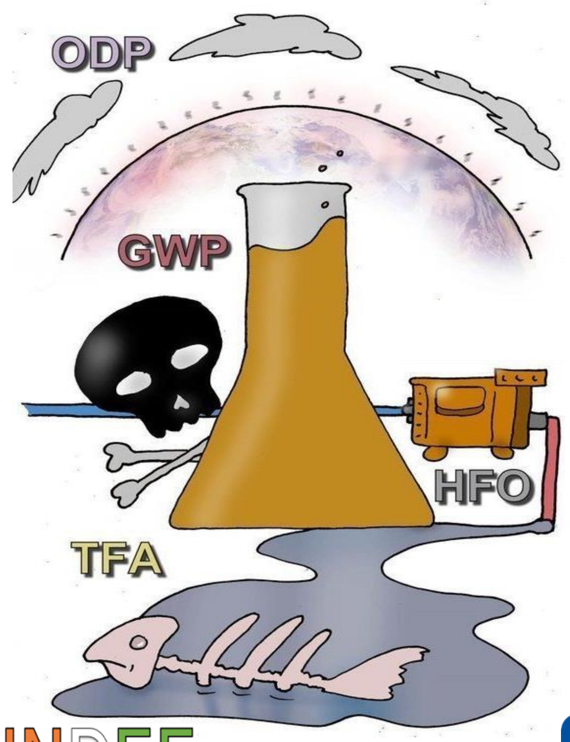


HFCs with ultra low lifetime do have ultra low GWP value.

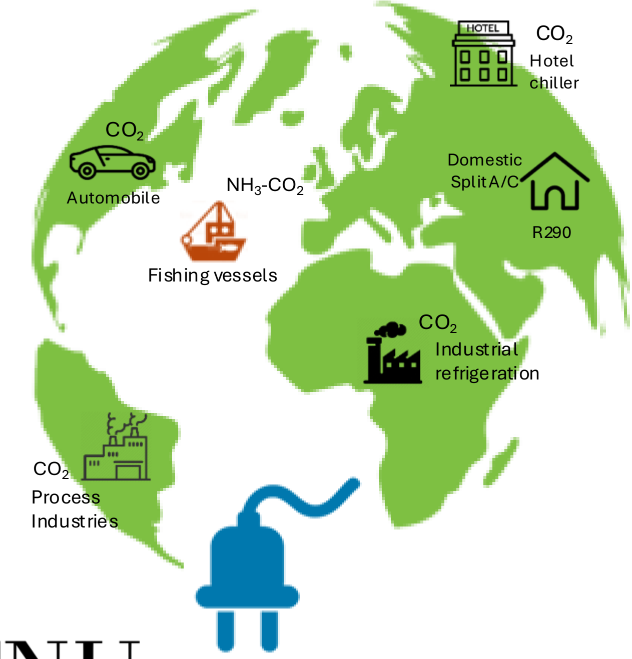
Nevertheless, all the other equally important environmental aspects are either **unknown** or **secret**

The wider market share of traditional man-made (synthetic) refrigerants is a major constraint.

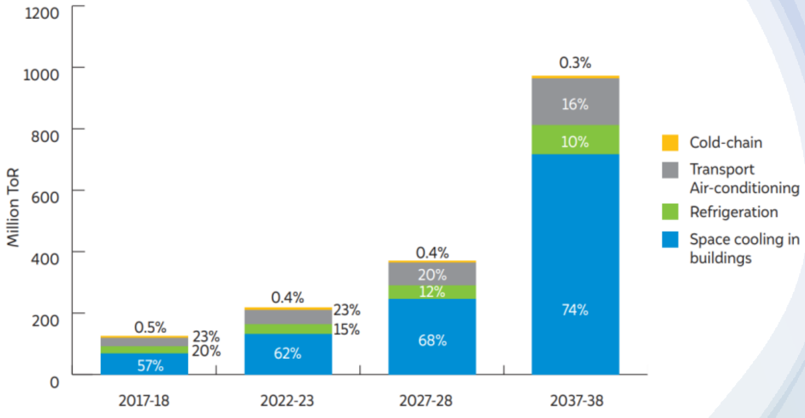
DON'T CALL IT CHANGE, CALL IT CLIMATE EMERGENCY



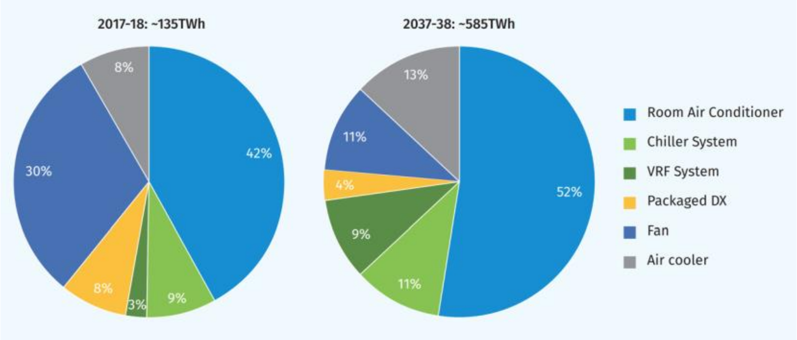
Need of the Hour



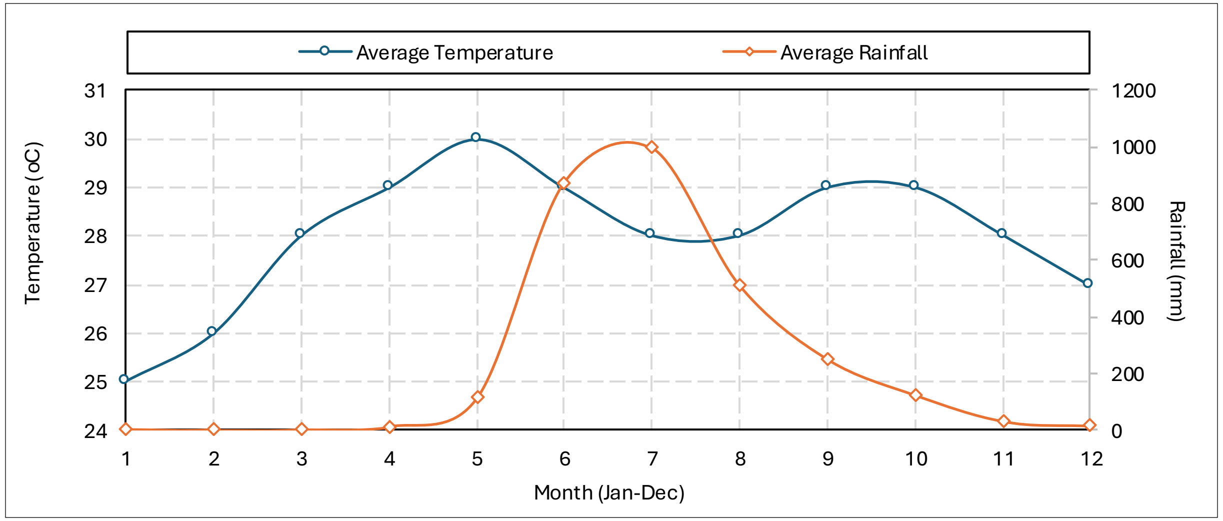
Current Status in India



Source: *Ozone Cell (2019)*

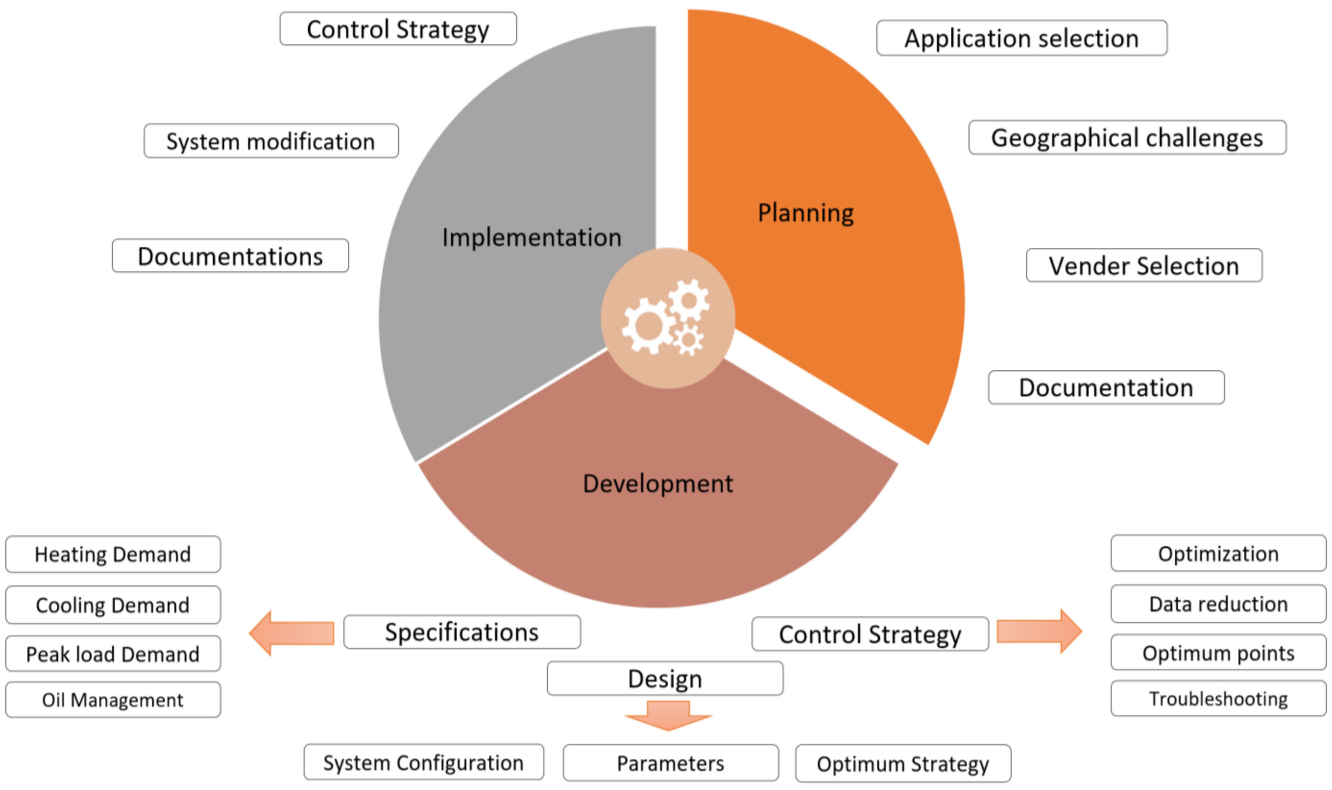


Space Cooling Energy Consumption by Equipment



Having the premises on a landscape location, greatly provides challenges to the water pipeline distribution channel.

Therefore, a systematic and augmented piping channel layout is outlined and finalized to reduce the overall pumping power/consumption throughout the hotel premises.



Phase I (Planning)

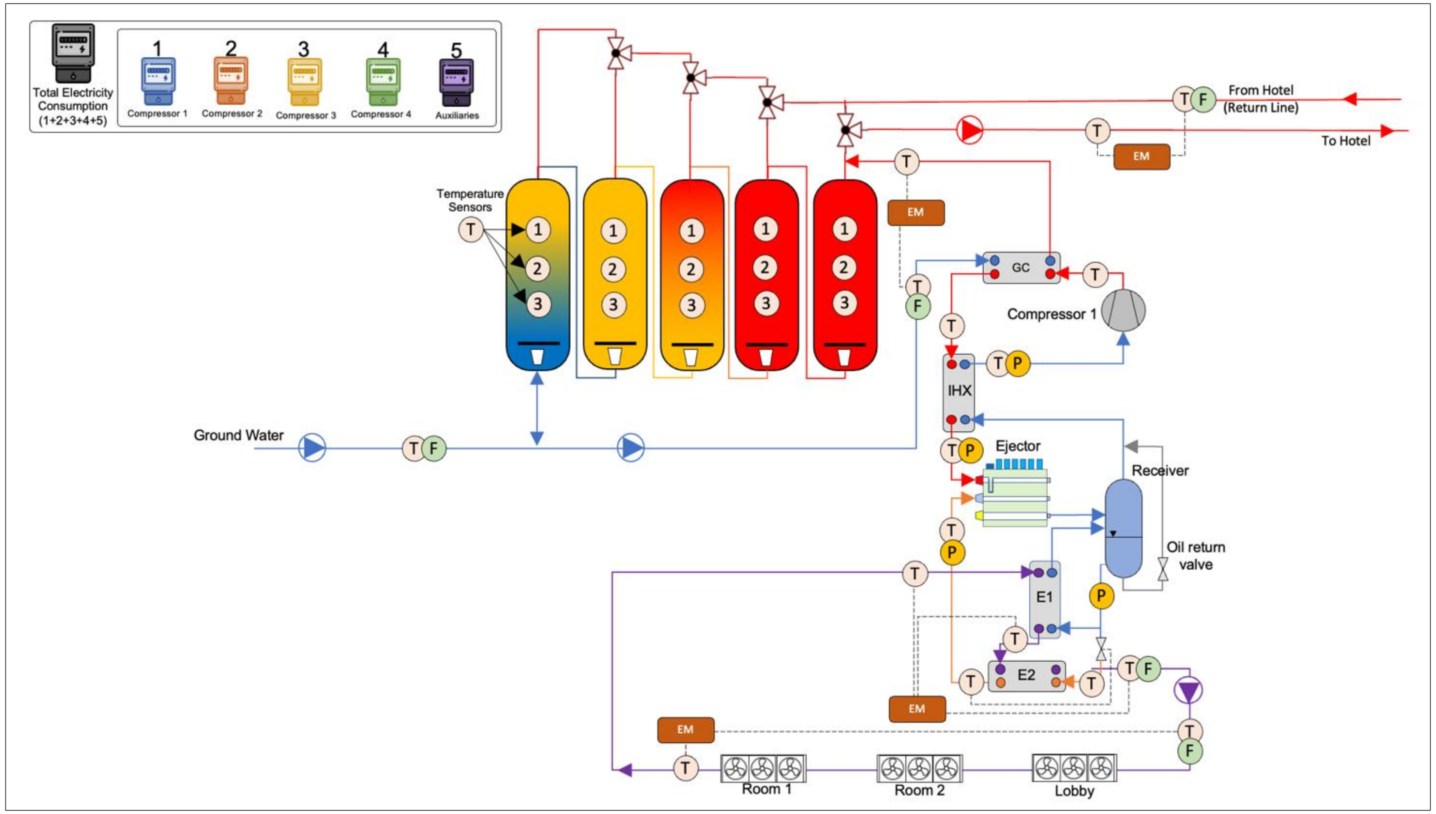
- ✓ Application selection
- ✓ Geographical challenges
- ✓ Ambient temperature frame

Phase II (Development)

- ✓ Assembly progress
- ✓ Control strategy has been working on
- ✓ Four modules (heat pump/chillers) are planned to smartly integrate
- ✓ A common thermal storage (hot water tanks)

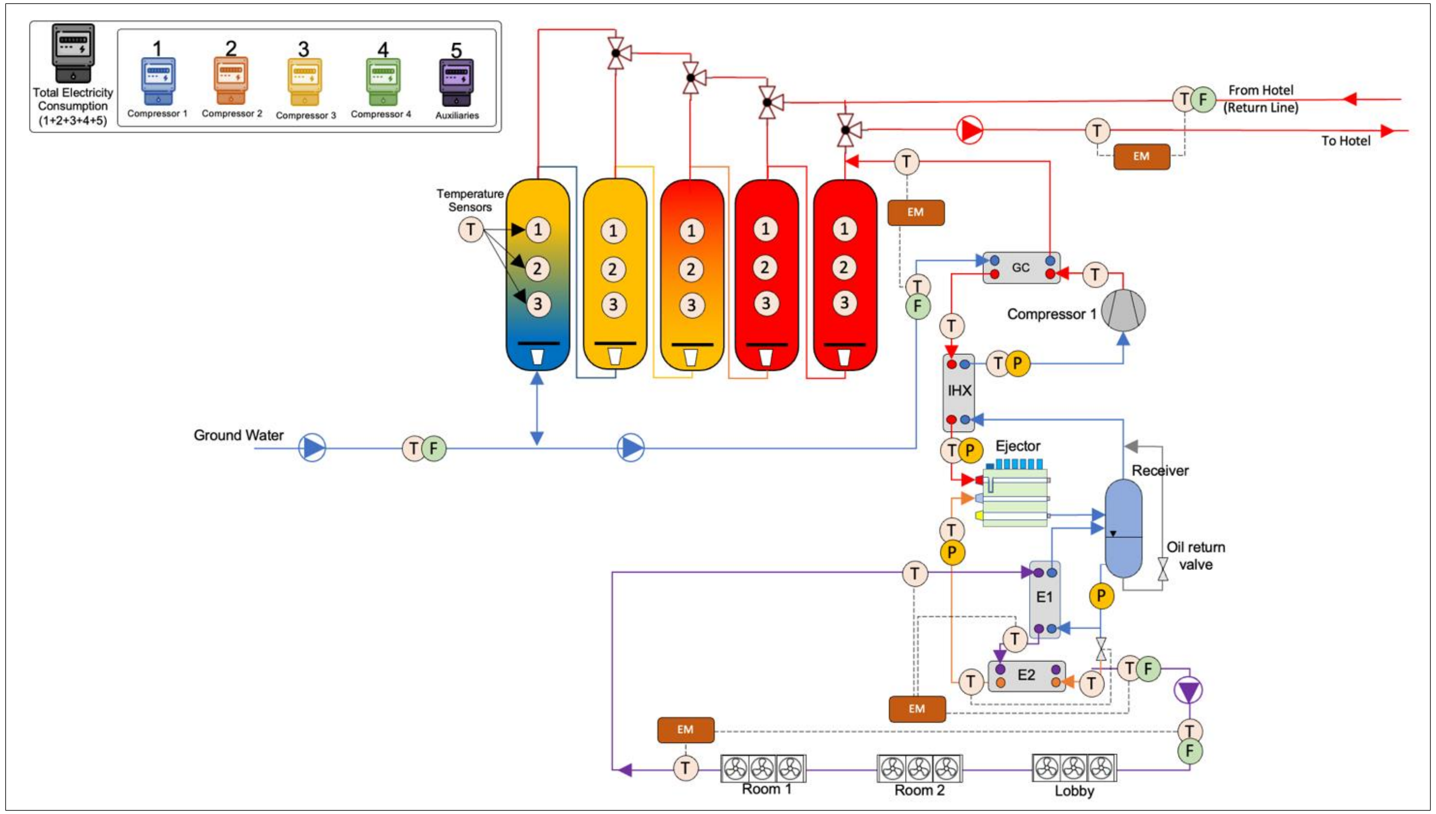
Phase III (Implementation)

- ✓ Peak load demands



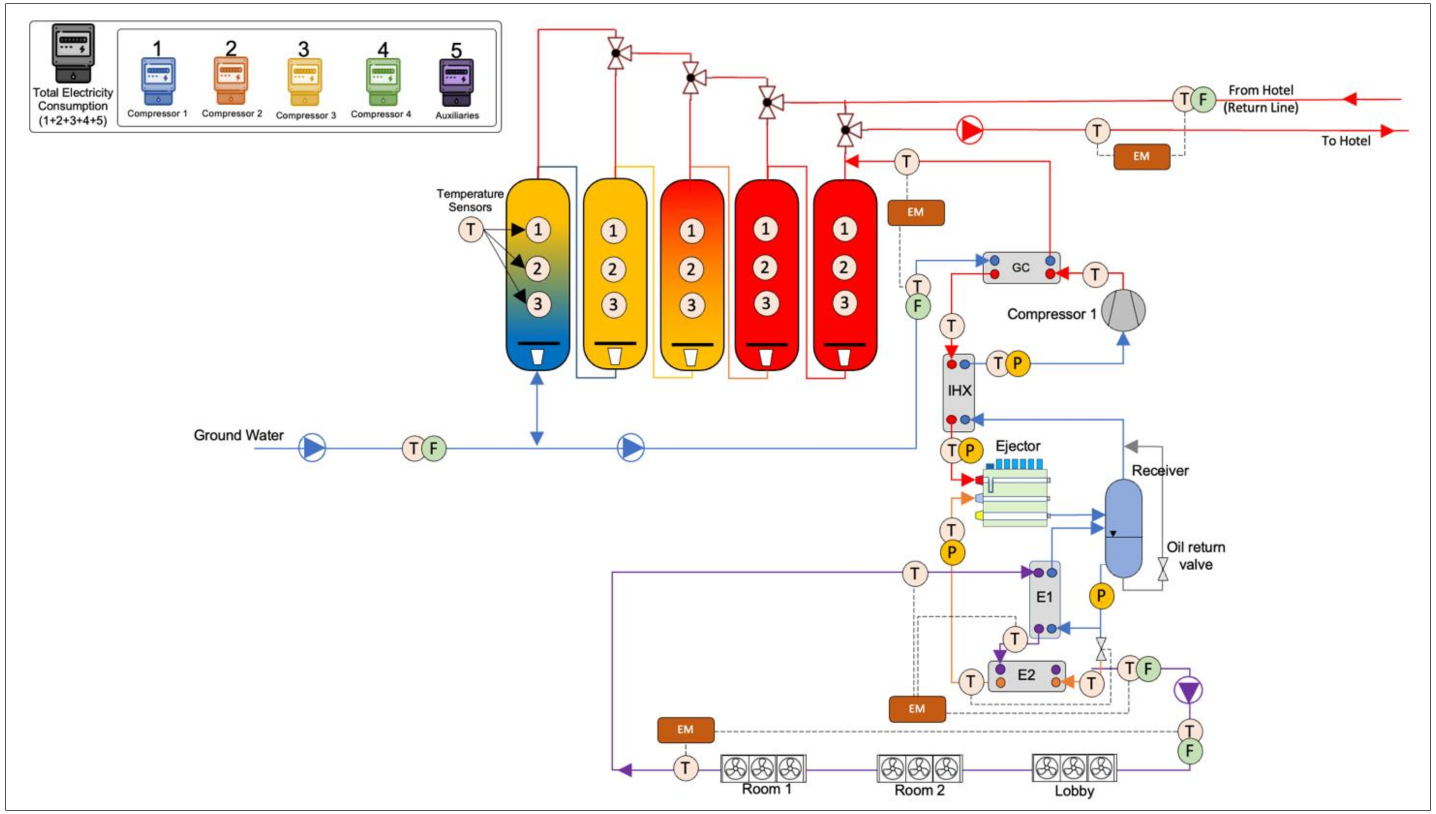
The thermal energy demand in the hotel is intended to be supported by an ejector-based R744 heat pump/chiller unit.

The heat pump/chiller of 120 kW cooling capacity (each evaporator of 60 kW) is designed to produce 70°C hot water and 7°C cold water.



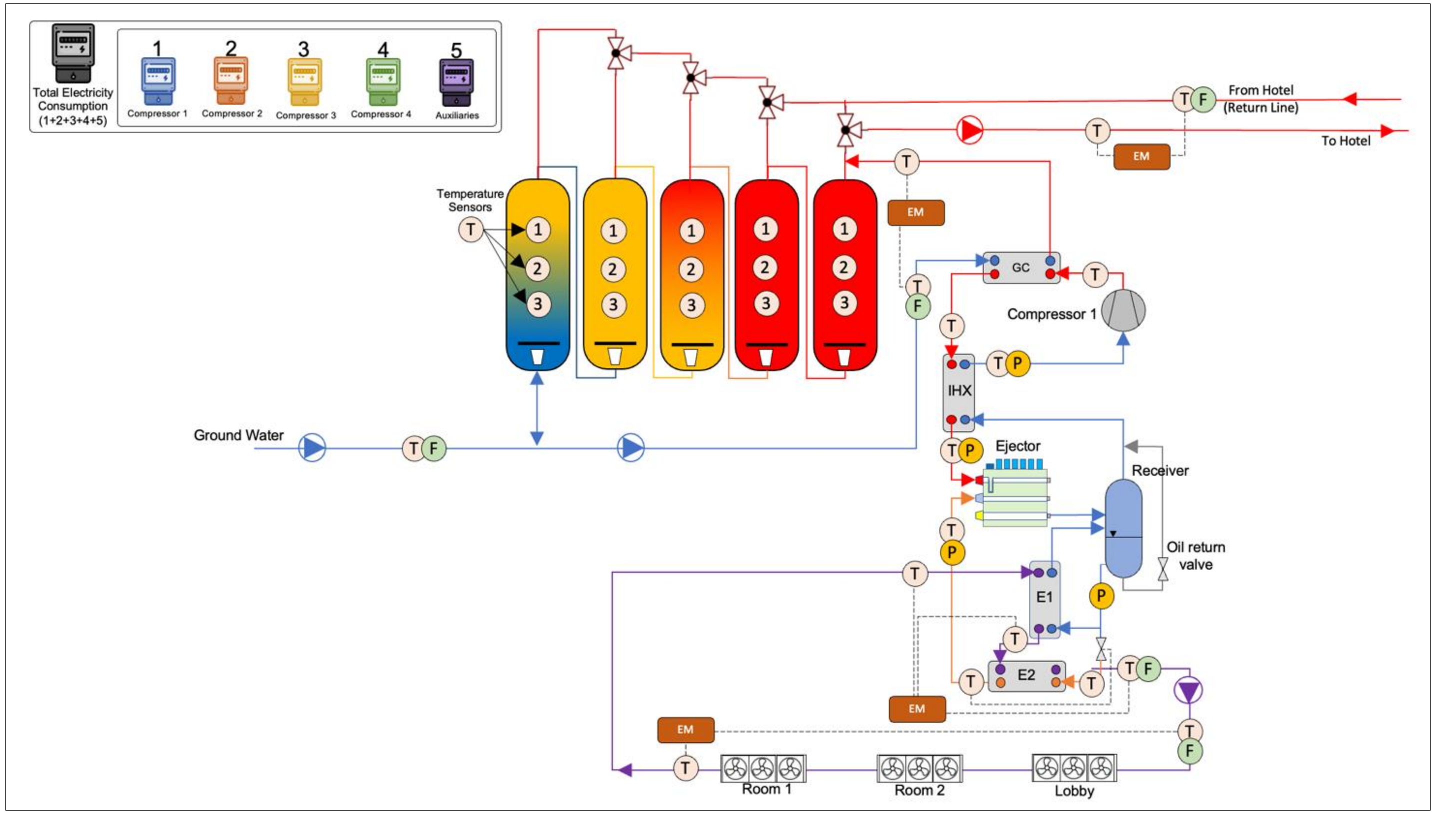
Heating loop

- ✓ The ground water at 24°C passes through the gas cooler, gain the rejected heat.
- ✓ The VFD is programmed to obtain the required high side pressure.
- ✓ The hot water gets collected in the 5th hot water tank through the three-way solenoid valve.
- ✓ After filling the 5th water tank the hot water is channelized towards the 4th, 3rd, 2nd, and later 1st pressurized hot water tank.
- ✓ Controller return water collection is going to be taken care of by an individual three-way solenoid valve connected to the high-rise of each hot water tank.



Chiller loop

- ✓ chiller loop is charged with glycol/water solution.
- ✓ The 1st evaporator temperature which is gravity feed.
- ✓ EEV is installed at the inlet of the 2nd evaporator to achieve the required cooling temperature.
- ✓ The mass flow rate of the water/glycol solution would be controlled to simulate the air conditioning set point temperature in the cooling loop.



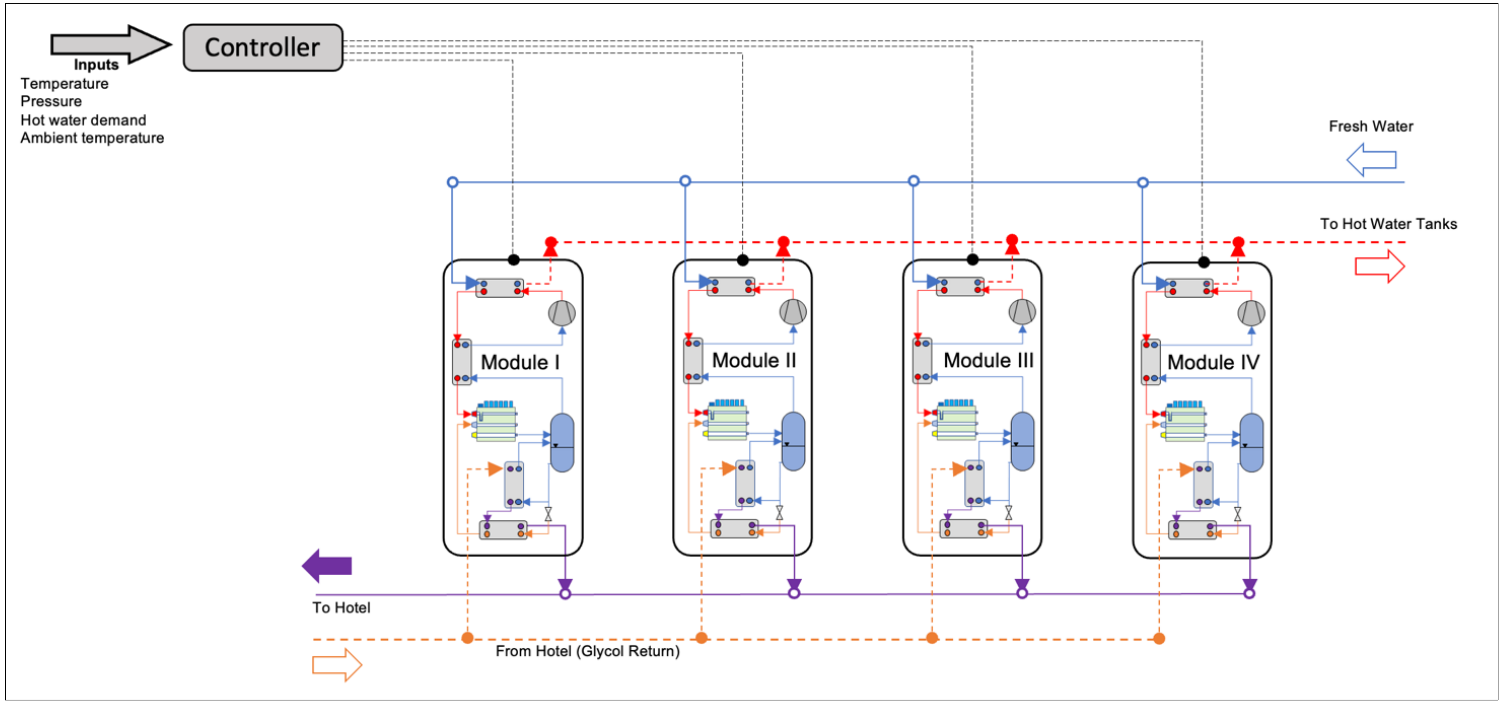
Mode 1: Chiller and DHW

Mode 2: Chiller

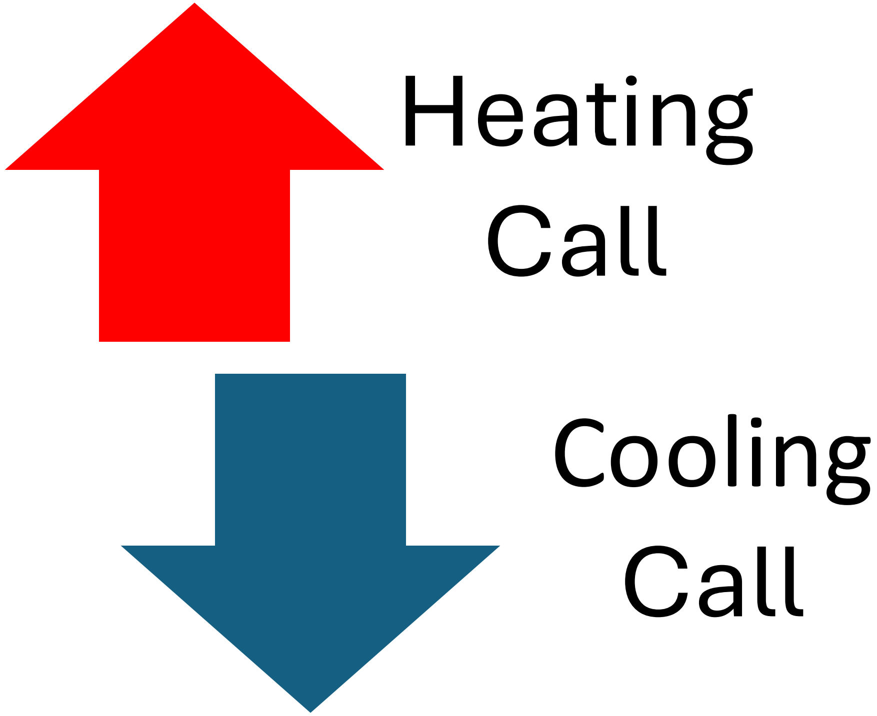
Mode 3: DHW

Three operational modes of the R744 heat pump/chiller are anticipated with the use of advanced directional control valves (DCV) and non-return valves (NRV)

An optimized modulation control strategy is identified as there are four modules (heat pumps/chillers) working in parallel to attain a common operation to fulfill heating and cooling in the hotel.

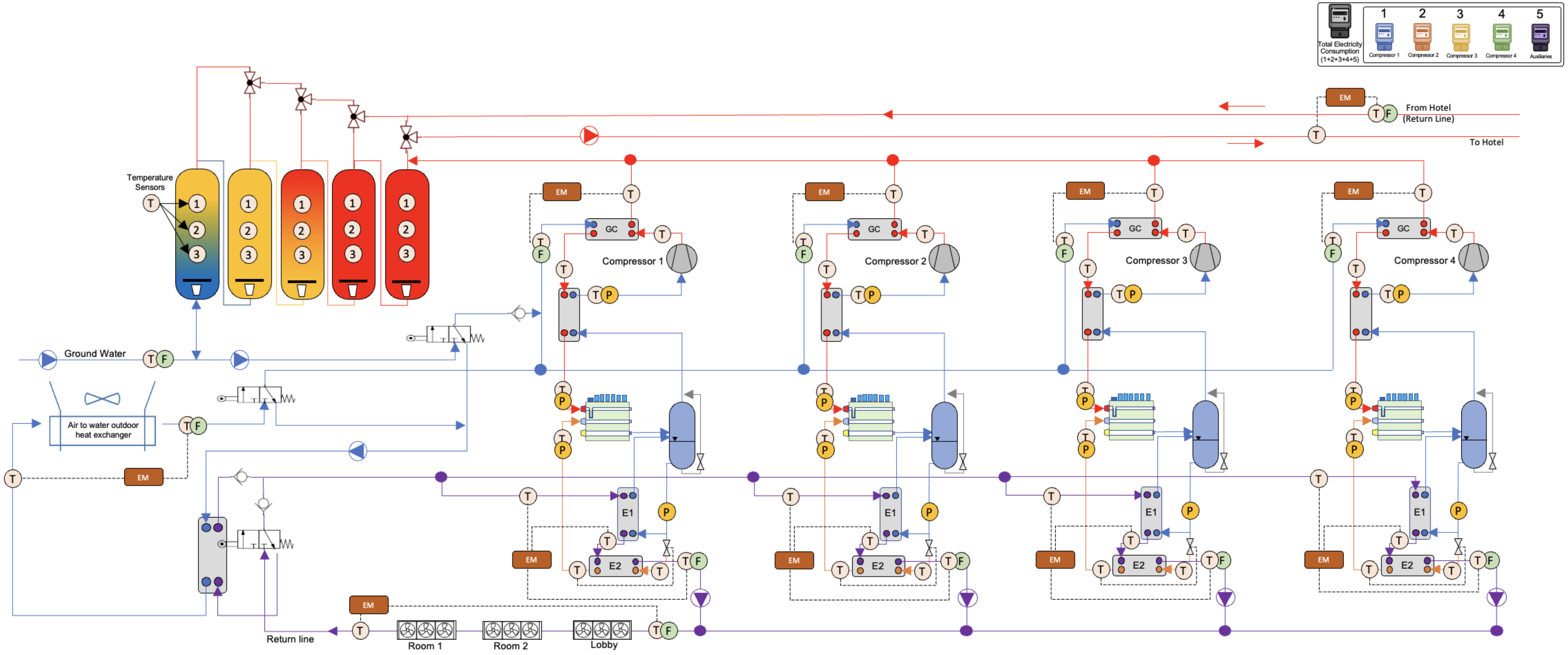


With the support of thermal storage water tanks, each of the four modules would be driven and operated to work as per the requirements. Each module (heat pump/chiller), however, has an independent control logic programme



- ✓ A heating call is generated once the water temperature in the 5th hot water tank is less than the set point temperature inside the tank
- ✓ A cooling call is generated once the return water/glycol solution temperature is more than the set point temperature for 1 minute.
- ✓ In both cases, the next module will be in ON/OFF operation to achieve the set temperature.

Project Introduction | Need of the Hour | Demosites Location | R744 Heat Pump Unit for Hotel | Modulation Control Strategy | On-going Challenges | Future Plans



Stage I:

- ✓ The initial testing of the first heat pump/chiller (module) is in-progress to ensure the unique approach and methods designed and used to fulfill heating and cooling demands in the hotel.
- ✓ Once the initial testing is performed, the rest of three heat pumps/chillers (modules) are planned assembled directly at the hotel site in Goa.

Stage II:

- ✓ The hot-water and cold-water piping networks are ongoing.
- ✓ Thermal storages or hot water tanks are under fabrication and testing process to ensure a streamlined water collection.
- ✓ Air to water outdoor heat exchanger is also under fabrication at a different location in Goa a planned.

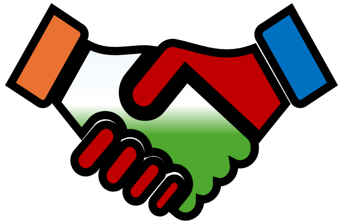
Stage III:

- ✓ System commissioning and data extraction development to support the knowledge disseminatio activities.

ACKNOWLEDGEMENTS

Norwegian Embassy
New Delhi

INDIA



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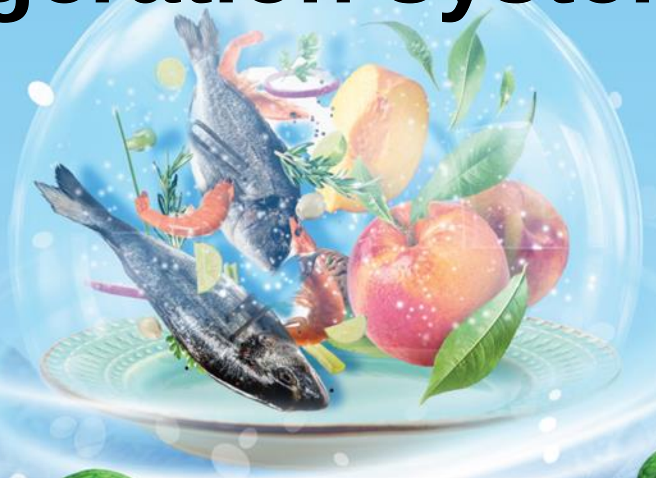
Performance evaluation of CO_2-NH_3 cascade refrigeration system for seafood deep freezing



Presented by
Arun. B. S
ICAR-CIFT Kochi

About ICAR-CIFT

- The ICAR - Central Institute of Fisheries Technology **(ICAR-CIFT**) set up in 1957 is the only national center in the country where research in all disciplines relating to fishing and fish processing is undertaken.
- Research centers function at Veraval, Visakhapatnam and Mumbai.
- INDEE+ Future Refrigeration India Project: Engineering Division at CIFT

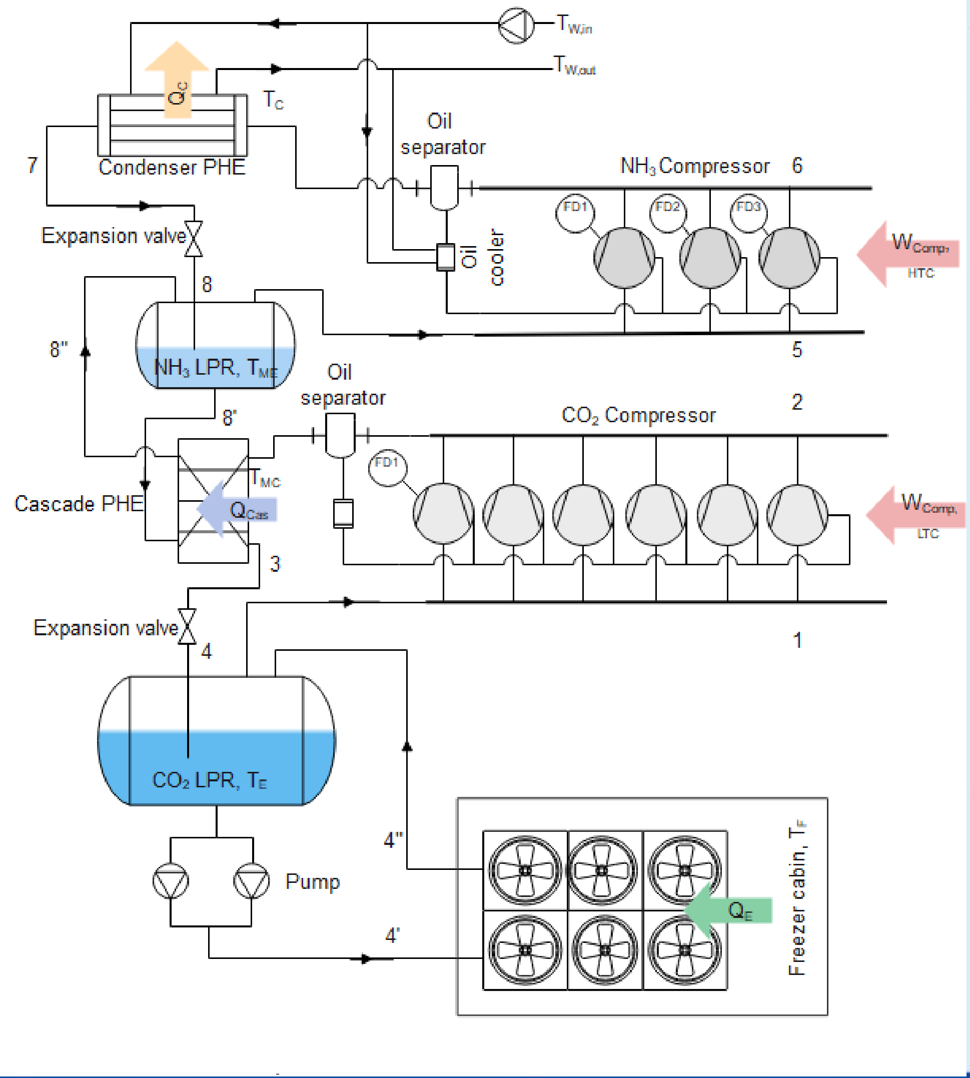
Demonstration site Bellfoods Pvt. Ltd. & NAS Fisheries Pvt. Ltd.

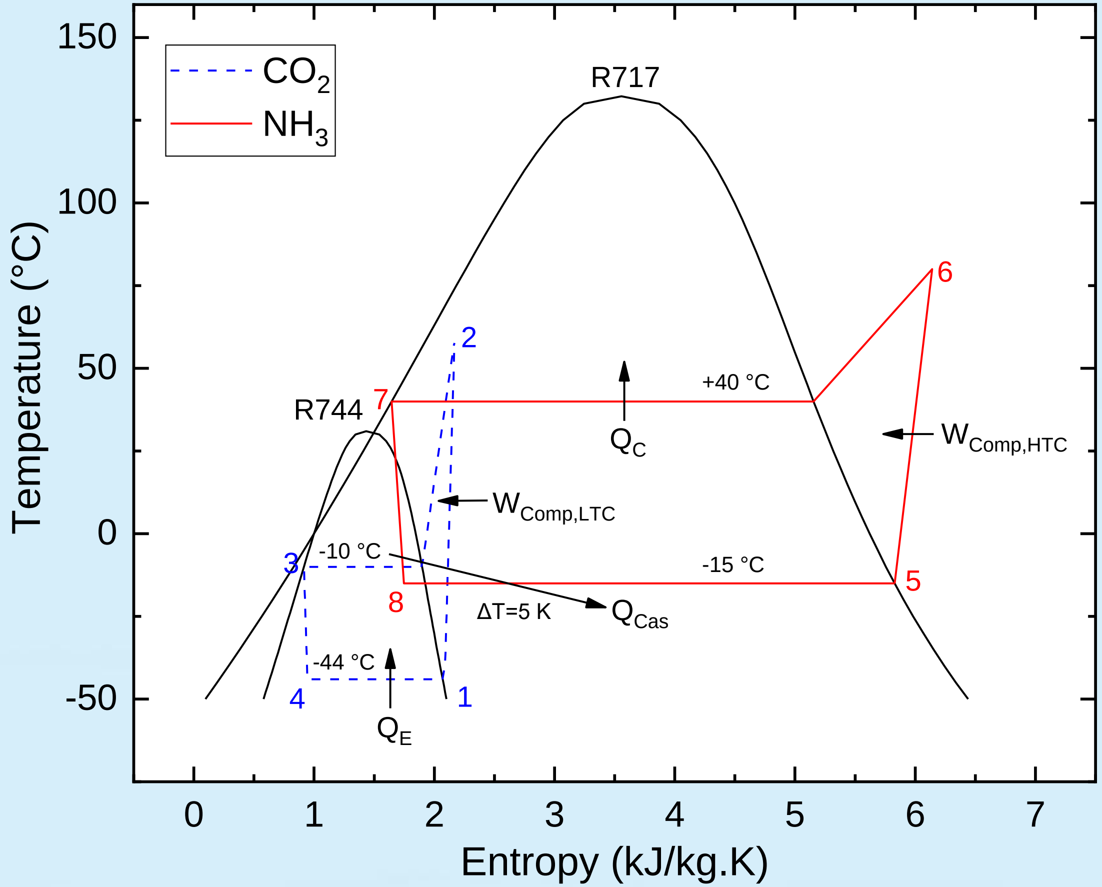
NAS FISHERIES PRIVATE LIMITED

- Tunnel freezer (IQF) with Cooling capacity 350 kW
- **CO_2-NH_3** cascade refrigeration system
- Evaporator temperature at -43 **°C**
- Loading capacity 1000 kg/h

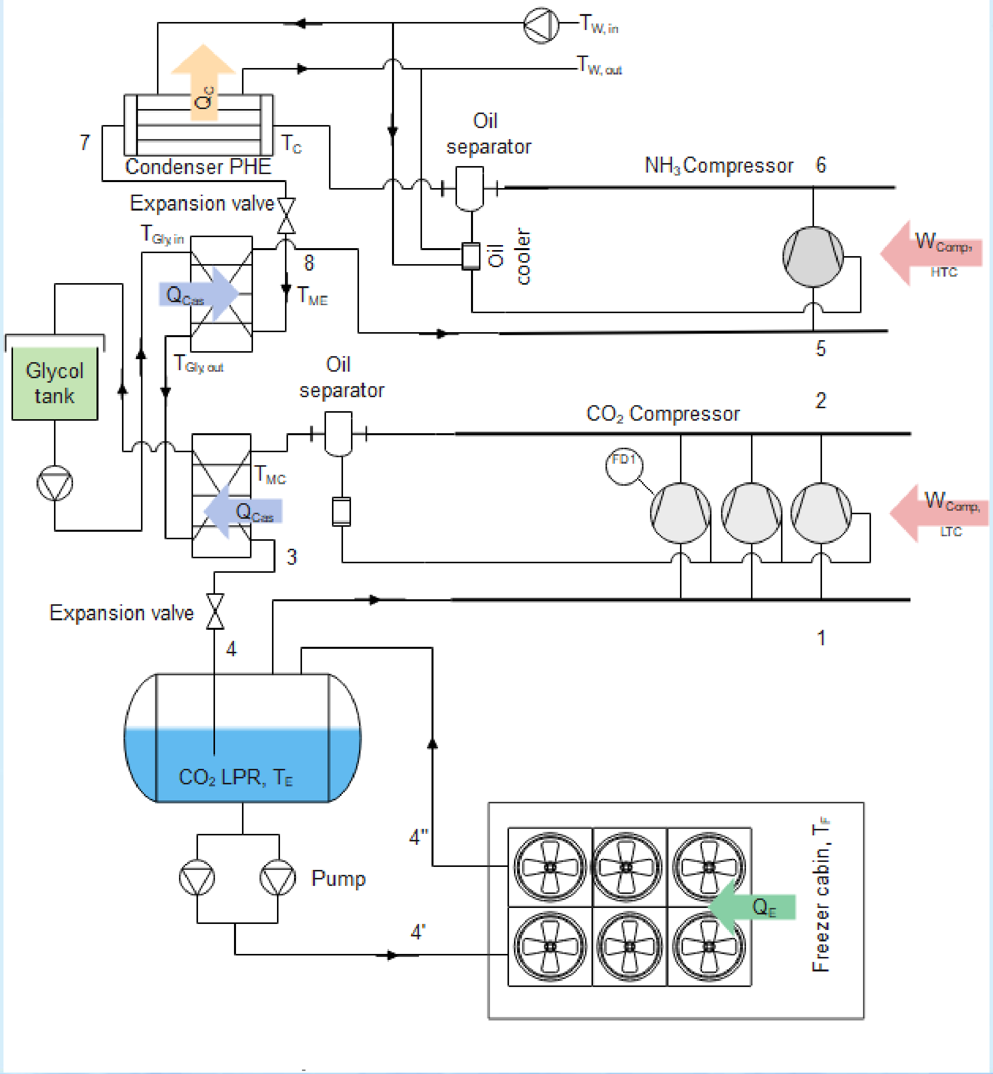
- Tunnel freezer (IQF) with Cooling capacity 150 kW
- Three Fluid system, **CO_2-Glycol-NH_3** cascade refrigeration
- Evaporator temperature at -44 **°C**
- Loading capacity 500 kg/h

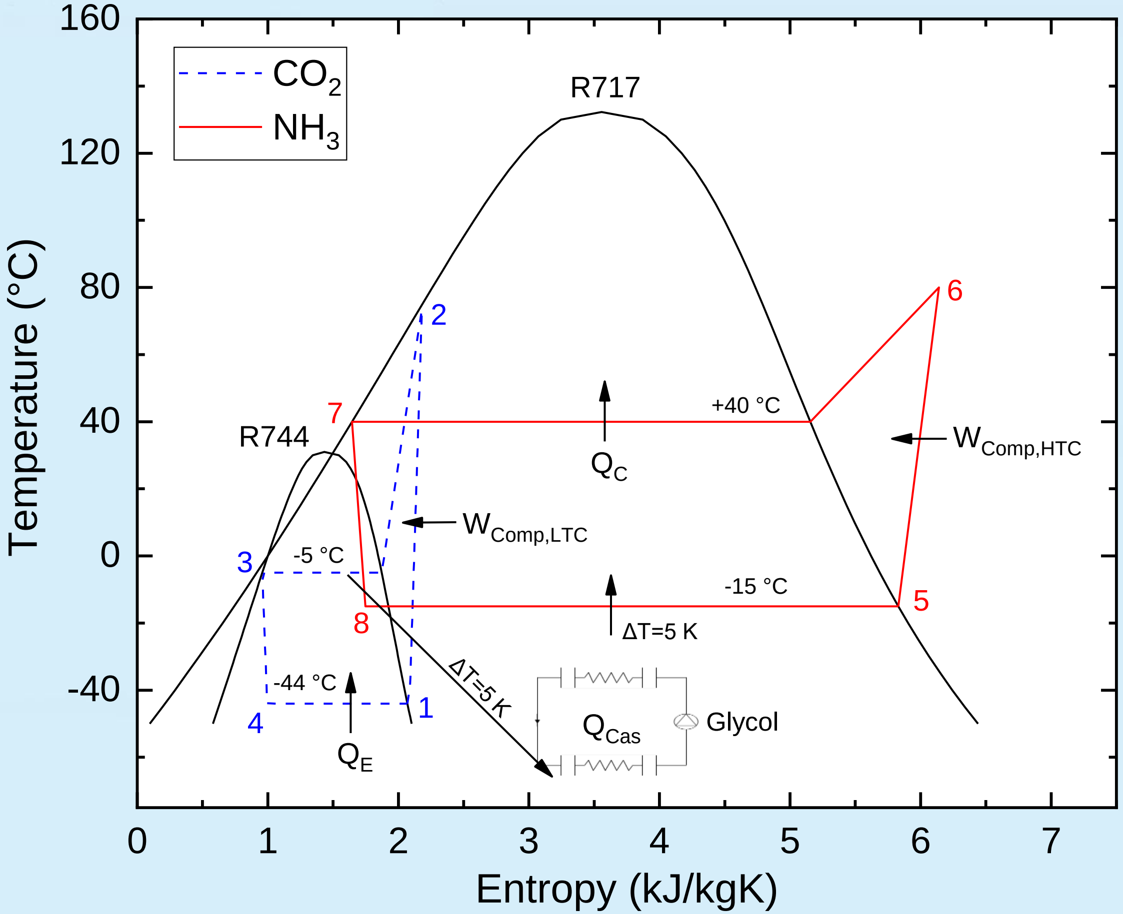
P&ID of CO_2-NH_3



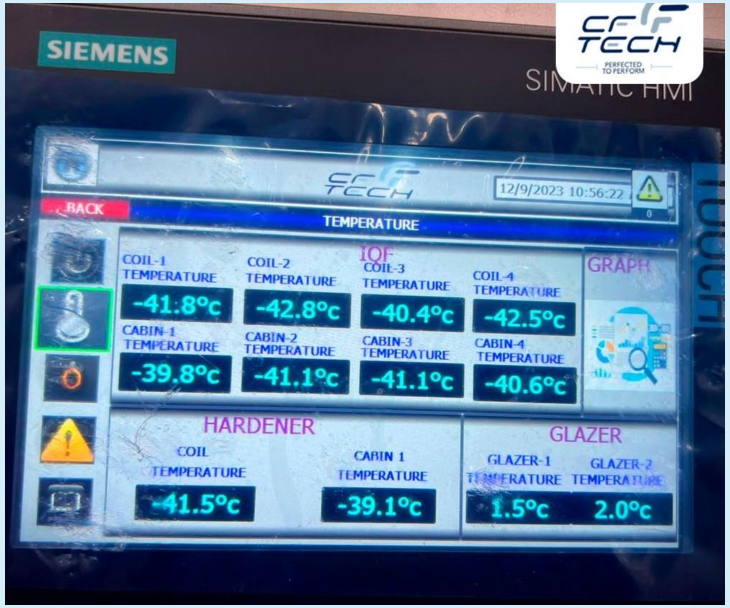


P&ID of CO_2-Glycol-NH_3

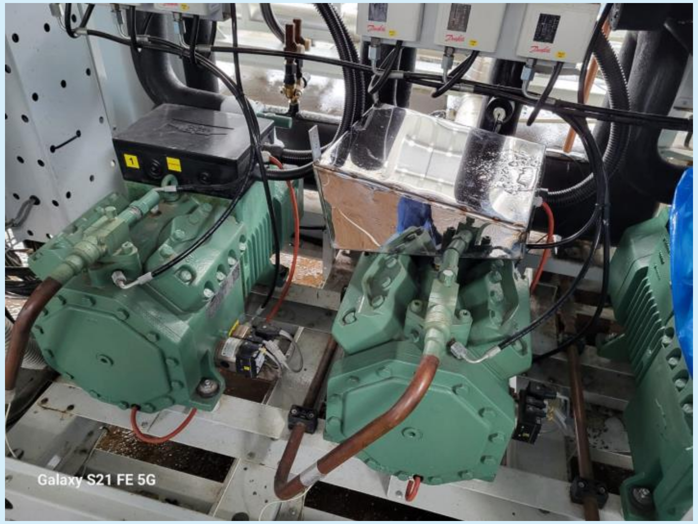


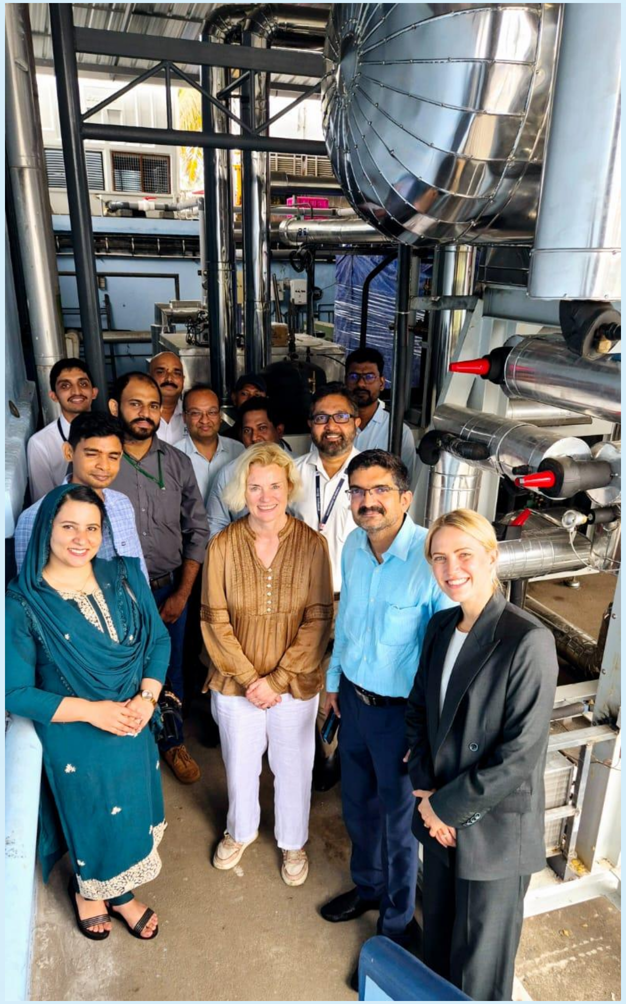


Photographs of CO_2-NH_3 (Commissioned in December 2023)



Photographs of CO_2-Gly-NH_3
(Commissioned in June 2024)





Data collection

Sensors used

a

b

c

d

a) Thermal energy meter/BTU meter/Flow meter
b) Temperature sensors PT1000 on CO_2 & NH_3 line
c) Temperature sensors on condenser cooling water line
d) Pressure sensors on suction and discharge

Data management

CO_2 unit PLC NH_3 unit PLC

- Suction temp. & pressure
- Discharge temp. & pressure
- Superheat
- PLC to PLC communication

→ PLC to PLC →

Freezer PLC

- Evap. coil temp.
- Freezer cabin temp.
- Electrical energy kWh
- Cooling water/glycol flow rate
- Water/glycol temp.

→

IoT device

- 24x7 internet connection
- Static IP address

→

Data hosting/cloud

- Hosted through website
- Accessed from India and Norway

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Screenshot from website

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CFT1092 — Multiple languages

«« « » »»
No.8Page Per Page1000 Row
Total **39839** Item

	IQF CABIN-1 TEMPERATURE	IQF CABIN-2 TEMPERATURE	IQF CABIN-3 TEMPERATURE	IQF CABIN-4 TEMPERATURE	DISCHARGE PRESSURE	DISCHARGE TEMPERATURE	SUCTION PRESSURE	SUCTION TEMPERATURE	CO2 KWh	COMPRESSOR-1 KWh	COMPRESSOR-2 KWh	COMPRESOR-3 KWh
…5	-38.9	-39.6	-39.4	-34.1	13.6	62.0	2.1	-16.2	123801	18512	38312	20353
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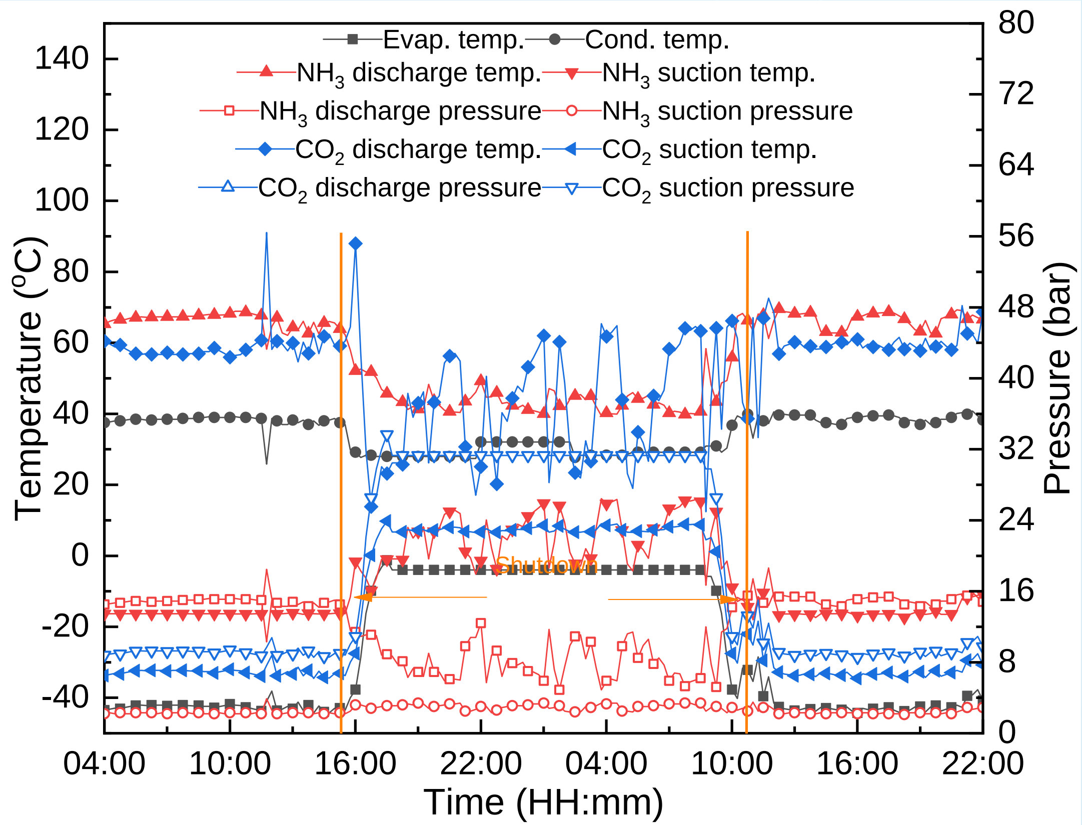
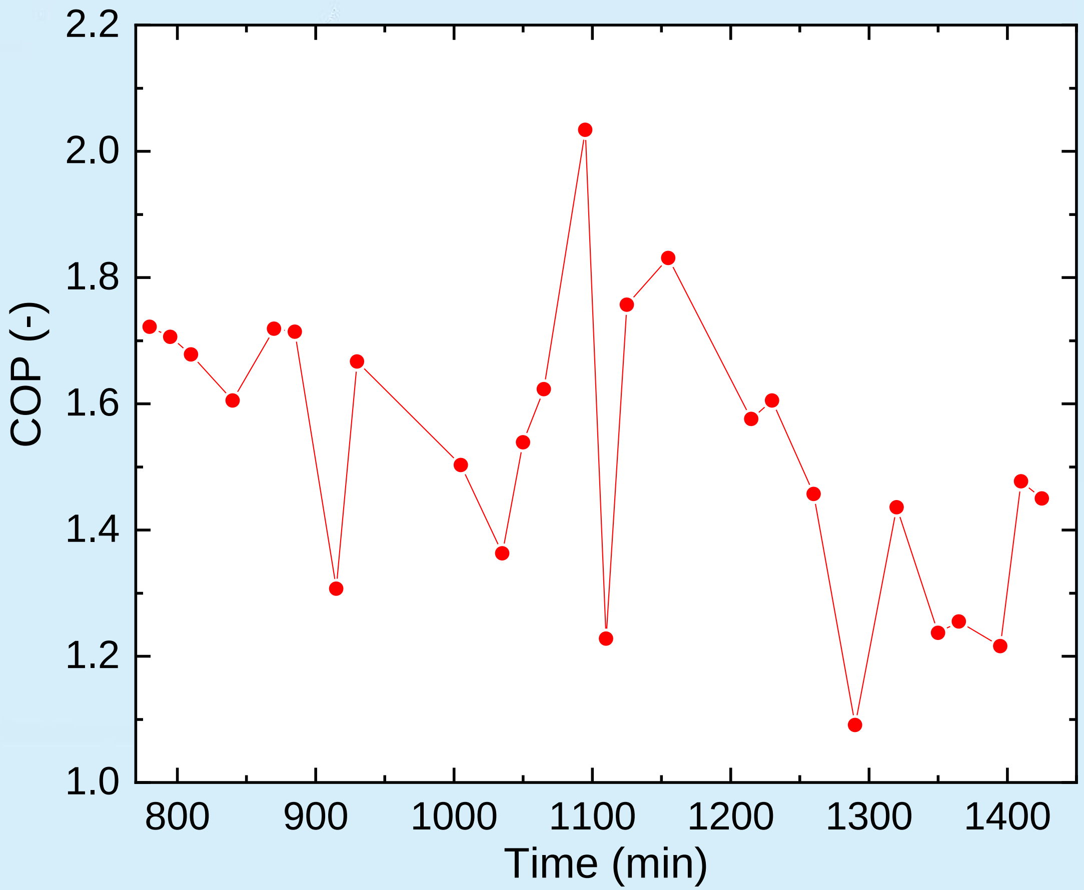
2024-09-07 07:12:46	-39.1	-39.8	-39.7	-35.0	14.4	65.3	2.1	-16.3	123808	18525	38312	20353
2024-09-07 07:13:46	-39.1	-40.0	-39.8	-35.1	14.3	65.6	2.1	-16.3	123809	18527	38312	20353
2024-09-07 07:14:46	-38.8	-39.8	-39.5	-34.9	14.1	65.7	2.1	-16.9	123809	18528	38312	20353
2024-09-07 07:15:46	-38.4	-39.6	-39.3	-34.6	13.8	65.5	2.1	-16.7	123810	18529	38312	20353
2024-09-07 07:16:46	-38.2	-39.5	-39.2	-34.4	13.6	64.8	2.1	-16.5	123810	18530	38312	20353
2024-09-07 07:17:46	-38.1	-39.3	-39.2	-34.3	13.6	64.3	2.1	-16.3	123811	18531	38312	20353
2024-09-07 07:18:46	-38.1	-39.2	-39.1	-34.1	13.6	63.9	2.1	-16.2	123811	18532	38312	20353

IQF CA...
IQF CA...
IQF CA...
IQF CA...
DISCH...
DISCH...
SUCTI...
SUCTI...
CO2 KWh
COMPR...
COMPR...
COM...

Plots showing operating parameters and performance

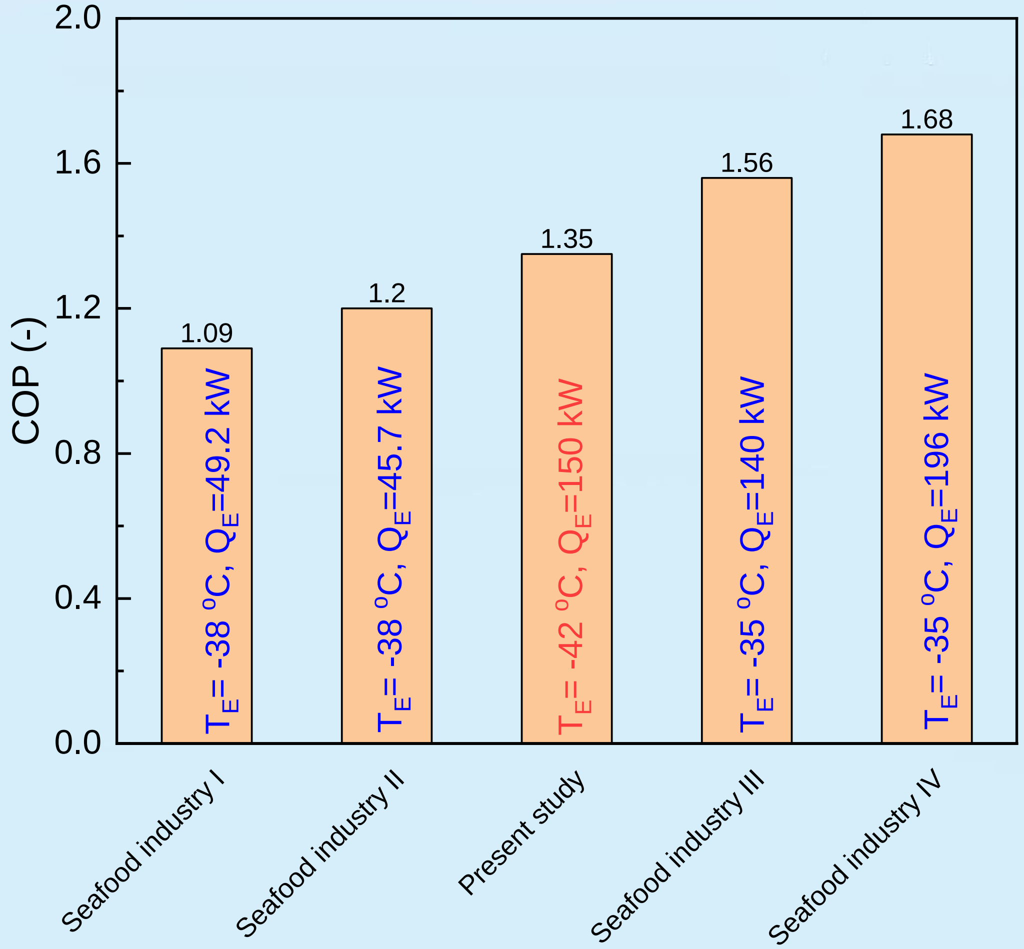


Variation of temperature and pressure with time



Instantaneous COP

Results



Seafood Processing Industry	Evaporator temperature (°C)	Cooling capacity (kW)	COP (-)
Present study (CO_2-NH_3)	-42	150	1.35
I (two-stage)	-38	49.2	1.09
II (two-stage)	-38	45.7	1.2
III (two-stage)	-35	140	1.56
IV (two-stage)	-35	196	1.68

Comparison between CO_2-NH_3 cascade and NH_3 two-stage refrigeration systems

Vendor & supplier details

Cochin Food Tech Pvt. Ltd.

Contact Person:

Mr. Saju George

Mob: +919656404300

email: saju.george@cftech.in

CF TECH
PERFECTED TO PERFORM

Bitzer | thermofin® | thermowave | ALFA LAVAL | CAREL | SIEMENS | MIRRANT | frascold

Conclusions

- ✓The demonstration sites are purchased and owned by the end-user.
- ✓INDEE+ team has provided active support during the design, tender and commissioning.
- ✓A data management plan is established, in agreement with the end-users.
- ✓Joint scientific publications for sharing the findings.
- ✓Local vendors will provide the service and maintenance even after INDEE+ is terminated.
- ✓Encouraging others to adopt similar refrigeration systems.

Conclusions

- We acknowledge the support received from the ongoing Indo-Norwegian project "Future Refrigeration India: INDEE+" (CIFT/FRI-INDEE+) funded by the Norwegians Ministry of Foreign Affairs, coordinated by Norwegian University of Science and Technology (NTNU) and SINTEF Ocean, Norway.

INDEE

Norwegian Embassy
New Delhi

INDEE

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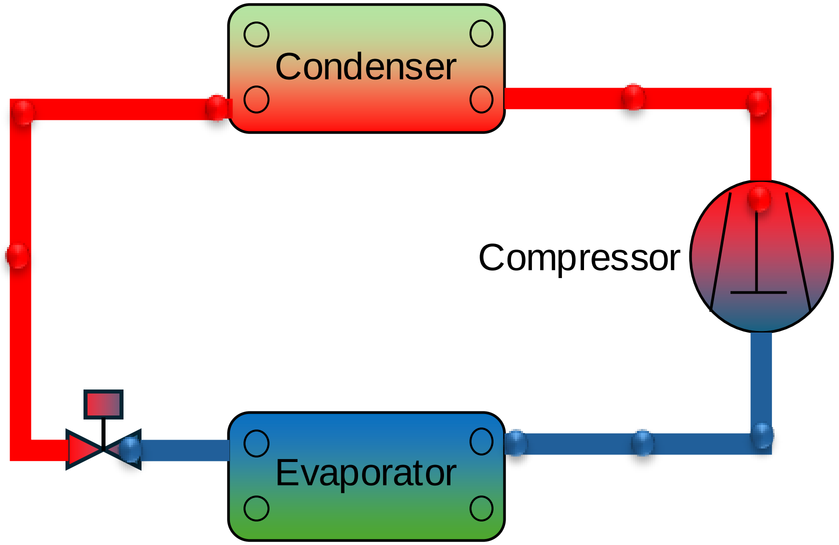
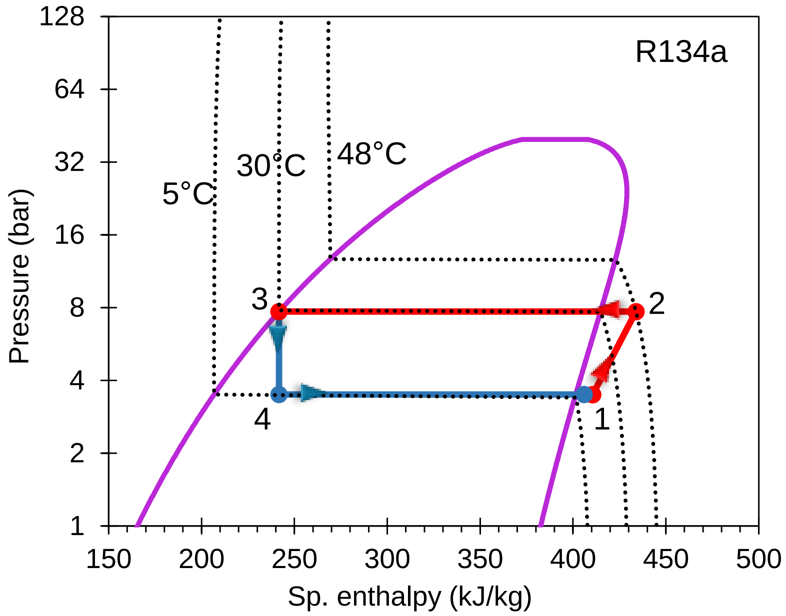
Learning from CO_2 refrigeration and heat pump system developed in India

VINOD LAGURI
PhD Scholar
Indian Institute of Science, Bengaluru, India

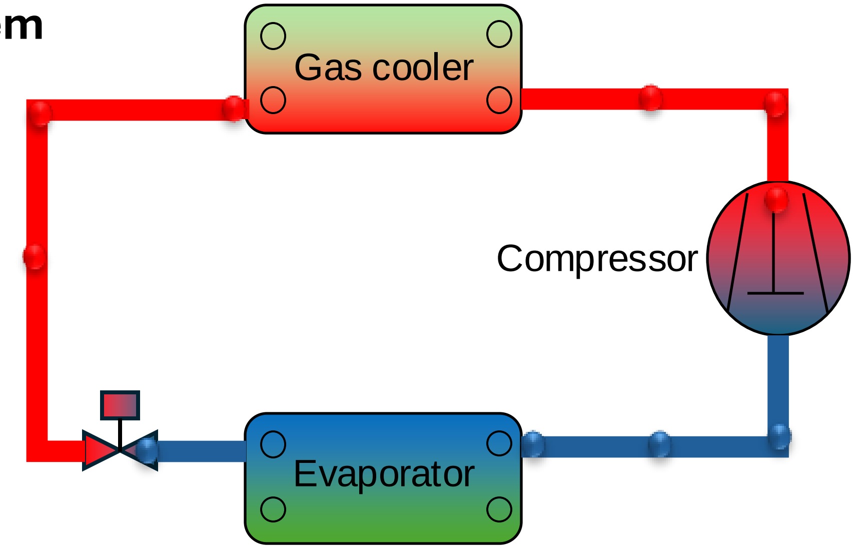
INDEE

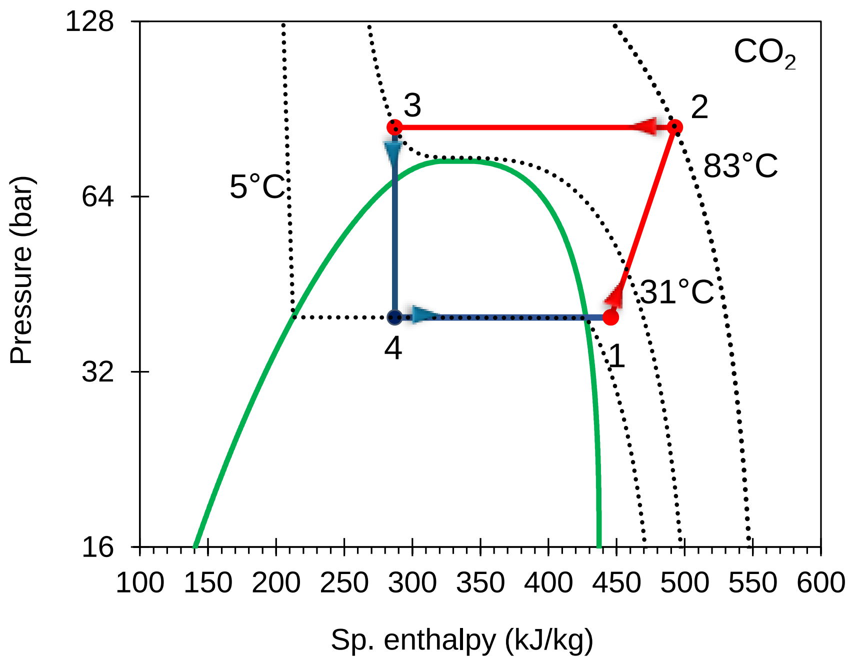
R134a system



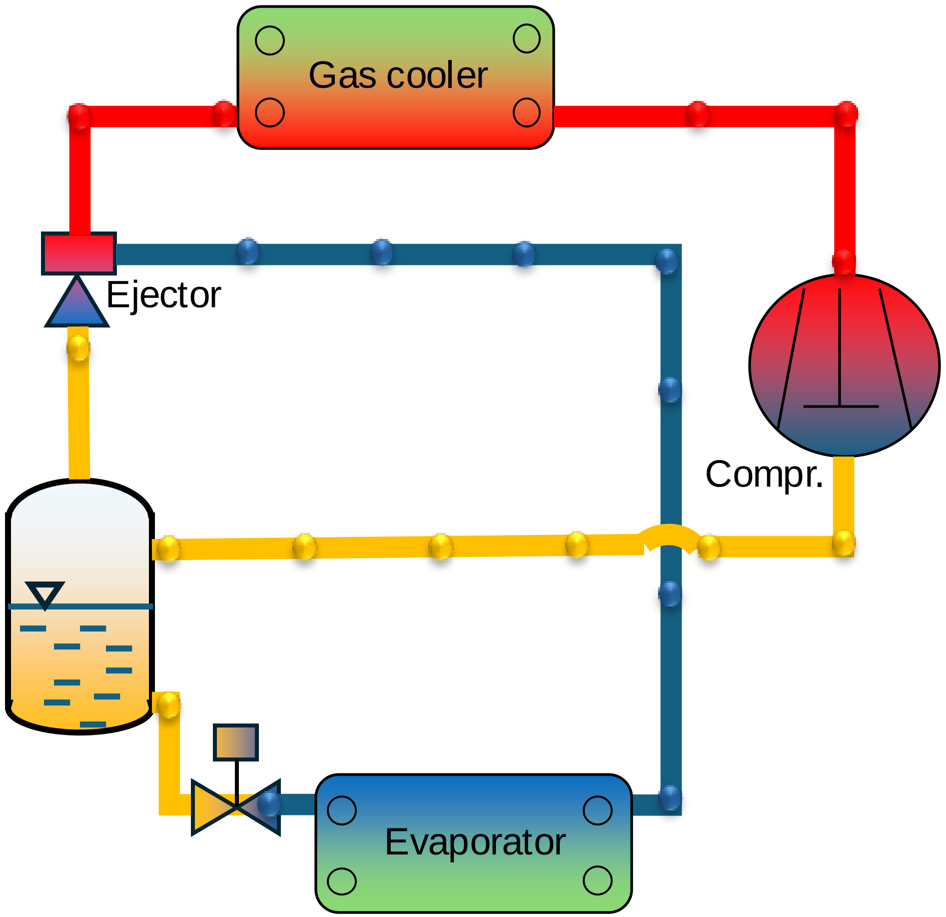


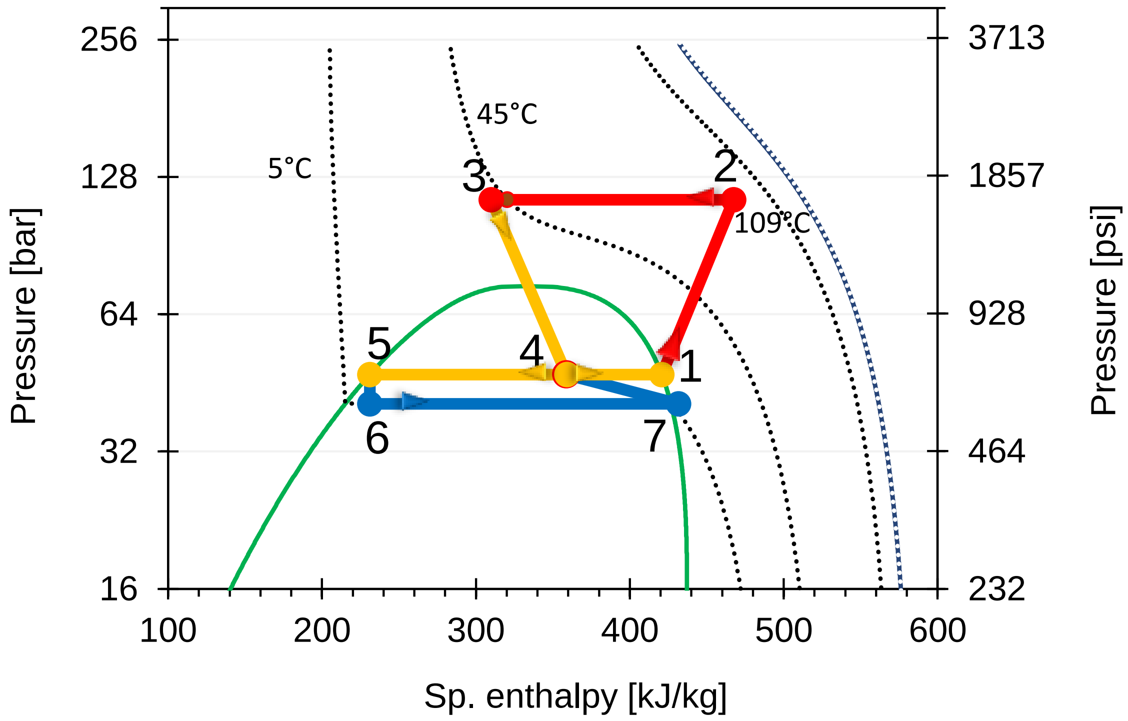
CO_2 system





Advantages of high pressure





- Environmentally friendly with low GWP (1).
- Safe, non-toxic, and non-flammable refrigerant.

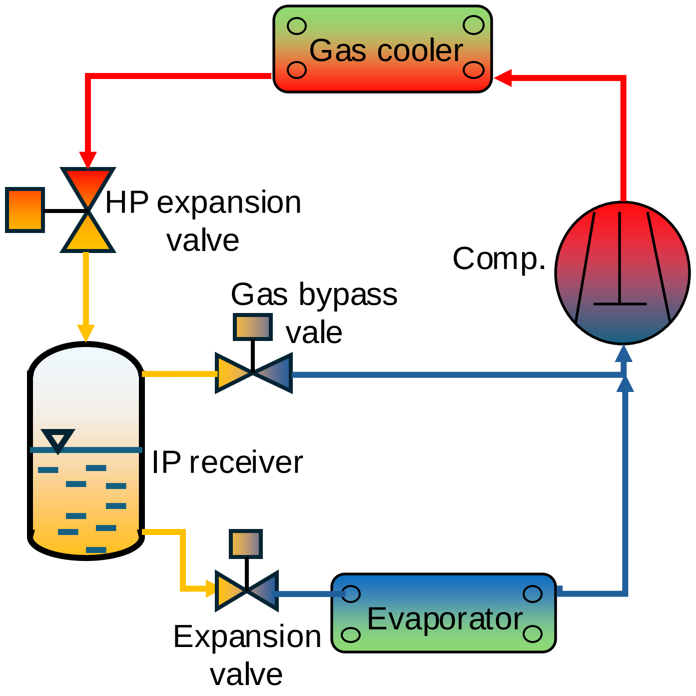
- 9% to 12% higher COP
- 10% to 25% energy savings.
- Compact design, reduce footprint up to 30%.

Basic design parameters

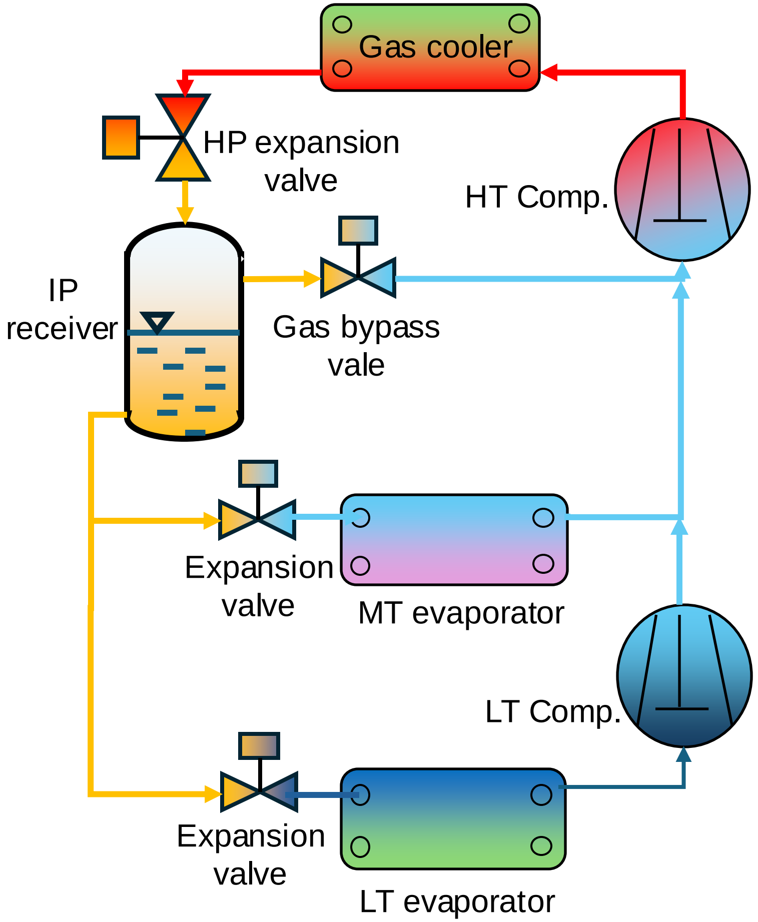
INDEE

- ✓ Applications: Freezing/Refrigeration/chilled water/Heat pump etc…
- ✓ Cooling capacity (kW/TR):
- ✓ Cabinet temperature (℃):
- ✓ Chilled water temperature (℃):
- ✓ Chilled water return temperature (℃):
- ✓ Heating capacity (kW/TR):
- ✓ Hot Water temperature (℃):
- ✓ Hot water return temperature (℃):
- ✓ Ambient Temperature: (Min, Max, Avg.):
- ✓ Relative humidity/Wet bulb temperature:

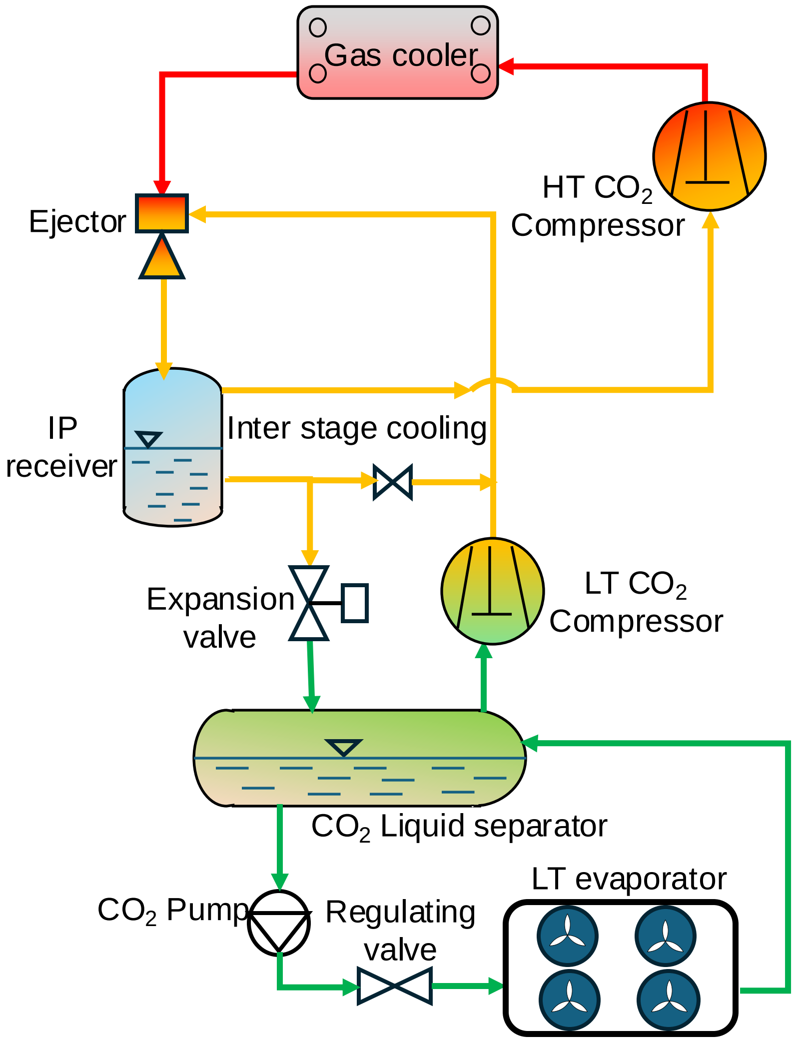
Selection/Design of system configuration



Simple gas bypass system



Two stage compression system



Two stage ejector compression system

Component selection

COMPRESSOR

BOCK

DORIN

Frascold

Bitzer

Selection parameters

Cooling / heating capacity : kW
Evaporator temperature : °C
Superheat : K
Gas cooler temperature : °C
Gas cooler pressure: bar

Component selection…

Alfa Laval

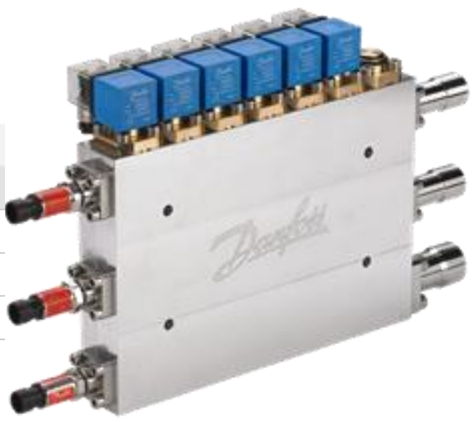
Heat exchanger

Selection criteria

1. Evaporator : Always go for distributor (H and M type plate preferred)
2. IHEx : Over surfacing more than 15%
3. AXP/CBXP series max. 300 plates is good to use
4. Gas cooler : higher delta T on water side
5. 300 kW and above capacity: Use multi evaporator

Danfoss

Selected	Type	NS	Max. capacity [kW]	Min. capacity [kW]	Load [%]	DP [bar]	Velocity, in [m/s]	Result
●	CCMT 2	15	31.33	0.492	32	45.65	0.40	✓
○	CCMT 4	15	82.96	1.304	12	45.65	0.40	✓
○	CCMT 8	15	147.3	2.317	7	45.65	0.40	✓
○	CCMT 16	25	294.7	14.03	3	45.65	0.14	⚠



Expansion valve

Ejector

Selection of controller

Danfoss controller

AK-PC 782A

EKE -1C

AK-SM 800

AK-PC 783A

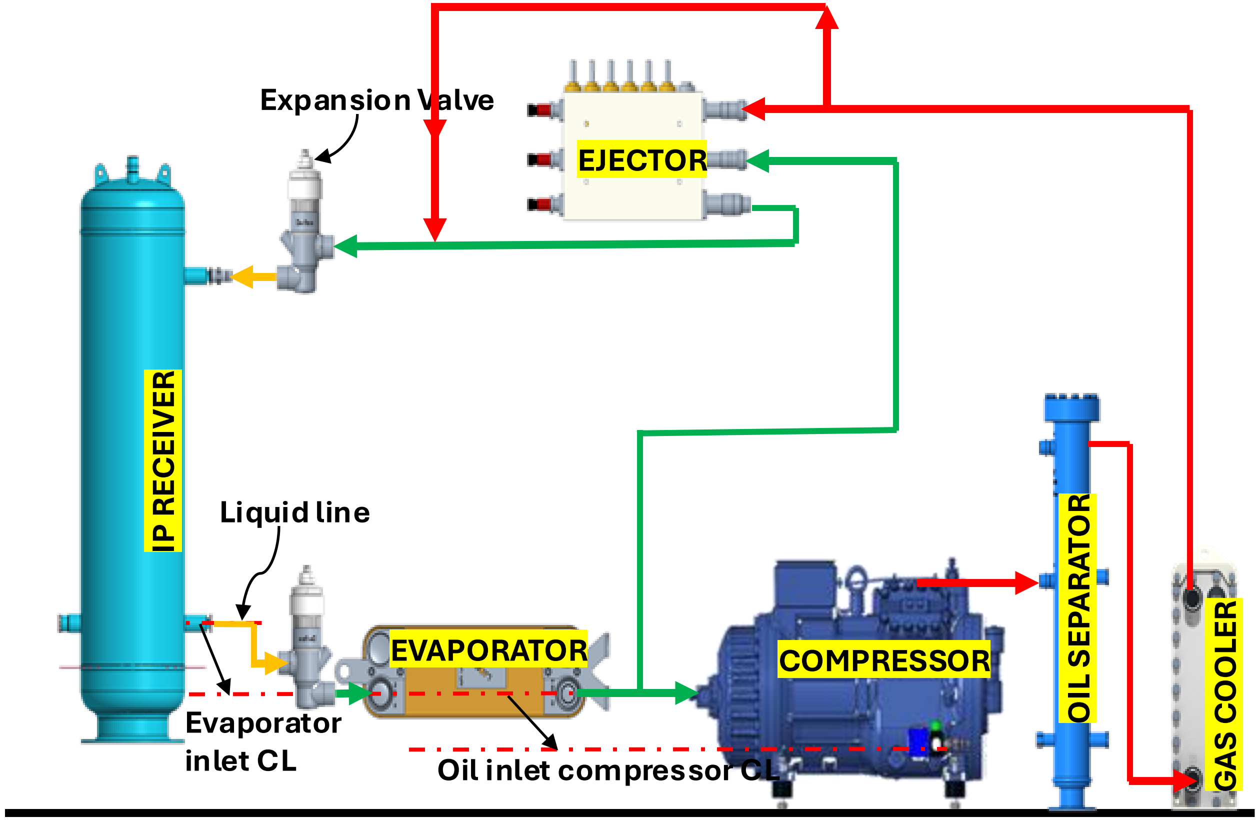
Main applications:

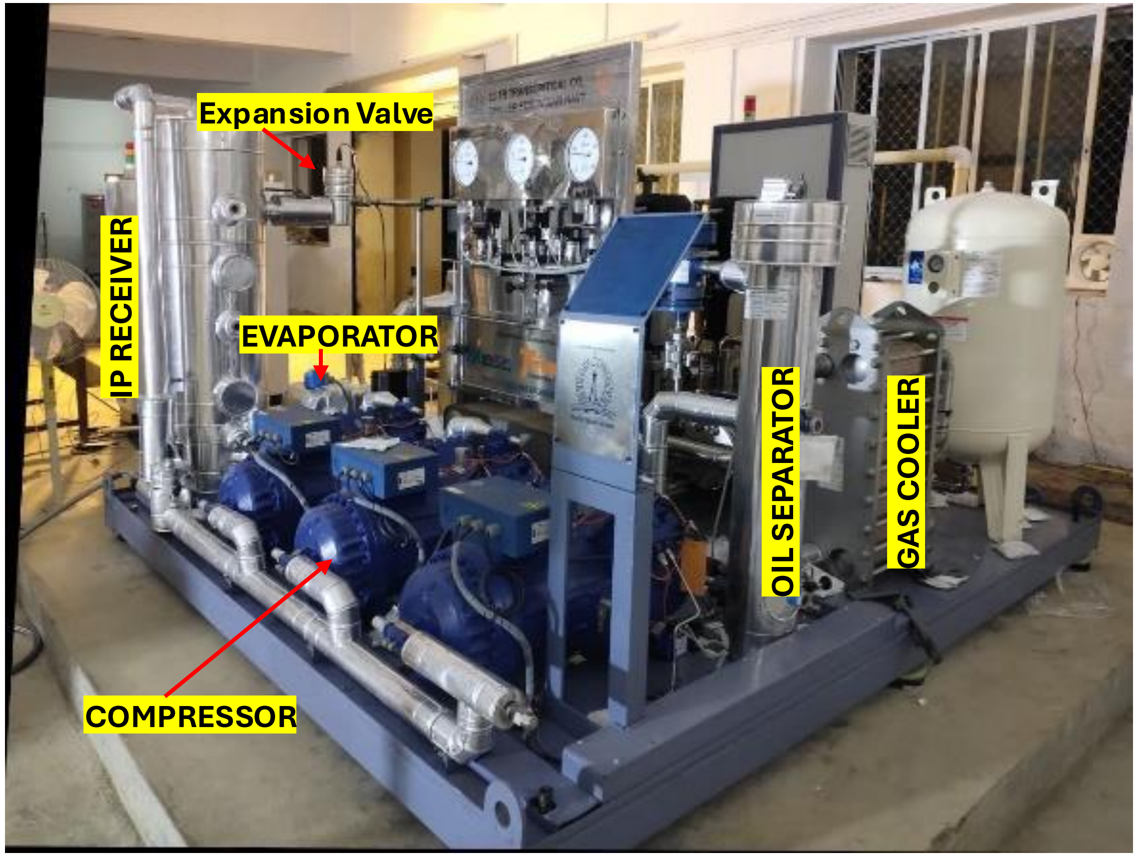
- Trans critical CO_2 booster applications

Main functionality (preliminary)

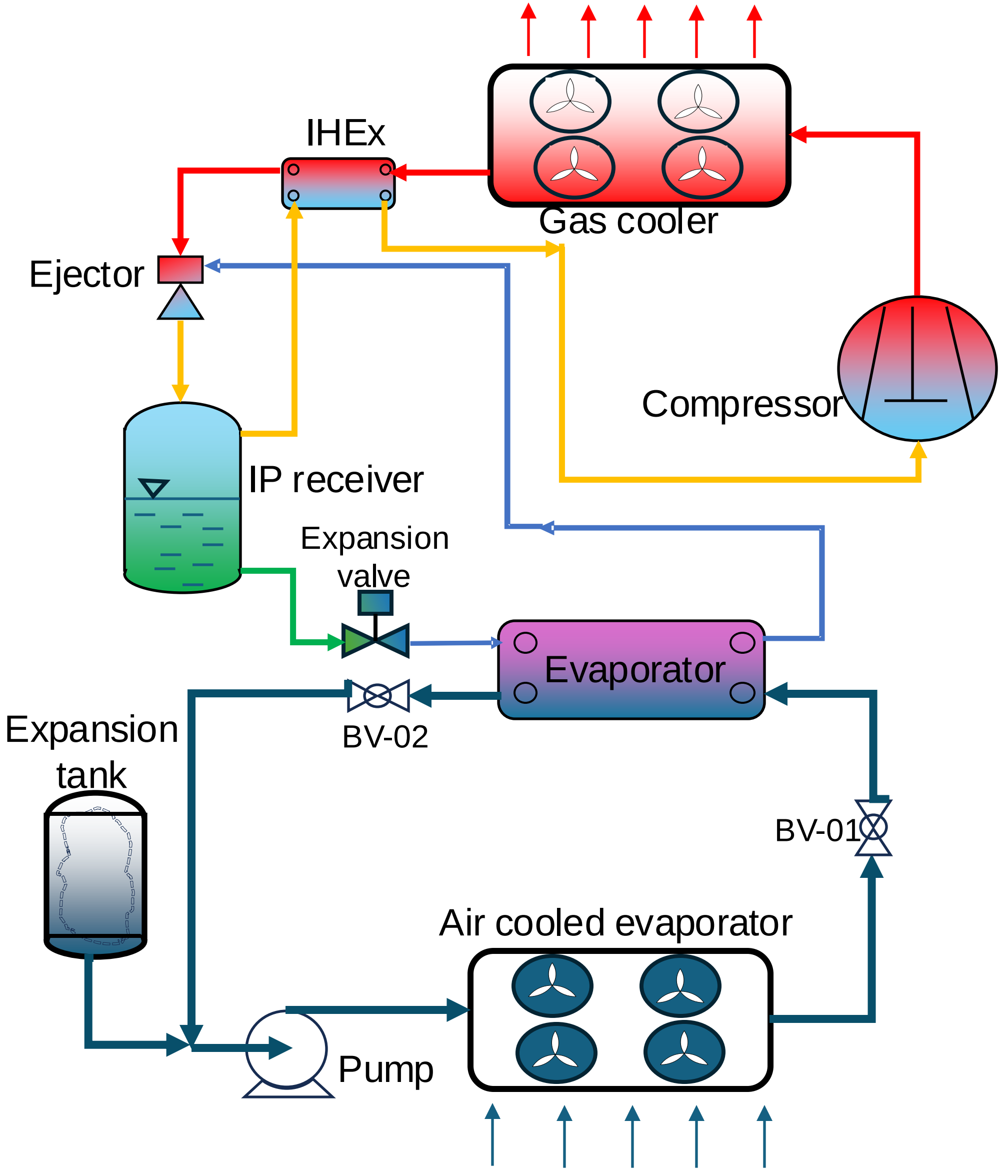
- <u>One</u> controller for 8 MT/IT (parallel compr.) + 4 LT
- Gas cooler control (as AK-PC 781)
- <u>Enhanced</u> Receiver control
- Heat recovery control (2 – as AK-PC 781)
- <u>Simplified</u> Oil management
- General purpose IO (25 - as AK-PC 781)
- General purpose PI controllers (3 - as AK-PC 781)
  - Smart PI configuration
- <u>Simplified</u> User Interface

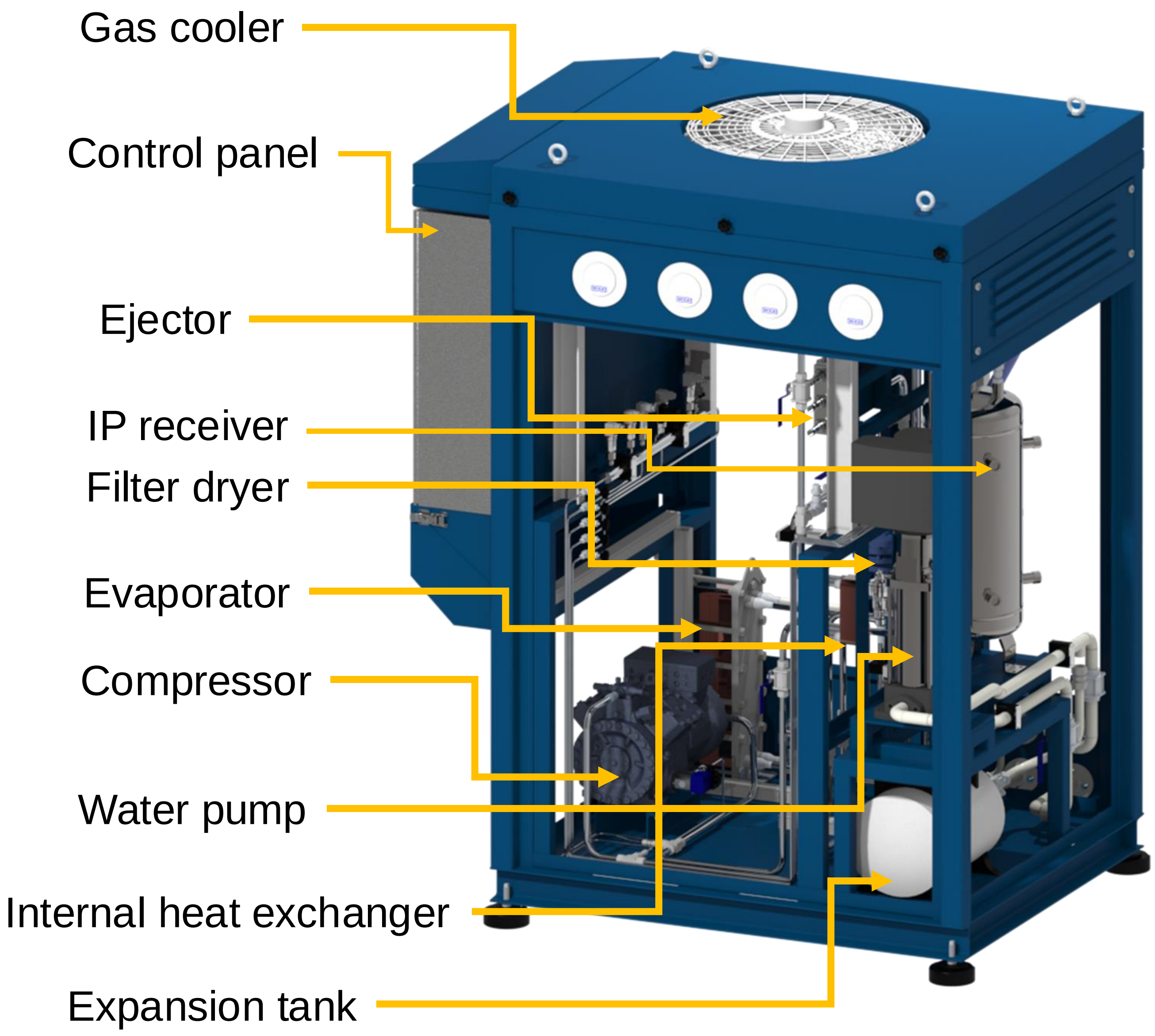
Component placement





Component placement



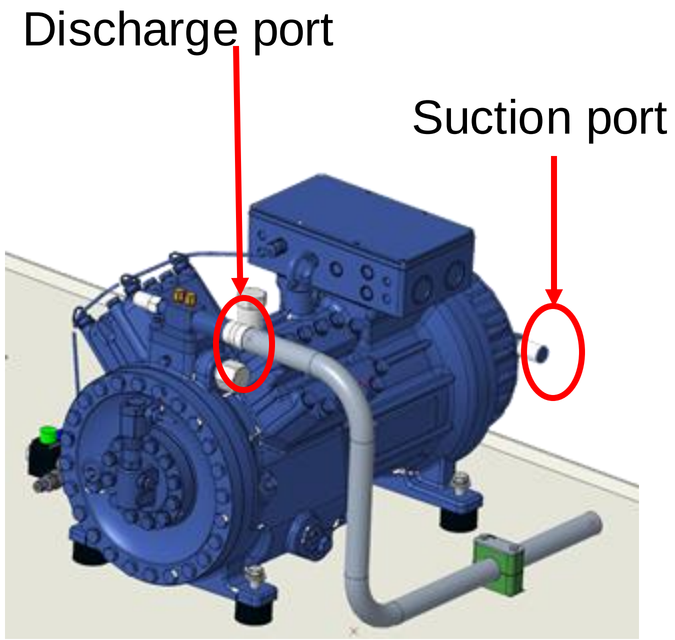


Pipe sizing

Pipe sizing criteria

The flow velocity in the pipeline should not exceed 10% of the speed of sound speed

Line section	Velocity (m/s)	Remarks
Suction line	8-12	A minimum velocity required for oil return
Discharge line	8-14	Higher velocity, lower oil separator efficiency
Liquid line (pump inlet)	<0.3	To avoid vapor flashing
Liquid line (EEV inlet)	<1.2	DX system to minimize liquid hammer
Flash Gas Bypass Lines	4 - 6	---
Oil return line	3 (minimum)	Horizontal line
	8 (minimum)	Vertical Line

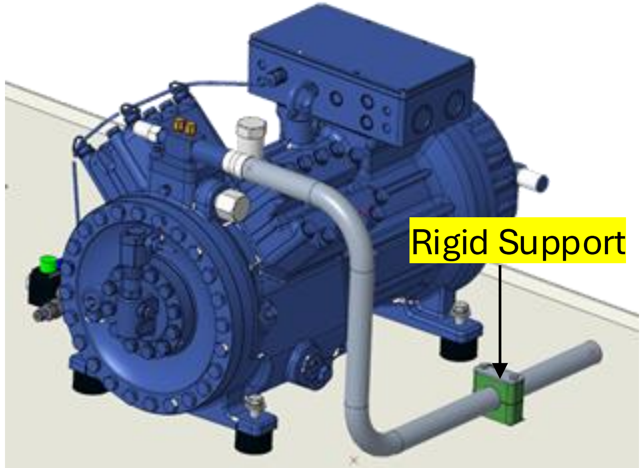


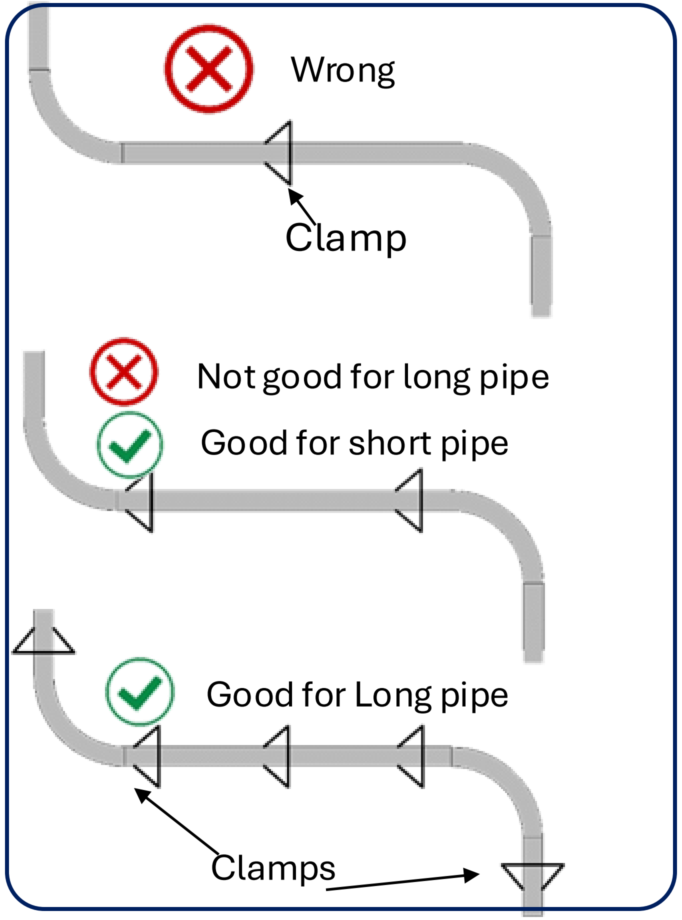
Software: Coolselector2

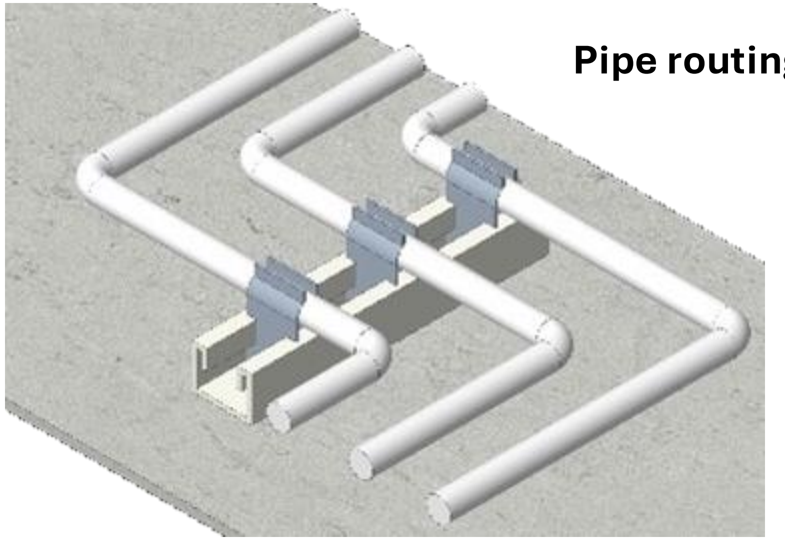
Note:

- ✓ Higher velocity leads to higher pressure drop
- ✓ Lower velocity results in a larger pipe size, it is not economical

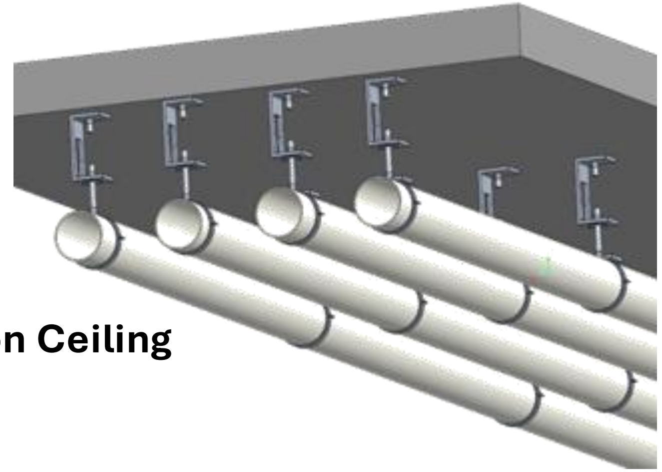
Piping and support







Pipe routing on floor



Pipe routing on Ceiling

Fail-safe and critical applications

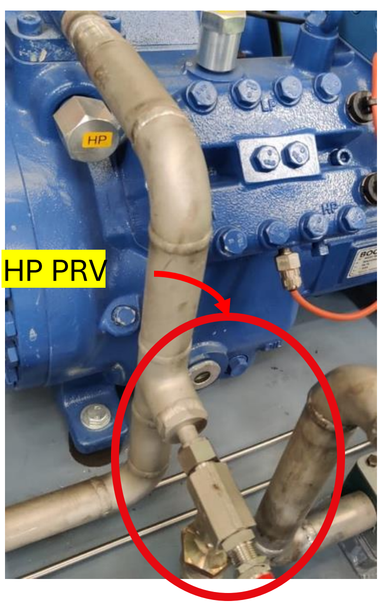
INDEE

✓ **Pressure Safety Valves (PSV)**

- All compressors are preinstalled with High pressure and Low-pressure safety valve
- Both safety valves are factory set. Do not modify/change the set pressure without consultation with the OEM

✓ **Pressure Relief Valves (PRV)**

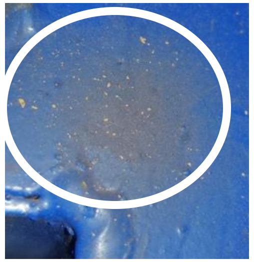
- HP side-Inline PRV; set >1.15 times higher than max operating pressure <compressor relief pressure
- Top of IP receiver; set >1.15 times IP receiver pressure



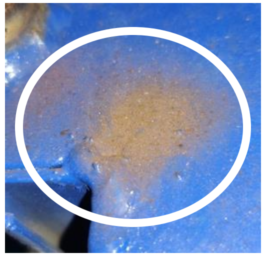
Pressure and leak test

Purging process

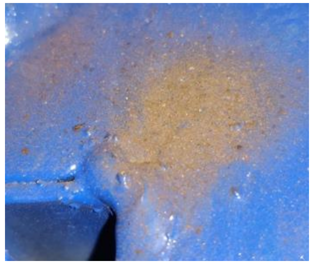
Purging Pressure(bar)	Medium	Flush out time
5	air	4
10	air	2
20	air	2



(a) At 5 bar.



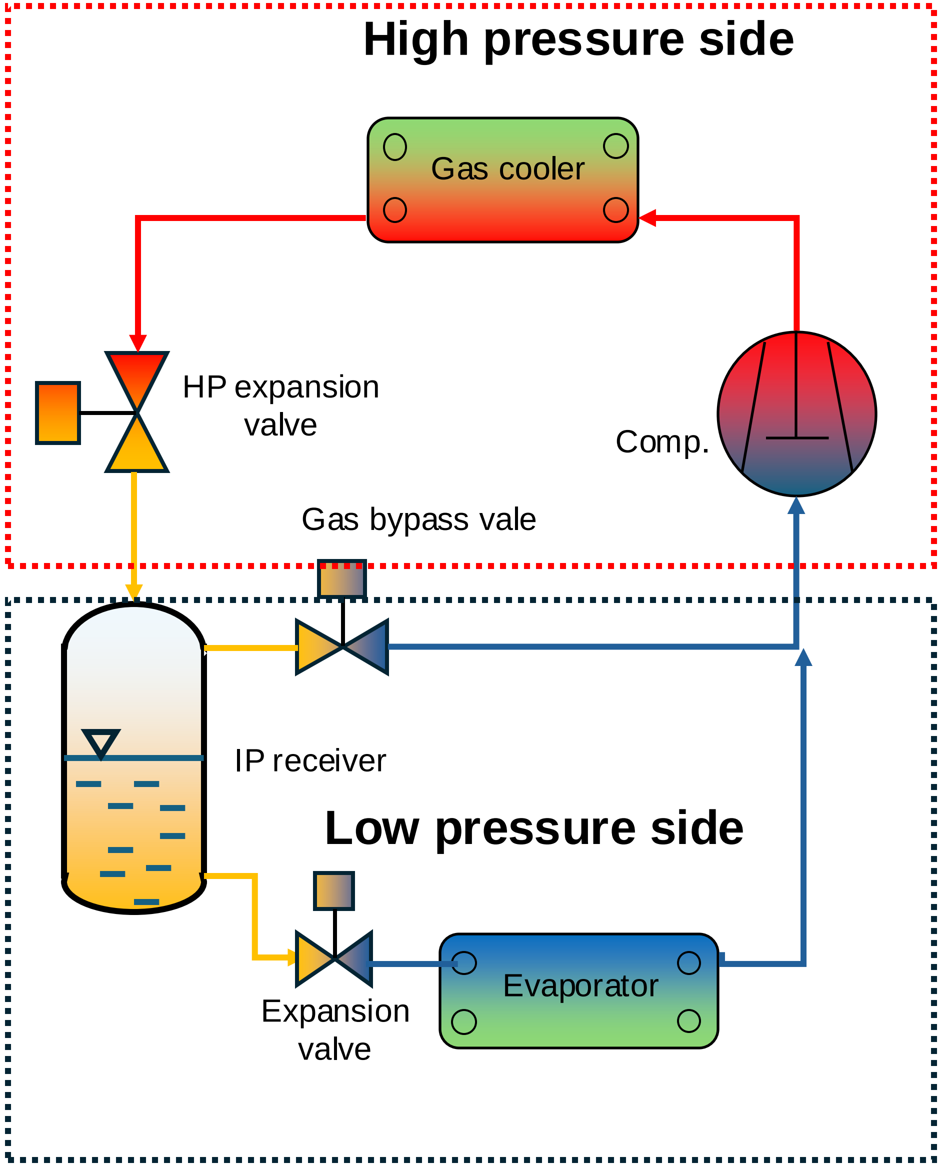
(a) At 10 bar.



(a) At 20 bar.

Pressure testing

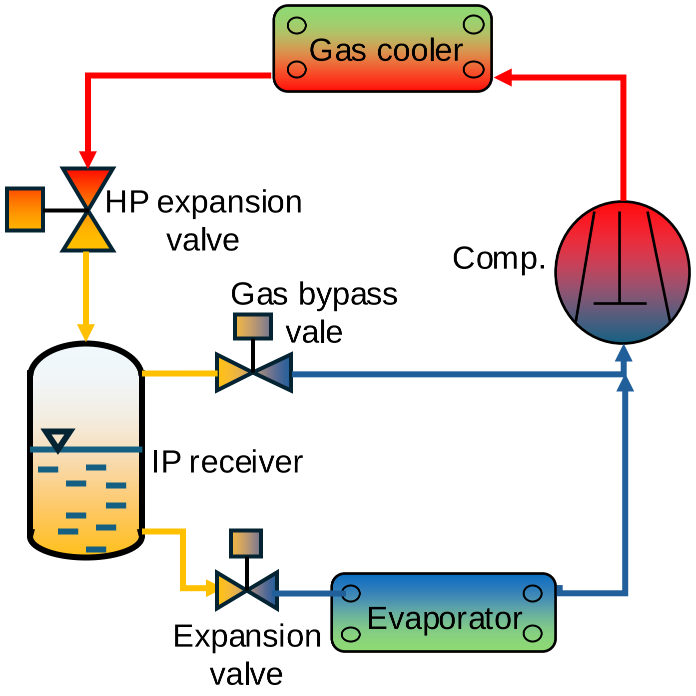
a. Minimum pressure test =1.0×MAWP
b. Maximum pressure test =1.15×MAWP
c. Leak tightness test =1.0×MAWP



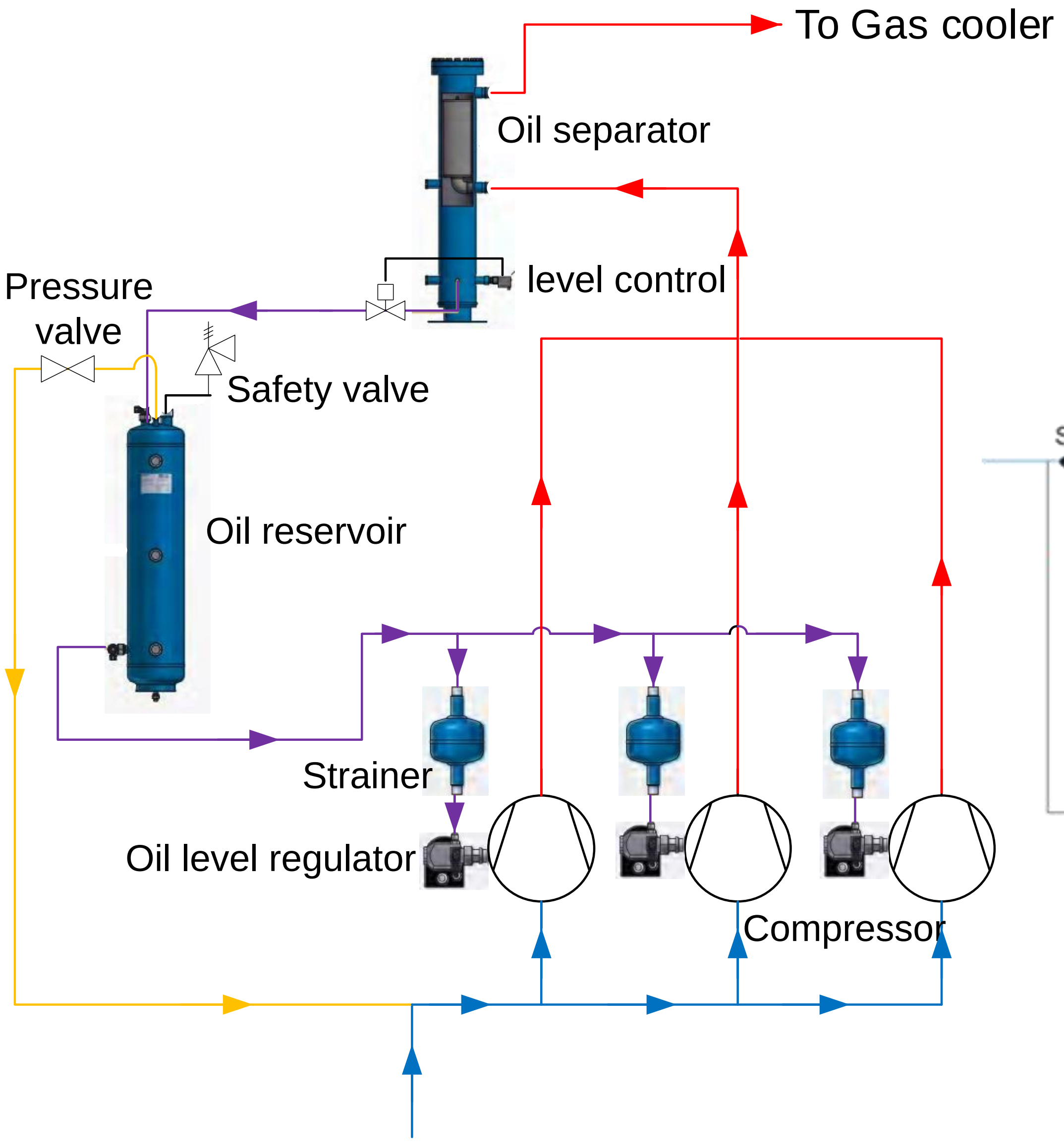
CO_2 leak detector

Snoop liquid leak detector

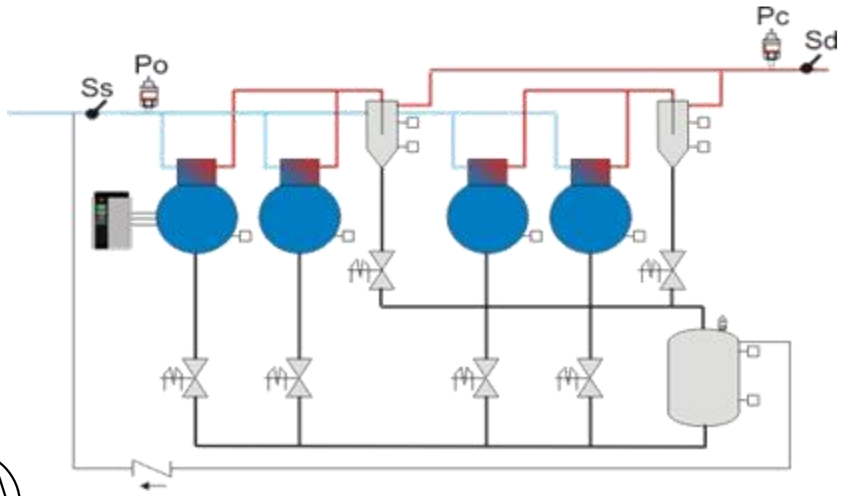
Oil management



Simple gas bypass system

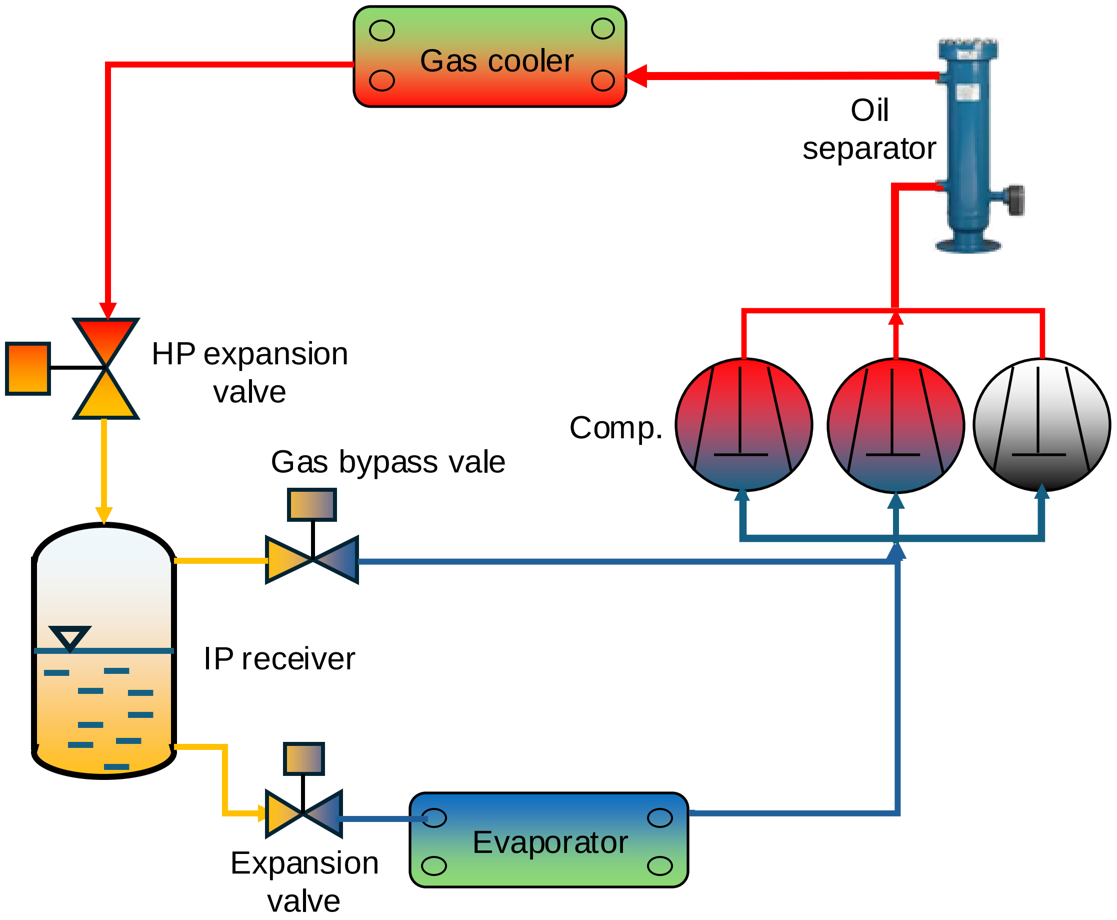


Multi compressor single stage system

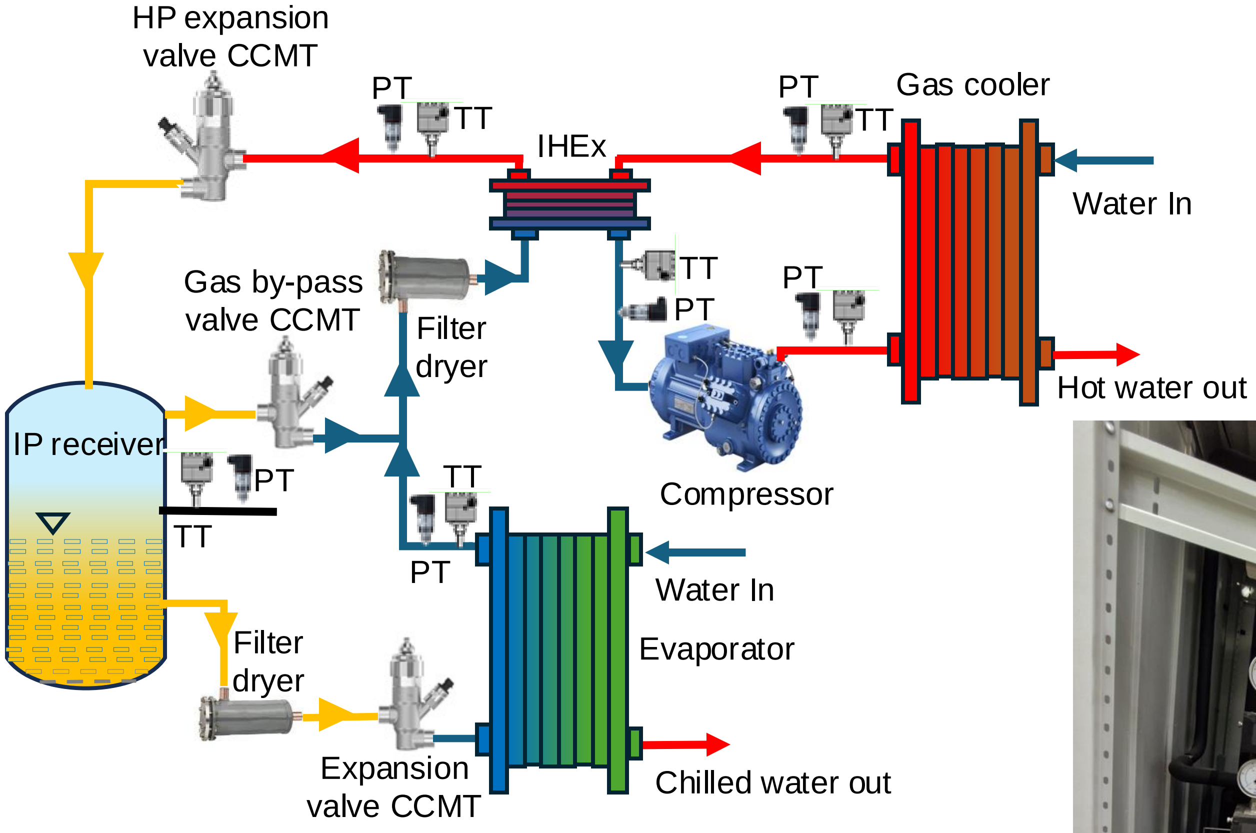


Multi compressor with oil reservoir

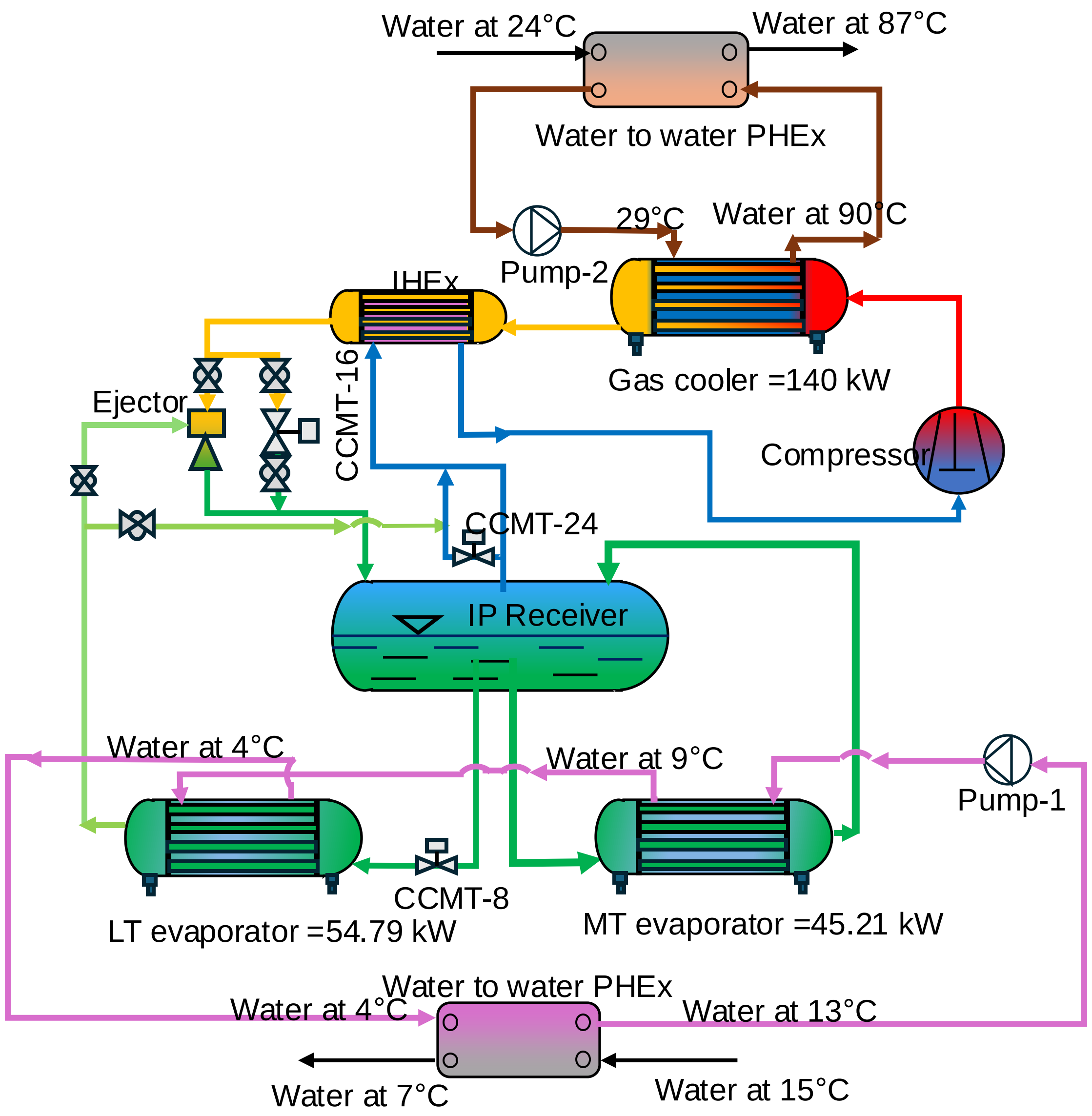
Oil management…..



Oil management…..



Oil management…..



Conclusions

- **Compact design**: Reduces system footprint by up to 30%.
- **Energy savings**: Achieves 10% to 25% energy savings.
- **Enhanced efficiency**: Delivers 35% to 50% higher COP (Coefficient of Performance) for both cooling and heating compared to other refrigerants.
- **Eco-friendly**: CO_2 systems offer a sustainable and environmentally-friendly solution.
- **Applications**: Ideal for use in process industries, hotels, kitchens, supermarkets, the pharmaceutical industry, hospitals, and marine applications.
- **Performance stability**: Provides more consistent system performance compared to other refrigerants.

"Save nature and it will save us"

VINOD LAGURI

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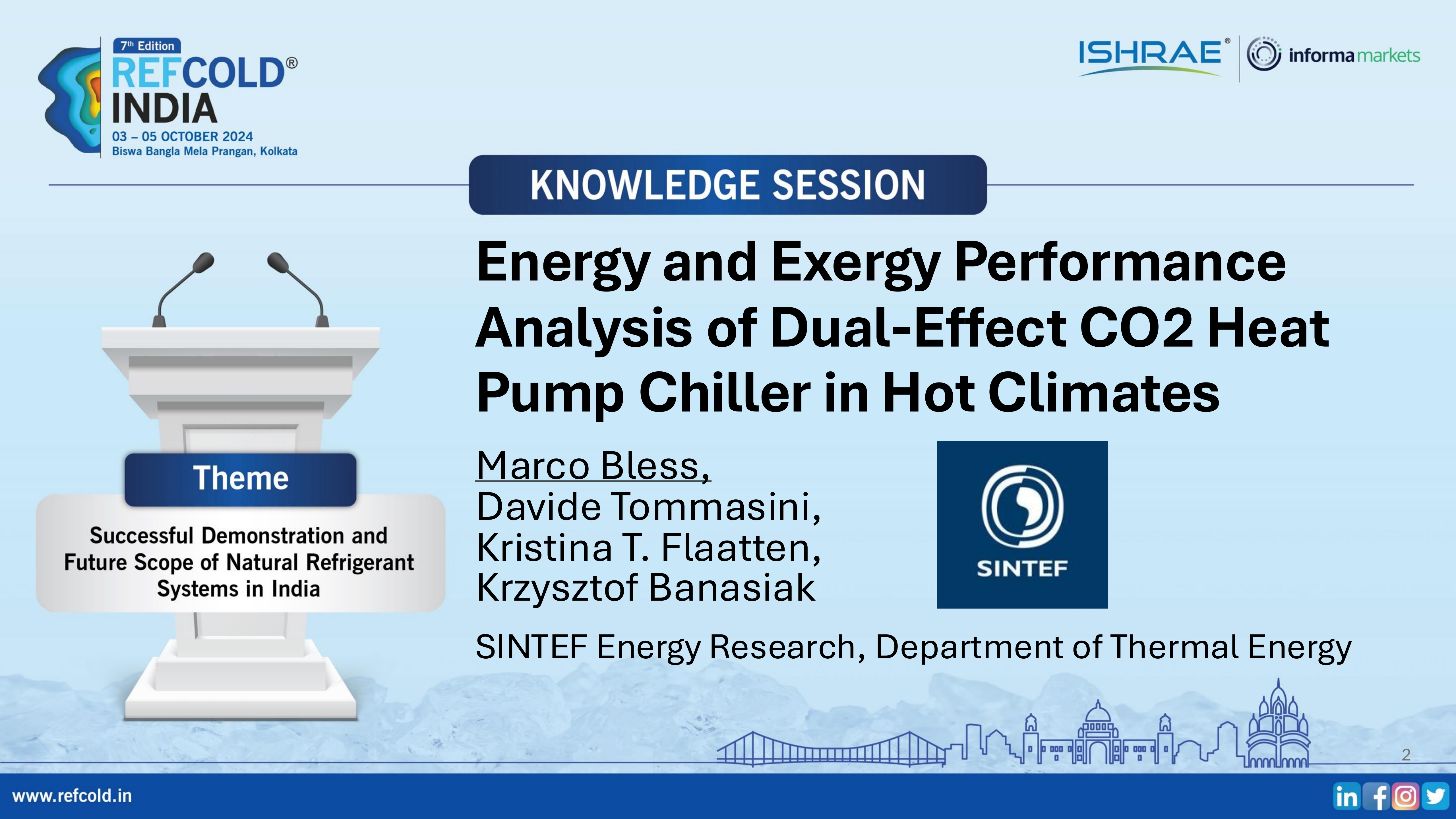
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Energy and Exergy Performance Analysis of Dual-Effect CO2 Heat Pump Chiller in Hot Climates
Marco Bless,
Davide Tommasini,
Kristina T. Flaatten,
Krzysztof Banasiak
SINTEF
SINTEF Energy Research, Department of Thermal Energy
Theme
Successful Demonstration and Future Scope of Natural Refrigerant Systems in India
2
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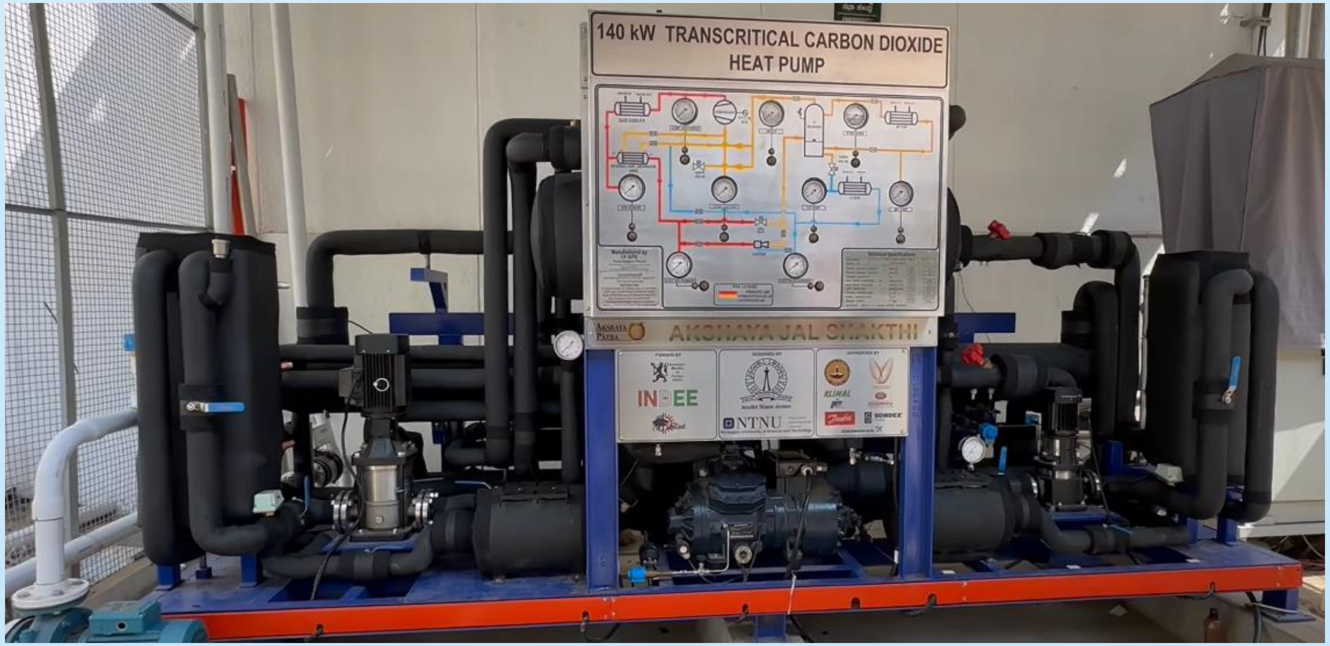
Agenda

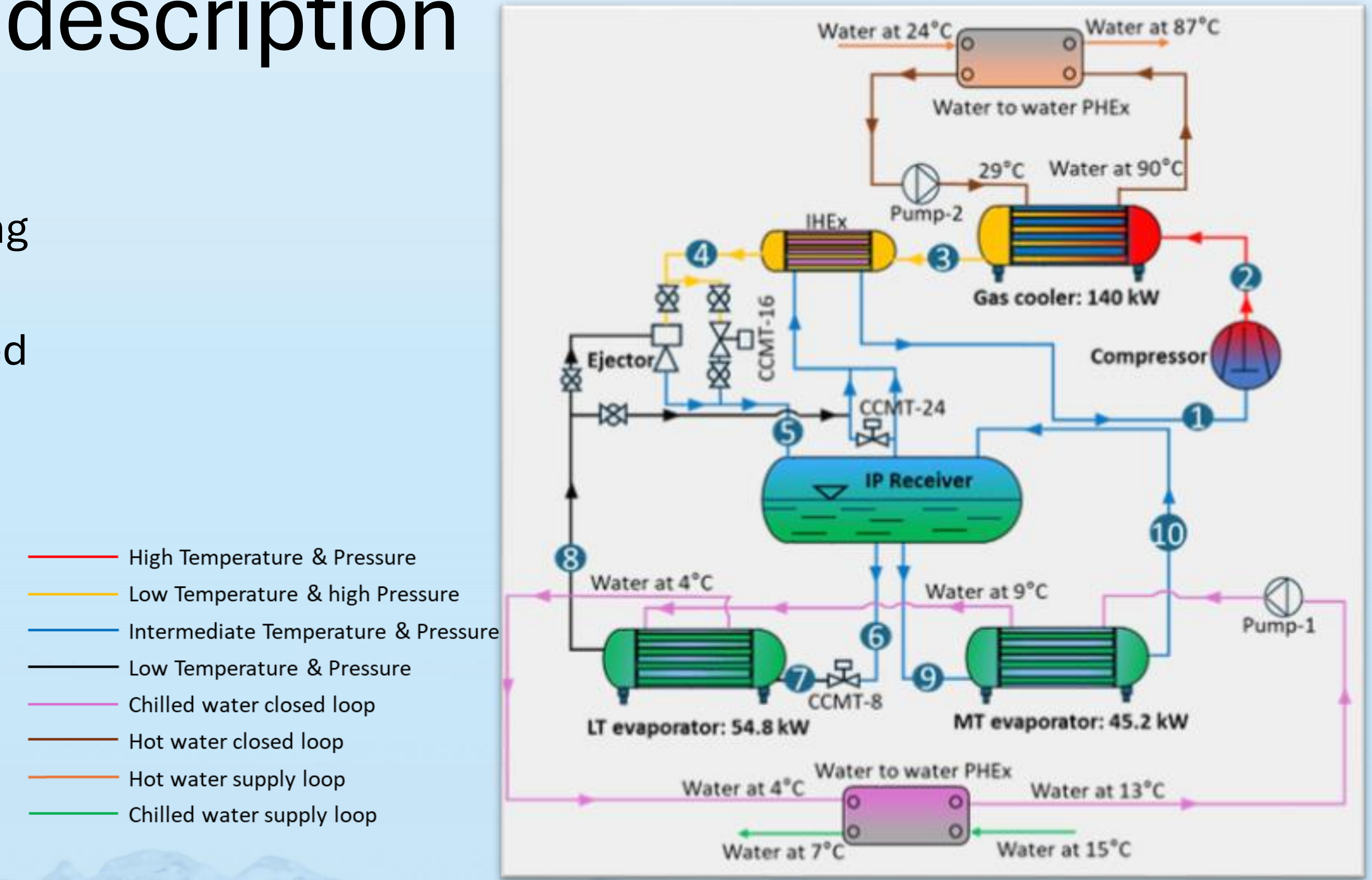
- System description
- Model description
- Performance Analysis
  - Energy
  - Exergy
- Component testing: Ejector
- Summary of Conclusions



140 kW transcritical CO2 heat pump at the Akshaya Patra Foundation in Bengaluru, India

System description

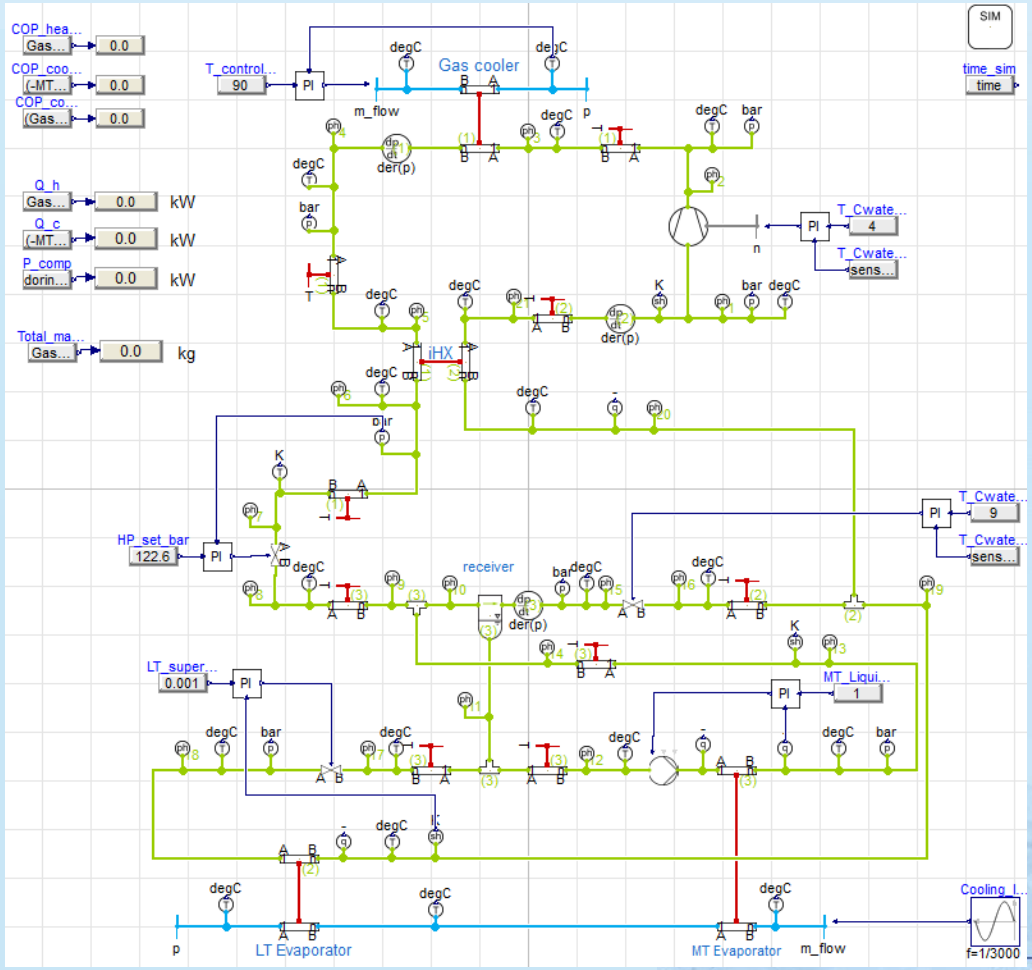
- Transcritical CO_2 combined heating and cooling system
- Two-stage evaporation with flooded evaporators
- One compression stage
- Direct expansion mode
- Ejector mode
- Secondary heat transfer circuits



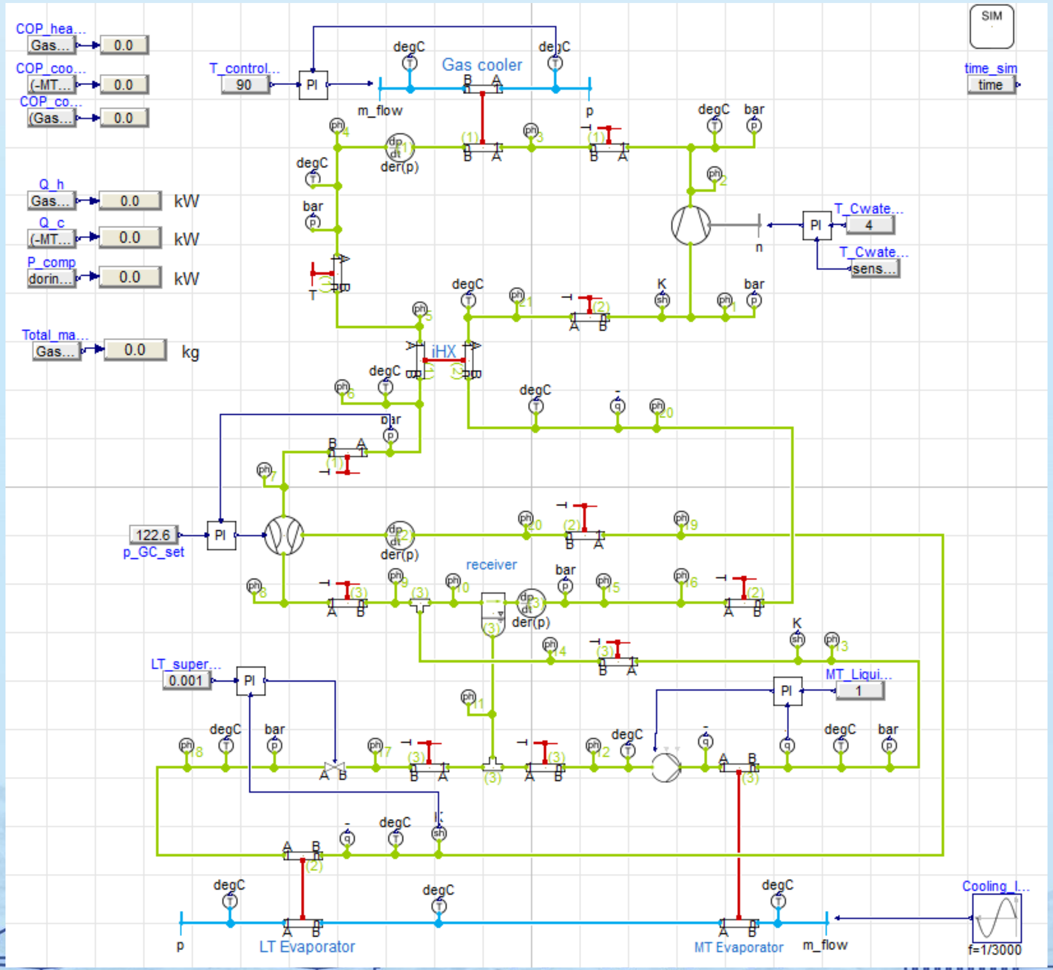
Piping diagram of the CO2 heat pump chiller. [1]

Model description

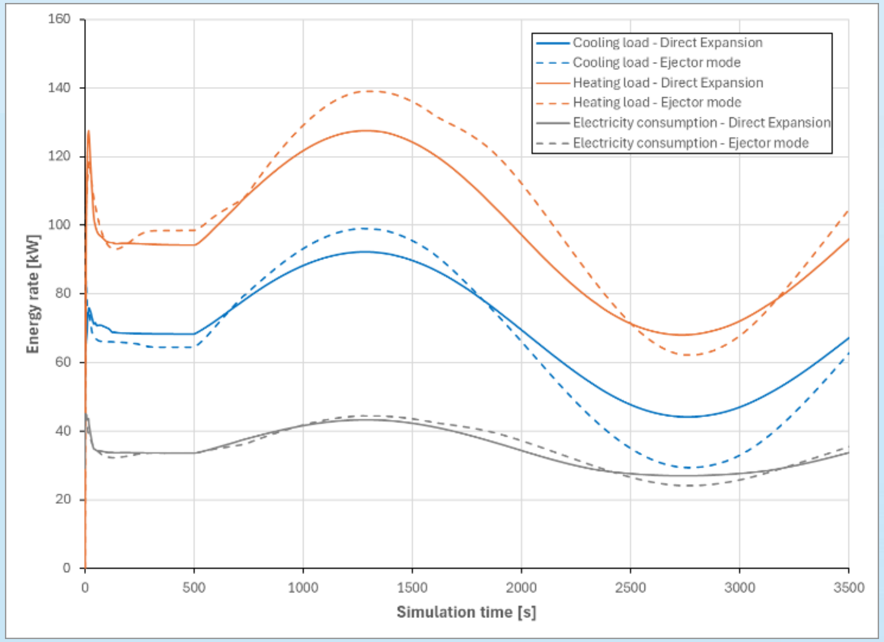
Direct expansion mode



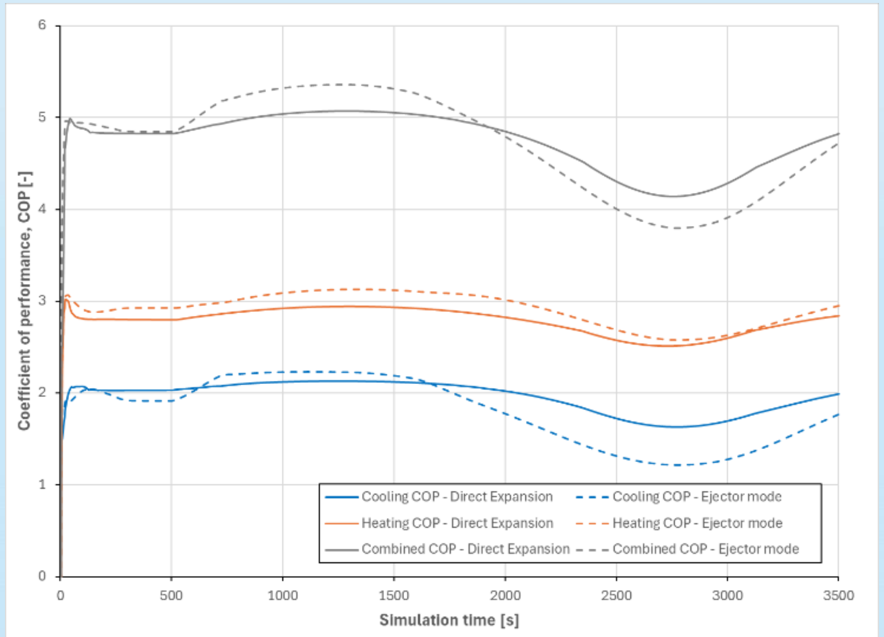
Ejector mode



Energy Performance Analysis



The heating, cooling and electrical power simulated with varying loads for the direct expansion and ejector mode. [2]



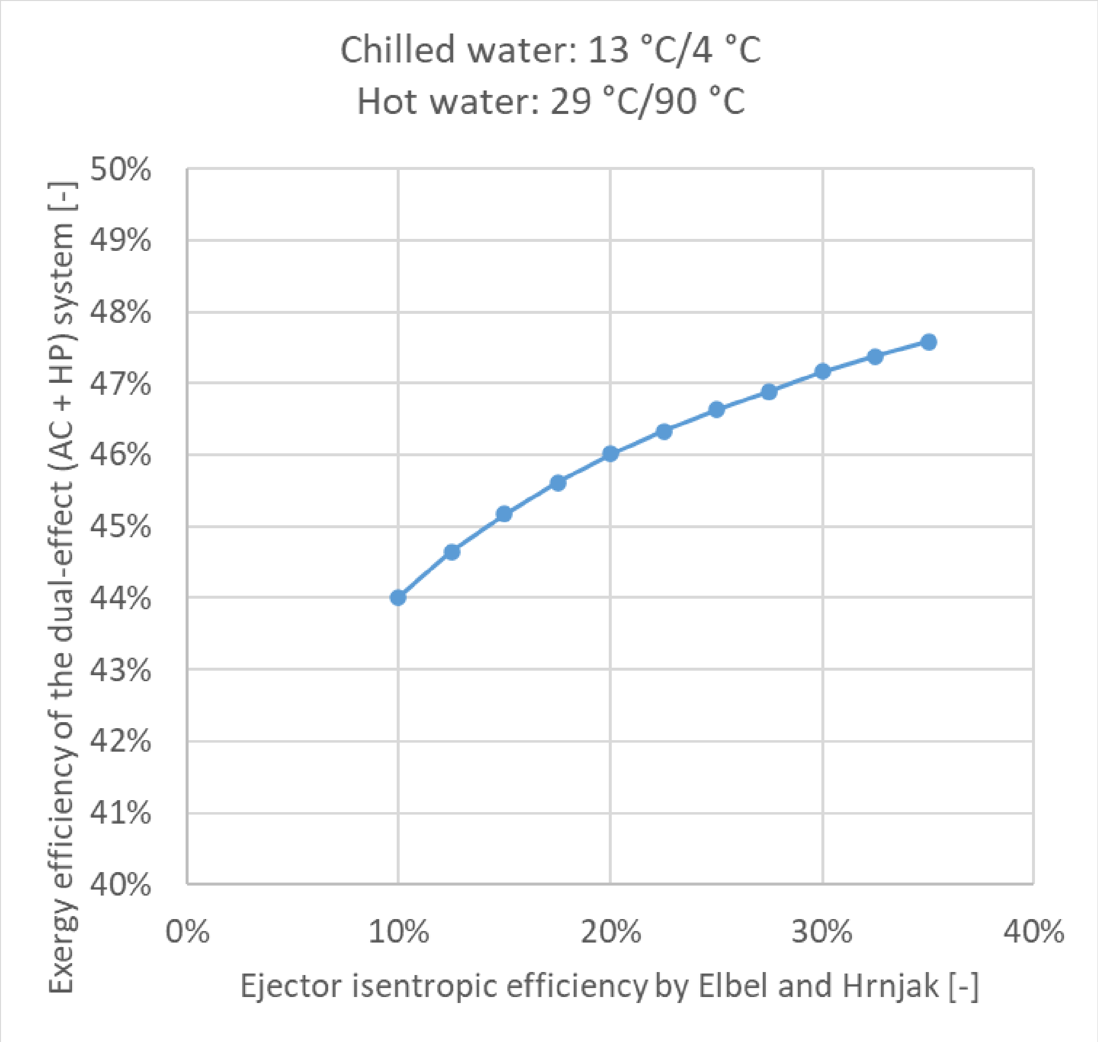
The heating, cooling and combined COP simulated with varying loads for the direct expansion and ejector mode. [2]

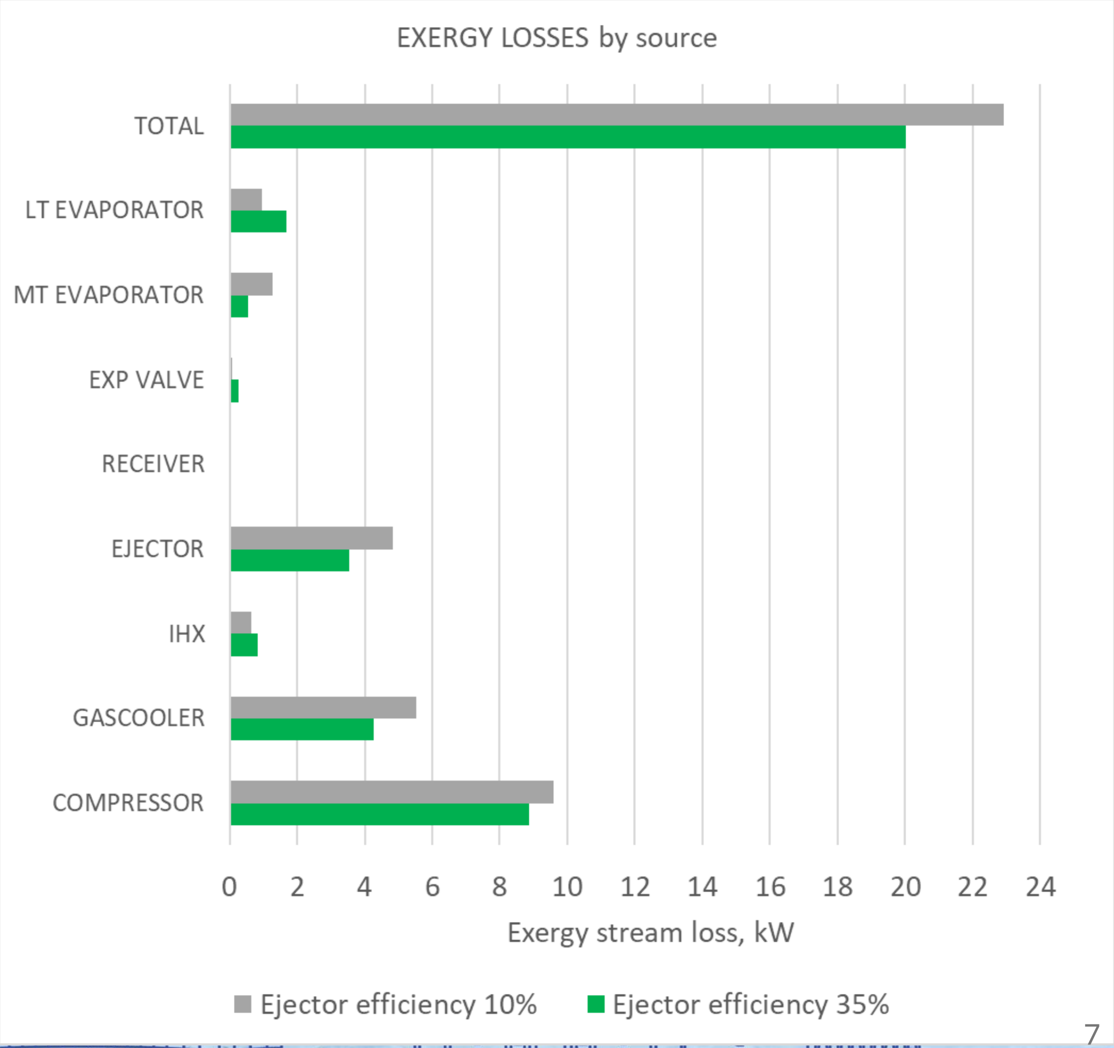
- The ejector mode has an increased operation range.
- Combined COP increase of 6% in the ejector mode at maximum load.
- The direct expansion mode achieves higher cooling and combined COPs in part load operation but at higher capacities

Operation mode	Load	Heating capacity [kW]	Cooling capacity [kW]	Heating COP [-]	Cooling COP [-]
Ejector mode	Maximum	29.3	62.3	2.6	1.2
	Minimum	99.0	139.1	3.1	2.2
Direct Expansion mode	Maximum	44.1	68.0	2.5	1.6
	Minimum	92.2	127.6	2.9	2.1

→ Depending on the load, mode switching becomes relevant to optimize the system operation.

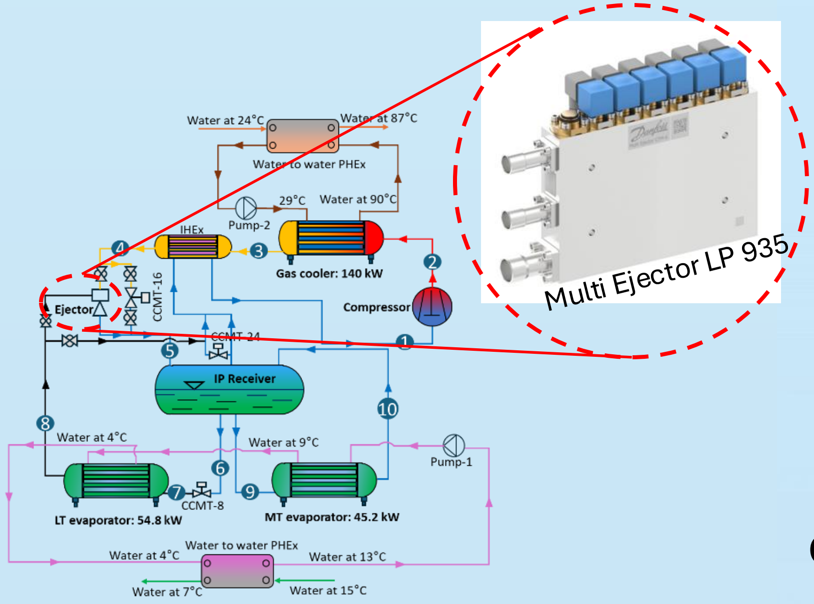
Influence of ejector performance: Exergy Analysis for the ejector mode

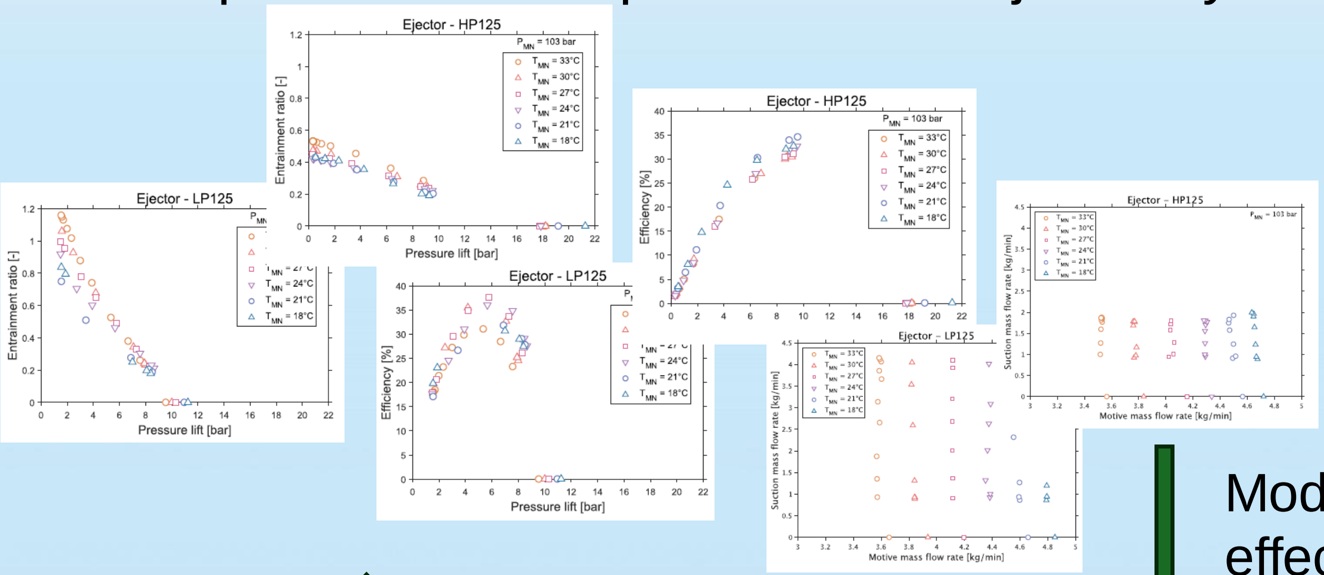




Component testing: Ejector

- To compensate for the lower efficiency in hot climates due to operation in the supercritical region, the unit comprises of an ejector-assisted work recovery system.
- Lab testing of the ejector has been performed for optimization of ejector system layout (LP vs. HP).





Component testing

Model tuning and effect on system performance

The impact of ejector cartridge type tested (LP vs. HP) is not significant.

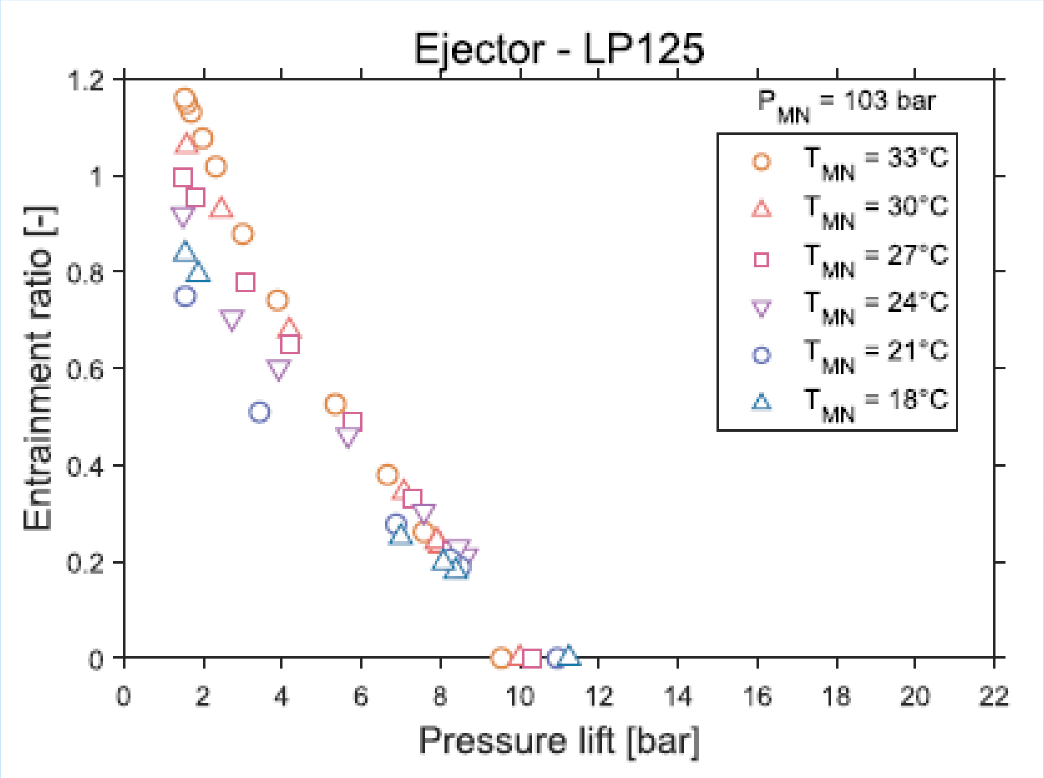
Geometry based models:

- Direct expansion mode
- Ejector mode

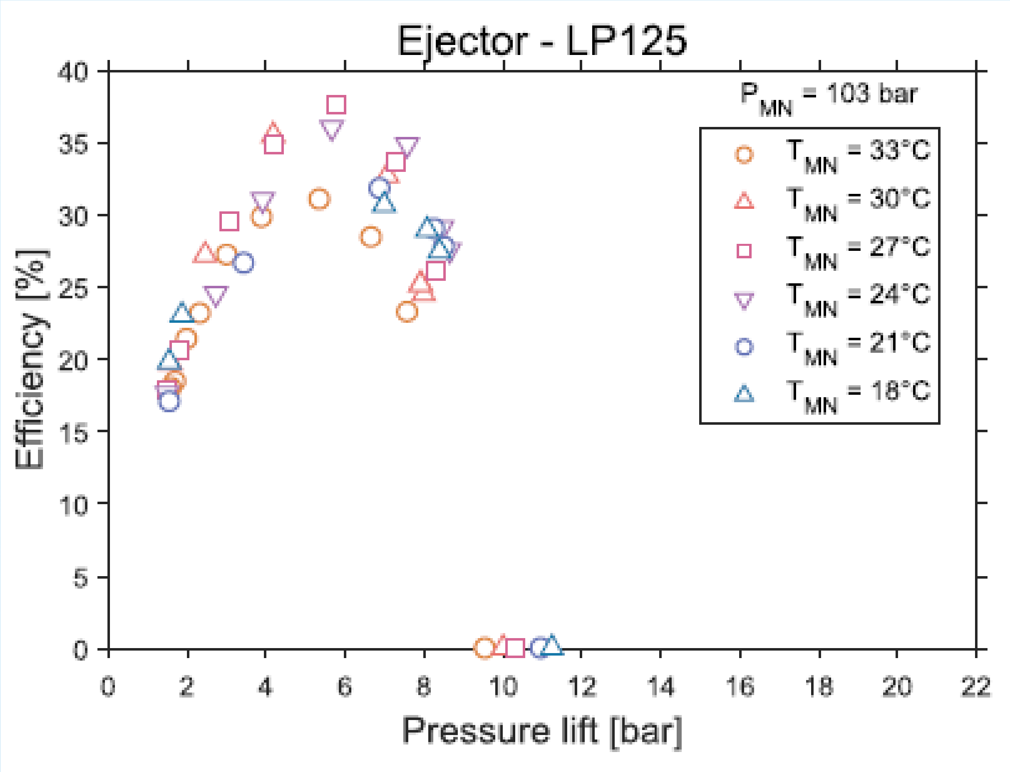
Expected area of operation

Boundary	p_{MN} [bar]	t_{MN} [°C]	p_{SN} [bar]	t_{SN} [°C]	p_{out} [bar]
Estimated range	115 - 130	15 - 35	34 - 37	Floating	40 - 44
Applied values	103	18 - 33	Floating	Floating	42.2

Component testing: Ejector



Variation of entrainment ratio with pressure lift [3].



Variation of ejector efficiency with pressure lift [3].

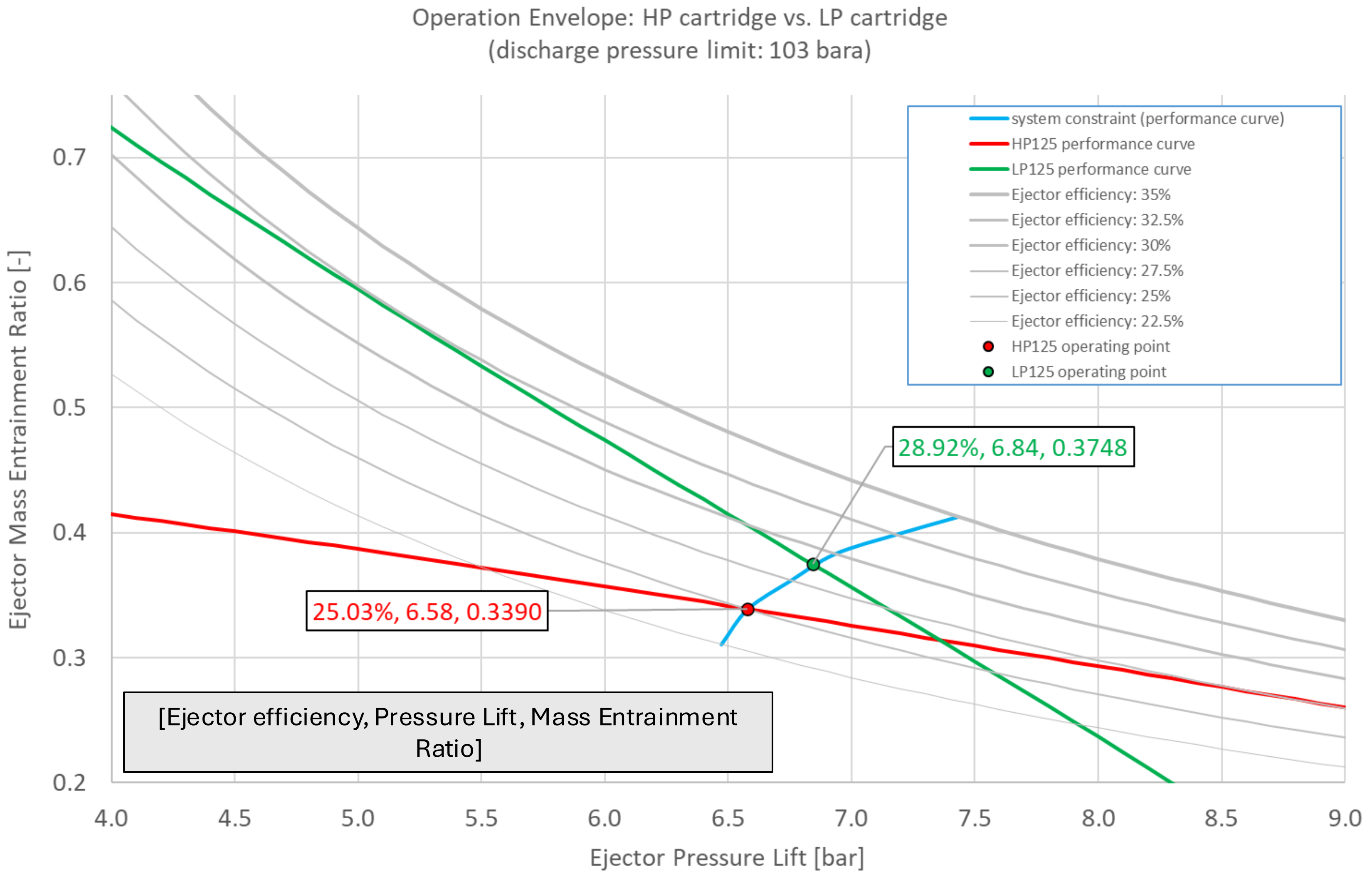
Influence of ejector performance – LP vs. HP design

System operation curve intersect both ejector operation curves relatively close to each other:

- small difference in ejector efficiency between LP125 and HP125 for the conditions analysed
- negligible difference in the overall system efficiency between LP125 and HP125 for the conditions analysed

Exergy efficiency of the LP125-supported system: 43.40%

Exergy efficiency of the HP125-supported system: 43.02%



Summary of Conclusions

Energy Performance Analysis

Geometry based models gave insights into system capacities and performances at rated and part load conditions for the direct expansion and ejector mode.

→ Depending on the load, mode switching becomes relevant to optimize the system operation.

Exergy Performance Analysis

- Relatively high exergy efficiency (close to 50%), due to the dual-effect feature (AC + HP)
- Exergy destruction in compressor dominating; ejector comes as 3rd contributor, after gascooler
- Efficient ejector performance improves overall exergy efficiency

Component testing: Ejector

- Proper selection of the cartridge type (LP vs. HP) for the working conditions given, is recommended
- For the operational envelope considered, performance penalty for 'improper' selection of the cartridge type is limited

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[2] Kochunni, S. K., Singh, S., Bless, M., Arun, B. S., Kumar, S. Tommasini, D., Singha P., Das, C., Laguri, V., Hafner, A., 2024. Upcoming Natural Refrigerant-driven Heating and Cooling Systems in India. Presented at the IIR Conference on Compressors and Refrigerants, Slovakia 2024. DOI: 10.18462/iir.compr.2024.0657, available under https://szchkt.org/a/conf/submissions/657?locale=en_GB

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INDEE+ team

KNOWLEDGE SESSION

Theme

Successful Demonstration and Future Scope of Natural Refrigerant Systems in India

NTNU SINTEF NORWEGIAN ENVIRONMENT AGENCY IIF IIR CEEW THE COUNCIL

India-Norway Collaboration 2021-2024

INDEE

Future Refrigeration India: INDEE+

NTNU SINTEF

Norwegian Embassy
New Delhi

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INDEE+ updates:

SINTEF

Solutions for reducing food loss and waste in cold chains

RefCold 5 October 2024 Kolkata

Kristina N. Widell, SINTEF

Foto: Shutterstock

Food Loss and Waste (FLW)

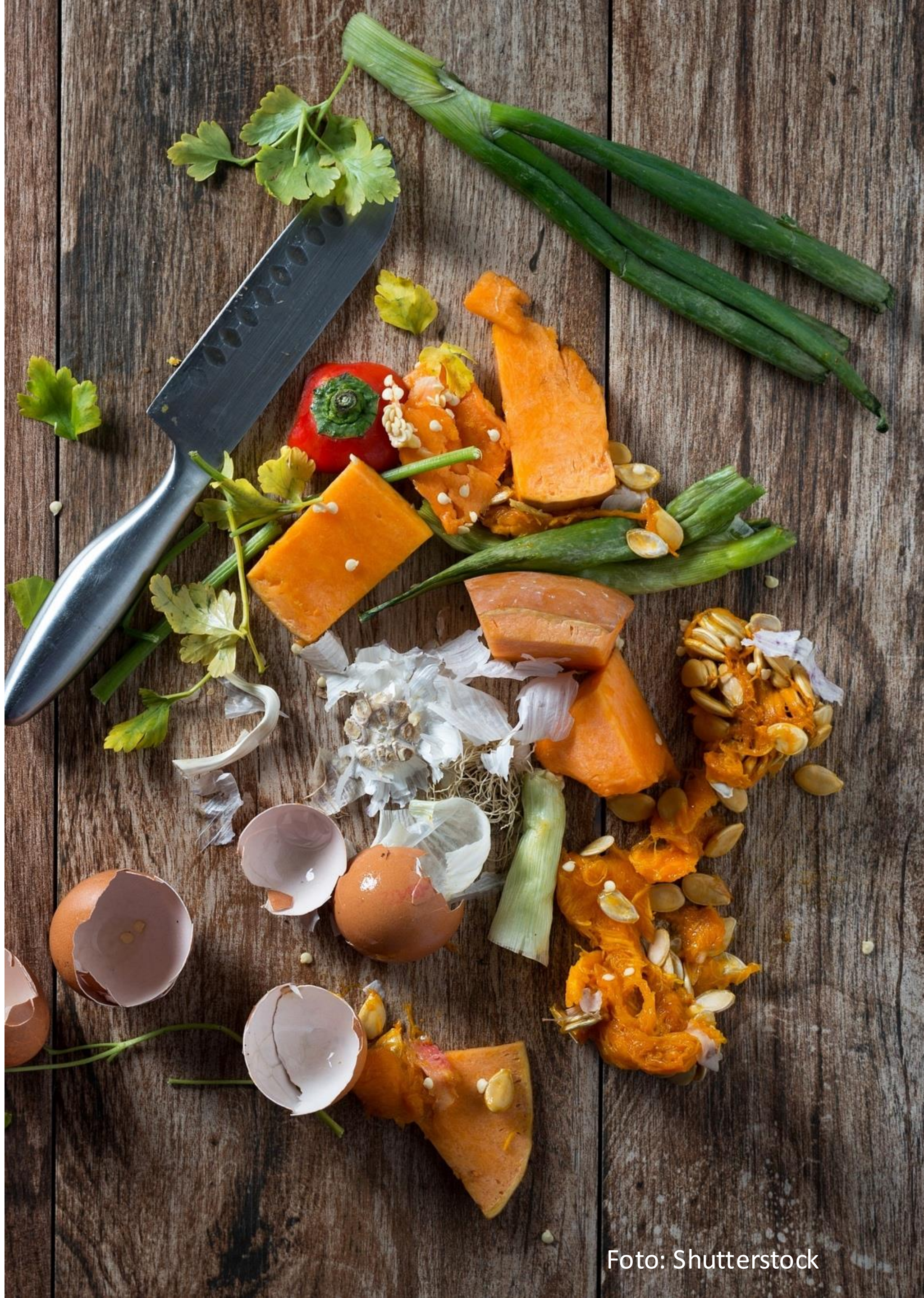
Source: FAO
More information: www.fao.org/save-food/savefood/en/

Food and Agriculture Organization of the United Nations

SINTEF

Globally

- 1/3 of all food produced is lost: 1.3 billion tonnes per year
- 25% of this could be recovered
- Global food production: 30% of total GHG emissions
- Resources: not only wasting food, but also water, energy and other resources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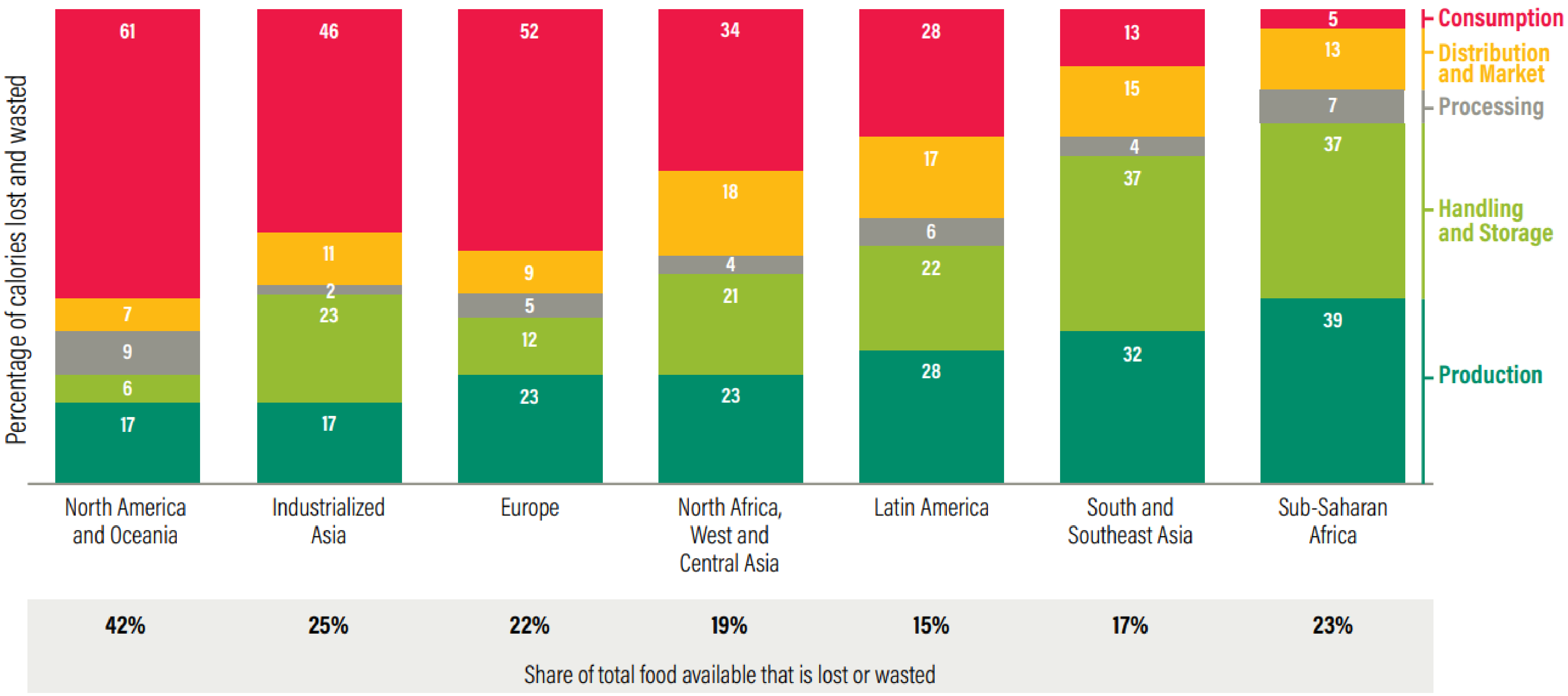
Differences between world regions



Source: WRI analysis based on FAO (2011b).

Solutions for reducing food loss and waste in cold chains

Participants

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EU project: ENOUGH

ENOUGH
EUROPEAN FOOD CHAIN SUPPLY TO REDUCE GHG EMISSIONS BY 2050

Thank you for your attention!

Teknologi for et bedre samfunn