

FRICK Sustainability with Ammonia Refrigeration **aar**
 Association of AMMONIA REFRIGERATION

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15/07/2025 Advantage Ammonia Webinar Series 1 2025-2026

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FOCUS IS ON SUSTAINABILITY **aar**
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- The focuses design on creating products, buildings, and systems that minimize negative environmental and social impacts throughout their entire life cycle.
- The design aims to reduce waste, conserve resources, and improve the well-being of both current and future generations.
- The integrated approach of environmental considerations into the design process, promoting long-term solutions and a circular economy.

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OZONE LAYER **aar**
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The ozone layer sits in the stratosphere between 15 km and 30 km above the earth and shields us and other living things from the sun's harmful ultraviolet radiation. Ozone layer depletion could have serious effects on human health and the environment.

THE EARTH'S ATMOSPHERE

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MAXIMUM OZONE HOLE EXTENT OVER SOUTHERN HEMISPHERE, FROM 1979-2024 **aar**
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- A significant reduction in the consumption of ozone-depleting substances (ODS) has been achieved globally since 1986. This reduction has largely been driven by the 1987 United Nations Environment Programme (UNEP) Montreal Protocol.
- The largest historical extent of the ozone hole — 28.4 million square kilometres — occurred in September 2000. This area is equivalent to almost seven times the territory of the EU.
- The 2024 ozone hole has been smaller than in 2023 and smallest since 2020.

Maximum yearly extent of the ozone hole

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REFRIGERANTS EVOLUTION **aar**
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Phasing out HCFCs and HFCs in line with the Montreal Protocol and its Kigali Amendment, as well as promoting the use of natural refrigerants.

CFC → **HCFC** → **HFC & blends** → **HFO & blends** → **Natural Refrigerants** (CO₂, Ammonia, Hydrocarbons)

Montreal Protocol controls: Ozone depleting, High global warming. Today's options (Kigali): Non-ozone depleting, Lower global warming. No Montreal Protocol controls.

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HCFC PHASE-OUT TIMELINE IN INDIA **aar**
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India's HCFC phase-out timeline was accelerated in 2007, advancing the complete phase-out date from 2040 to 2030. Key reduction milestones include a 10% reduction by 2015, 35% by 2020, 67.5% by 2025, and 97.5% by 2030, with a 2.5% service tail allowed until 2040.

As the second-largest producer and consumer of HCFCs globally, India's efforts are vital for protecting the ozone layer and mitigating climate change.

Year	Consumption Limit (ODP TUNNES)
2010	1400
2013	1400
2015	1300
2020	1000
2025	500
2030	200
2040	200

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DEFINE REFRIGERANT

The working fluid used in the Refrigerant System for cooling, heating or reverse cooling/heating cycles of air Refrigeration, Air Conditioning & Heat Pumps.

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AMMONIA

- Ammonia is a Chemical generally used in chemical industries, used as Fertilizer and used as **Refrigerant**.
- Refrigerant Classification: B2L (B-Higher Toxicity; 2L-Low Flammability & Slow Burning)
- Refrigerant Number allotted for Ammonia: R717
- The "700 series" designation for refrigerants specifically for inorganic compounds. The 700 is added to the molecular weight of the compound. For ammonia, the molecular weight is approximately 17 (14 for Nitrogen + 3 for Hydrogen). Therefore, 700 + 17 = 717, resulting in the designation R717 for ammonia.
- Chemical Formula: NH₃

Chemical Structure

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WHY AMMONIA IS SUSTAINABLE?

- Environment Friendly
- Chemical characteristics appropriate for use as a refrigerant.
- Energy Efficient owing to superior thermodynamic performance.
- Ammonia is a naturally occurring substance, not produced synthetically.
- Cost-effective with potential for long-term savings.
- Modern systems have simplified the handling of ammonia.
- Government and environmental policies support the use of ammonia.

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HOW AMMONIA IS ENVIRONMENTALLY FRIENDLY?

Zero Ozone Depletion Potential (ODP):
Ammonia does not contain chlorine or bromine which are the elements responsible for ozone layer destruction in refrigerants like CFCs and HCFCs, so it does not harm the ozone layer.

Zero Global Warming Potential (GWP):
Its GWP is effectively zero (GWP = 0), unlike many synthetic refrigerants such as HFCs and HCFCs, which are potent greenhouse gases, which are the causes for Global Warming.

Biodegradable (♻️)
If leaked, ammonia breaks down quickly in the environment without leaving long-lasting residues. But in Freon Refrigerant gas fluorine and chlorine remains as residues and

ODP / GWP OF REFRIGERANTS				
Refrigerant	Fluorine (Parts Per Billion)	Bromine (Parts Per Billion)	Ozone Depletion Potential (ODP)	Global Warming Potential (GWP)
Ammonia (R717)	-	-	0	<1
CFC (trichloro)	CFC-11 (Baseline)	50	14000	-
CO ₂	-	-	-	1
HFCs	HFC-25	102	0.055	1800
	HFC-135	13.3	0.005	1600
	HFC-152	1.4	0.02	95
	HFC-143a	8.4	0.11	630
	HFC-125	14.6	0	3300
	HFC-227a	7.3	0	830
	R-502	-	0	895
	HFC-360 (Propane)	-	0	3
	R-290 (Propane)	-	0	<2
	R-600a (Isobutane)	-	0	3360
	R-407A	-	0	1770
	R-410A	-	0	2080
	R-417A	-	0	1780
	CO ₂ (R-744)	-	0	1
	R22*	-	0	4.7
	1234ze	-	0	4.7

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AMMONIA CHEMICAL PROPERTIES

- Chemical Formula: NH₃
- Molecular Weight: 17.03 g/mol
- Boiling Point: -33.3 °C at 1 atm (Can be used for Negative very low temperature application)
- Latent Heat of Vaporization: 1370 kJ/kg (very high, contributing to efficiency)
- Critical Temperature: 132.4 °C
- Critical Pressure: 113.5 bar

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AMMONIA IS ENERGY EFFICIENT

- Ammonia has a high latent heat of vaporization and a favorable pressure-temperature relationship, which makes systems using it more energy-efficient than those using many synthetic refrigerants.
- Because of its efficiency, systems using ammonia typically consume less electricity—reducing both costs and indirect CO₂ emissions.

Refrigerant	AMMONIA C.O.P. (EFFICIENCY) COMPARISON WITH OTHER REFRIGERANTS FOR VARIOUS APPLICATIONS			
	Evaporating Temperature 2°C	Evaporating Temperature -5°C	Evaporating Temperature -25°C	Evaporating Temperature +40°C
Ammonia-R717	6.2	4.965	2.91	2.06
R410A	5.43	4.8	2.5	1.75
R134a	5.88	4.67	2.7	Not used
R404A	5.18	4.07	2.26	1.52
R22*	5.93	4.74	2.79	1.98

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COST OF THE REFRIGERANT & ITS OIL

Naturally Readily Available Refrigerant

Ammonia is a naturally occurring substance and can be produced from air, water and biomass. Ammonia is widely available So cheaper than synthetic refrigerants

Cost of Mineral Oil

Mineral Oil is used along with ammonia for compressor lubrication and the Oil is Naturally, available substance So cheaper than synthetic oil which is used for Freon Refrigerants.

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AMMONIA IS LESS EXPENSIVE

- Ammonia is the cheapest refrigerant.
- The price per kg for R 404A / R407C is about 10 times the price of Ammonia.
- For a large cold storage, the operation costs are 20-30% lower with Ammonia than R 404A / R407C.
- Besides that, only half as much refrigerant needs to be purchased to charge a system because the density of Ammonia is half of halocarbons.

Indicative Refrigerant Cost

Ammonia costs about R717 – US\$1/ Kg
R404A/ 407C costs about – US\$10/kg

** Density of at 1.013bar at boiling point: 682kg/m3 (ammonia liquid), 1413kg/m3 (liquid HCFC) and 1376kg/ m3(liquid R134a)

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HANDLING AMMONIA REFRIGERANT

- Very Minor Leak (5 PPM) of Ammonia from the Refrigeration System is easy to identify due to its pungent smell.
- Tolerance limit of Leakage: 500 to 1000 PPM.
- Now a days Efficient ammonia leak detection system are available, rectifying leakage in early stages is easy.
- Now a days automated refrigeration system are foolproof to run the system with high standard safety.

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MISCONCEPTION: TOXICITY OF AMMONIA

Ammonia has a pungent odor and small leak as low as 5 ppm is detectable by smell and serves as early warning. Almost all human beings can detect levels up to 25 ppm and continuous exposure to 50 ppm level is permitted for 8 hours per day per week.

AMMONIA CONCENTRATION, PPM	EFFECTS
150 to 200	Affected eyes to a limited extent after about a 1-minute exposure, but vision not seriously impaired; breathing not affected.
440	Affected eyes more quickly, but not sufficiently to impair vision seriously.
600	Eyes streamed within about 30 seconds; still breathable.
700	Tears to eyes in a few seconds; still breathable.
1000	Eyes streamed instantly and vision impaired but not lost; breathing intolerable to most subjects; skin irritation after several minutes.
1500 or greater	Instant reaction was to get out of the area.

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GOVERNMENT & ENVIRONMENT REGULATIONS FAVORING AMMONIA

Protocol / Amendment	Year	Focus Area	Target Gases	Binding?	Scope
Montreal Protocol	1987	Ozone layer	CFCs, HCFCs, Halons	Yes	Global
Kyoto Protocol	1997	Climate change	CO ₂ , CH ₄ , N ₂ O, HFCs, etc.	Yes (for developed countries)	Mostly developed countries
Kigali Amendment	2016	Climate change	HFCs (high GWP)	Yes	Global, with phased timelines

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AMMONIA MARKET SIZE

Ammonia Market
Size, by Product, 2020 - 2030 (USD Billion)

2020: \$213.9B
2021: \$218.5B
2022: \$223.1B
2023: \$227.7B
2024: \$232.3B
2025: \$236.9B
2026: \$241.5B
2027: \$246.1B
2028: \$250.7B
2029: \$255.3B
2030: \$259.9B

5.9% CAGR Market CAGR, 2025-2030

Ammonia Market
Share, by Application, 2024 (%)

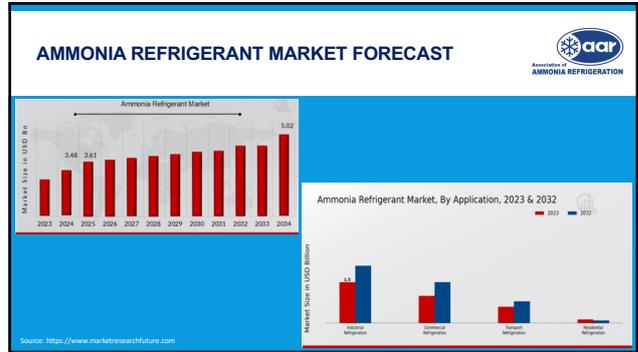
\$224.1B Global Market Size, 2024

Legend: Fertilizers, Refrigerants, Pharmaceuticals, Textile, Others

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ANHYDROUS AMMONIA CHARACTERISTICS



- Refrigerant grade
 - 99.95% Purity
 - 75 PPM H₂O (max)
- Vapor tends to be lighter than air
- Liquid specific gravity ~ 0.65
- Alkaline – pH of 11.6
- Pungent odor makes it self-alarming
- **Highly soluble in water**
- **Very corrosive to human tissue upon exposure!**
- **Toxic at elevated concentrations**

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FLAMMABILITY CHARACTERISTICS



- ASHRAE 34 flammability classification: 2L
- DOT classified as non-flammable
- Autoignition temperature: 1204°F
- Lower flammability limit (vol.%)¹ 15-16
- Upper flammability limit (vol. %)¹ 25-28
- Combustion products: oxides of nitrogen
- Fire hazard: slight



¹ IAR Ammonia Data Book, (2009)

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TYPES OF AMMONIA REFRIGERATION SYSTEM



TRADITIONAL AMMONIA SYSTEM

A traditional ammonia refrigeration system uses over 10,000 lbs (4,536 kg) of ammonia for a 500 TR refrigeration load, usually with a glycol loop, in what is called a central system. This central system uses air handling units, cooling coils, etc. located throughout the facility. The main components, such as the compressors, condensers and vessels of the system, are in a central machine room. Ammonia is then piped from the machine room to the evaporators at the load.

LOW-CHARGE AMMONIA: OPTIMIZED SYSTEM

An optimized low-charge ammonia refrigeration system works by using the traditional industrial ammonia refrigeration technology and further optimizing it with low-charge components, such as specifically designed evaporators, controls, heat exchangers, compressors and condensers.

A properly designed low-charge optimized system, uses less than 6,053 lbs (2,746 kg) of ammonia and requires therefore fewer vessels, fewer pipes, smaller pipe diameters and no pumps. Nevertheless it still needs a machine room.

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TYPES OF AMMONIA REFRIGERATION SYSTEM



LOW-CHARGE AMMONIA: PACKAGED SYSTEM

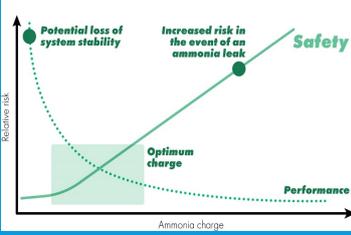
A packaged ammonia system eliminates the huge quantities of ammonia inventory, and piping, by moving to smaller self-contained systems that are usually placed on the roof/ground outside preventing any danger from leaks. These self-contained systems have about 1 lbs/TR ammonia charge and usually combine the compressor, evaporator valve system and control systems into one easily installed and movable packaged system.

LOW-CHARGE AMMONIA: NH₃/CO₂ CASCADE SYSTEM

An ammonia/CO₂ system can come in various formats (such as cascade, CO₂/NH₃ with pumped volatile brine and ammonia DX system using liquid CO₂ overfeed) but the main idea is to isolate the ammonia charge, which is usually between 0.25 lbs/TR, to the machine room and use the CO₂ as the secondary coolant that can be pumped into cold-rooms in the facility. The system might require additional equipment to pump the CO₂, along with extra compressors and other components for the CO₂ side.

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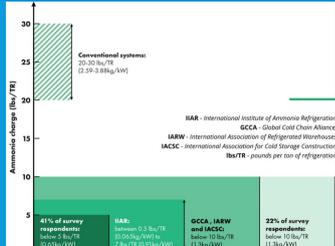
OPTIMIZING CHARGES

It is important when optimizing and reducing the ammonia charge in a system to take into consideration the performance and potential loss of stability within a low-charge ammonia refrigeration system when using the lowest possible charge (less than 5.51 lbs/2.5 kg). Conversely, when using higher charges (such as over 10,000 lbs/4,536 kg) a facility operator increases the risk of ammonia to human health in the event of a leak.

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HOW LONG IS LOW CHARGE AMMONIA?

Conventional systems: 20-30 lbs/TR (2.29-3.38 kg/ton)

IAR - International Institute of Ammonia Refrigeration
 GCCA - Global Cold Chain Alliance
 IARW - International Association of Refrigerated Warehouses
 IAISC - International Association for Cold Storage Construction

41% of survey respondents: below 5 lbs/TR (0.45-0.91 kg)

IAR: between 0.5 lbs/TR (0.45 kg) to 2 lbs/TR (0.91 kg)

GCCA, IARW and IAISC: below 10 lbs/TR (0.91-1.82 kg)

22% of survey respondents: below 10 lbs/TR (0.91-1.82 kg)

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LOW CHARGE CHILLER ASPEN MODELING

The graph plots Overall heat transfer coefficient, $W/(m^2 \cdot K)$ on the y-axis (0 to 30) against Circulation ratio on the x-axis (0 to 7). Three curves are shown for different flow rates: 4400 W/m² (1000 Btu/hr-ft²), 3300 W/m² (750 Btu/hr-ft²), and 630 W/m² (150 Btu/hr-ft²). The curves show a sharp increase in heat transfer coefficient as the circulation ratio increases from 0 to 1, then levels off.

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LOW CHARGE AMMONIA SYSTEM IN THE MARKET

The image shows a complex industrial ammonia refrigeration system with various pipes, tanks, and machinery. Text overlays describe the system as 'The Natural Leader in Complete Self-Contained Low Charge Ammonia Refrigeration Systems' and mention 'The Efficient Low Charge Refrigeration Chiller (LCR) operates on a single source responsibility'.

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LOW CHARGE AMMONIA SYSTEM IN THE MARKET

FRICK® LCSS – The True Low Charge Solution from a Single Source

The reliable, high efficiency central air generation system with a total system ammonia charge 85-95% less than traditional central ammonia systems.

The FRICK Low Charge System (LCS) reduces the operational efficiency and reliability of a central ammonia system by adding the controlled precision of the FRICK ammonia remote distributed condensing (RDC) units.

The innovative configuration reduces the total system ammonia charge to less than 1/10th of a traditional system. The ammonia is safe and secure as it is contained in many small, sealed vessels instead of being in many lines, with a built-in regulatory system and emergency stop as well as recovery lines.

Based on a complete FRICK low charge system (including compressors, condensers, evaporators, and controls).

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LOW CHARGE AMMONIA SYSTEM IN THE MARKET

The image shows two different industrial ammonia refrigeration systems. The left one is a smaller unit with a prominent compressor and various pipes. The right one is a larger, more complex unit with multiple tanks and piping.

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LOW CHARGE AMMONIA REFRIGERATION SYSTEM

S.NO	EQUIPMENT	LITERS	VOLUME	VAPOUR	LIQUID	VAPOUR	LIQUID	TOTAL
			m3	%	%	NH3	NH3	NH3
						kg	kg	kg
1	COMPRESSOR	1.22	0.00122	100	0	0.005	0	0.005
2	OIL SEPARATOR (50% OIL)	518.00	0.51800	50	0	11.261	0	11.261
3	SUCTION LINE	17.85	0.01785	100	0	0.0685	0	0.069
4	DISCHARGE LINE	23.17	0.02317	100	0	0.920	0	0.920
5	LIQUID LINE - 32 NB CONNECTION	6.79	0.00679	0	100	0.000	4.250	4.250
	SUCTION RISER	30.03	0.03003	85.3	16.7	0.096	3.179	3.275
	SUCTION CONNECTION	2.36	0.00236	85.3	16.7	0.008	0.249	0.257
	LIQUID RISER	24.57	0.02457	0	100	0.000	15.576	15.576
	LIQUID CONNECTION	8.65	0.00865	0	100	0.000	5.484	5.484
6	HIGH PRESSURE FLDT	43.03	0.04303	0	60	0.000	1.559	1.559
7	ACCUMULATOR (20 mm of liquid head)	863.00	0.86300	97.29	2.71	3.204	14.828	18.052
8	PHE CONDENSER	43.00	0.04300	80	20	1.426	4.751	6.177
9	PHE CHILLER	20.85	0.02085	0	100	0.000	13.219	13.219
	TOTAL AMMONIA CHARGE							80.14
SPECIFIC CHARGE QUANTITY =		80.14 Kg /150 TR						
		0.534 Kg/TR = 112 grams/TR						

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LOW CHARGE AMMONIA REFRIGERATION SYSTEM

S.NO	EQUIPMENT	LITERS	VOLUME	VAPOUR	LIQUID	VAPOUR	LIQUID	TOTAL
			m3	%	%	NH3	NH3	NH3
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	LIQUID CONNECTION	8.65	0.00865	0	100	0.000	5.484	5.484
6	HIGH PRESSURE FLDT	43.03	0.04303	0	60	0.000	1.559	1.559
7	ACCUMULATOR (50 mm of liquid head)	863.00	0.86300	93.25	6.775	3.089	37.069	40.158
8	PHE CONDENSER	43.00	0.04300	80	20	1.426	4.751	6.177
9	PHE CHILLER	20.85	0.02085	0	100	0.000	13.219	13.219
	TOTAL AMMONIA CHARGE							102.25
SPECIFIC CHARGE QUANTITY =		102.25 Kg /150 TR						
		0.681 Kg/TR = 147 grams/TR						

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DESIGN OF CO2 REFRIGERATION SYSTEM

Direct method vs **Indirect method**

- Least potential of ammonia leakage in storage room
- Uses very small amount of ammonia
- Compare with direct & indirect system, Indirect method is more complicated system

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DESIGN OF CO2 REFRIGERATION SYSTEM DIRECT METHOD

Ammonia/CO2 Cascade System

In a two-stage, cascade refrigeration system, CO₂ is specifically used for the low-temperature stage together with ammonia which is used for the high-temperature stage. When it comes to refrigeration equipment size, CO₂ usually comes in a smaller footprint and takes up less physical space since it is a very dense gas.

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DESIGN OF CO2 REFRIGERATION SYSTEM INDIRECT METHOD

Ammonia/CO2 Brine System

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ADVANTAGE OF CO2 REFRIGERANT

- It's non-toxic, non-corrosive and non-flammable. CO₂ works well at lower temperatures, making it common refrigerant for freezer application.
- Another benefit of CO₂ is that it's inexpensive
- The evaporation latent heat of CO₂ is large and the refrigerating capacity per unit volume is high (22.6 MJ/m³ at 0 °C), about 5 to 8 times that of traditional refrigerants
- The thermal conductivity of CO₂ is high, and the ratio of liquid density to vapor density is low. After throttling, the refrigerant can be distributed evenly in the refrigeration pipes. These excellent flow and heat transfer performances of CO₂ can significantly reduce the size of compressor and refrigeration equipment, making the whole system very compact.

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HEAT PUMP PRINCIPLE

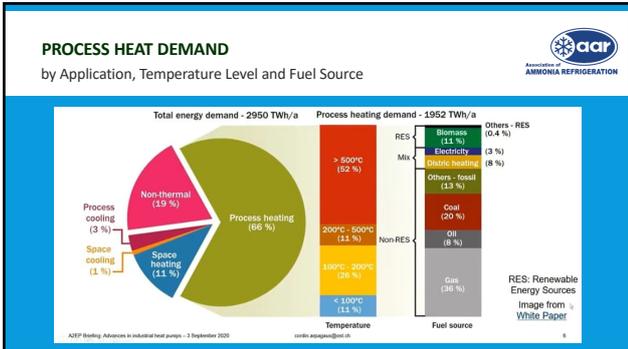
- Provides 10% of heat demand in Utrecht
- Has a capacity of 27 megawatts – the country's largest
- Supplies sustainable heat to approx. 20,000 households

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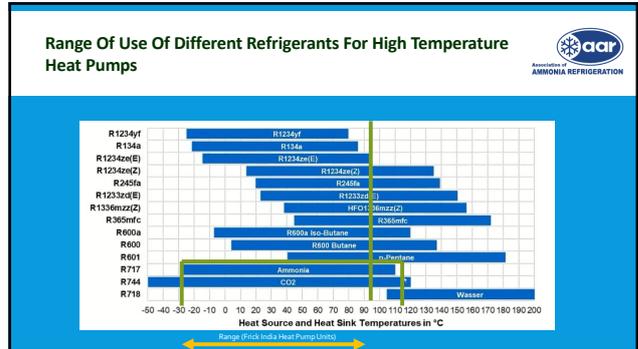
HEAT PUMP BENEFITS

- Energy absorbed from water
- NH₃ refrigerant is compressed to be supercritical fluid of high temperature and pressure.
- Hot water is supplied by using pumped heat from water and energy of compressor.
- Condition where heat can be given from water through expansion valve

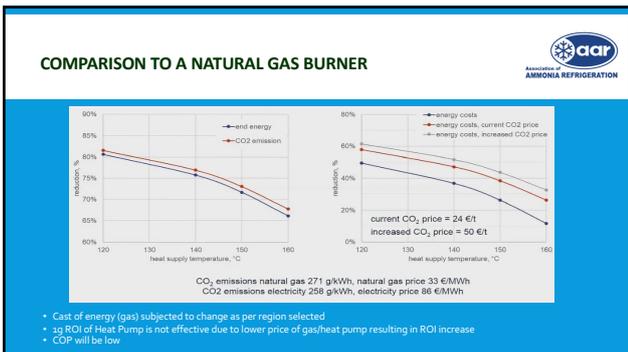
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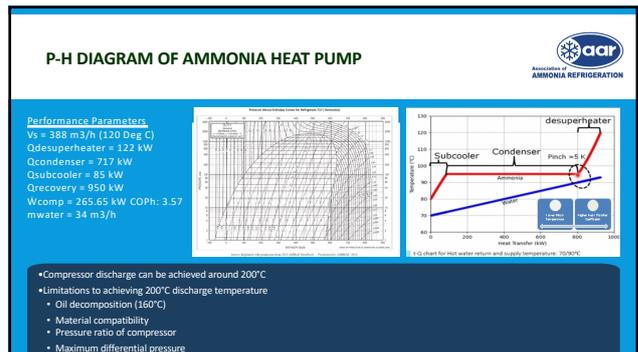
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CONCLUSION

- Ammonia is a natural refrigerant - Sustainable
- It has lower power consumption - Energy Efficient
- It has a zero ODP and less than 1 GWP - Environment Friendly
- Design expertise - Forex Savings
- Most equipment available locally - Make in India
- Long life of equipment, locally available parts and service - Lower Life Cycle Costs

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Sustainability with Ammonia Refrigeration

Thank You
Any queries ?

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