2ND ANNUAL REFRIGERATION CONFERENCE 2018

Non-HFC Cold Chain

NON-HFC COLD CHAIN

Food Production

- *(Source: Arab Agricultural statistics year book – Alpen Capital)*
- Due to the scarcity of arable land and an arid climate, agricultural food production in the GCC region has been minimal. **According to the FAO**, of the total area, the land suitable for cultivation is just **1.7%** in **Saudi Arabia** and **3.0%** in the **UAE** compared to **18.4%** in the **US**, **23.7%** in the **UK, 16.3%** in **China** and **51.6%** in **India**.

GCC countries largely rely on imports to meet most of their food requirement. They imported as much as 37.2 million metric tons of food in 2007, more than three times the food produced locally.

For Food Safety and extended safe shelf life of food items, Refrigeration is a must from farm to fork

NON-HFC COLD CHAIN

Exhibit 6: Country wise food consumption share within GCC (%)

Country	2011	2013	2015
Saudi Arabia	64.9%	64.5%	64.0%
UAE	18.3%	18.5%	18.9%
Qatar	3.6%	3.7%	3.9%
Oman	6.1%	6.2%	6.3%
Kuwait	5.5%	5.5%	5.4%
Bahrain	1.5%	1.5%	1.5%
GCC Total	**100%**	**100%**	**100%**

Source: Arab Agricultural Statistics Yearbook, Alpen Capital

NON-HFC COLD CHAIN

- While Refrigeration industry is helping food safety and extending food shelf life in one hand, it adversely affects food security and our environment on the other hand. Environment being atmosphere, land and ocean
- ODP, GWP, TEWI

THE RESULTS

- ✓ Threatening life on our planet – ODP
- ✓ Depleting and contaminating water reserves from cooling towers and evaporative condensers highly concentrated bleed.
- ✓ Melting ice and erosion on land – GWP.
- ✓ Sick oceans – increasing CO_2 level – threatening sea food security

NON-HFC COLD CHAIN

RECOMMENDED SOLUTIONS

1. Phase out CFC & HCFC refrigerants: Assumed almost done.
2. Eliminate or reduce the use of HFC refrigerants and replace with Natural refrigerants to minimize the foot print of carbon emission.

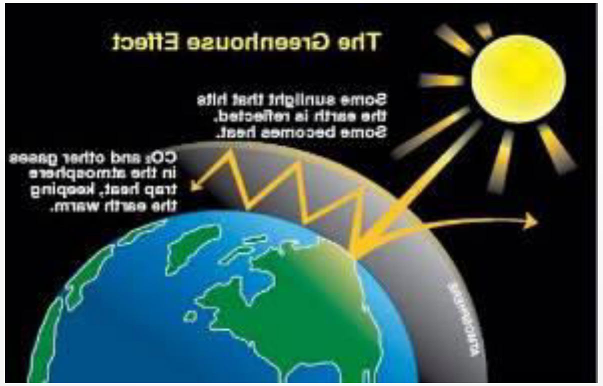
The burning of fossil fuels not only increases CO_2 in the atmosphere but also in the ocean. As a result, the concentration of hydrogen ions increases (increasing acidity) whilst the concentration of carbonate ions decreases.

Source University of Maryland.

Ocean Acidification: The Other CO_2 Problem

Ocean based food security threatened in a high CO_2 world

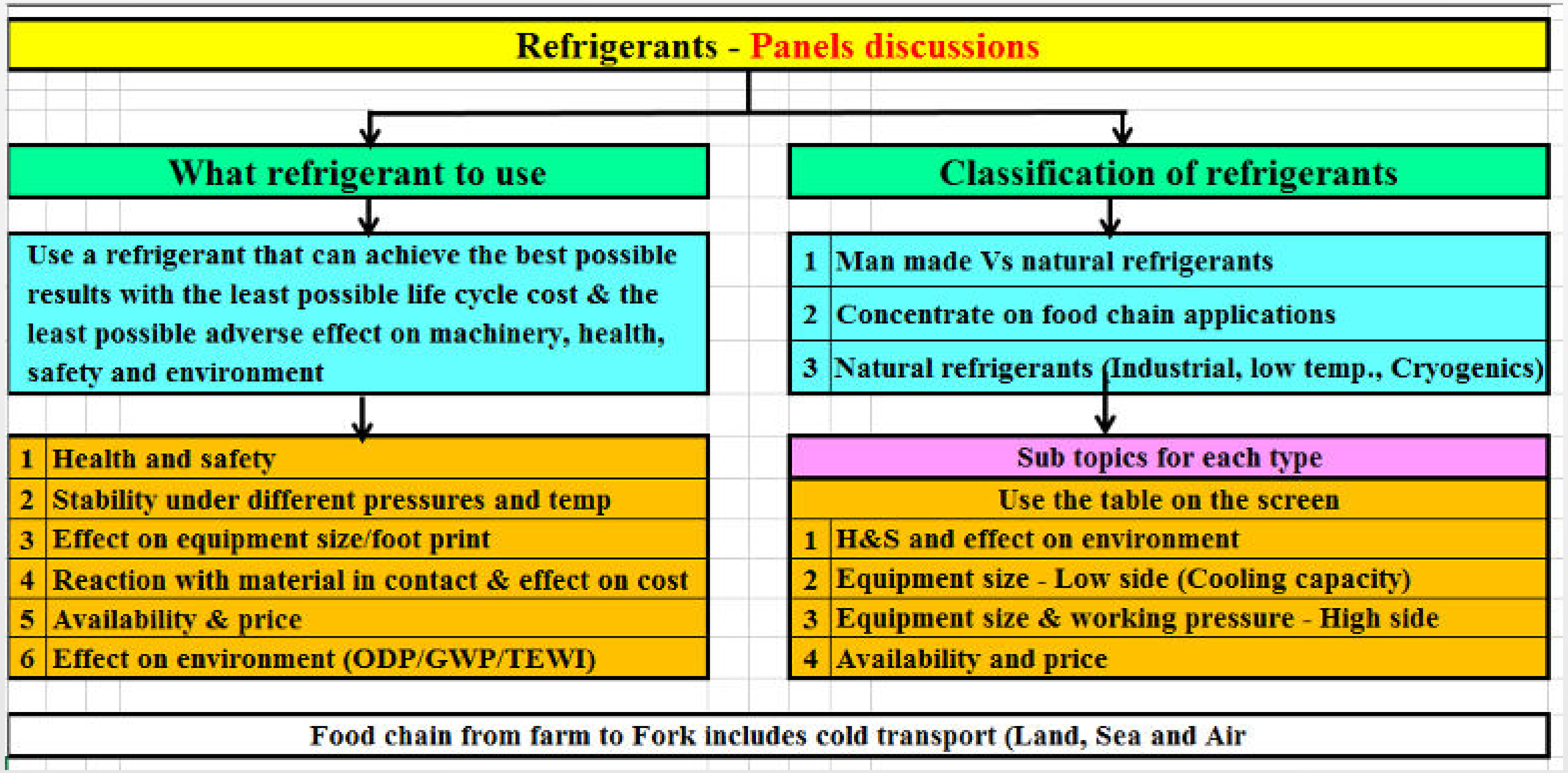
NON-HFC COLD CHAIN



Fish and sea food are a primary source of protein for more than one billion of poorest people on Earth

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries



NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Most common SSTs used in food industry in GCC countries

1. Dry stores around +2 degrees Celsius
2. Chilled products around (-10) degrees Celsius
3. Holding freezers and blast freezing applications around (-30) degrees Celsius

Most common SCTs in food industry in GCC countries

1. Air cooled condensers around 55 degrees Celsius
2. Evaporative condensers around 40 degrees Celsius
3. CO_2 requires a condensing temperature not to exceed (15) degrees Celsius

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Main Refrigerant properties affecting the technical and financial selection

1. Density/specific volume at design conditions
2. Working pressure at design conditions
3. Latent heat at design conditions
4. Safety
5. ODP, GWP, TEWI

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Sn.	Refrigerant		Press kPa	Sp Vol Mt^3/kg	Density kg/Mt^3	L heat kJ/kg	Comments and Clarifications	Affected system parts (Size and Cost)		
Dry storage application to give chilled water temp around 4 °C - Saturated Suction conditions at + 2 oC										
Man Made Refrigerants							Effect of each of the 4 Variables on equipment and material cost	KJ/Liter	L/S for 100 KW C C Sys	Kg/S for 100 KW C C Sys
1	R22	ChlorodiFluoromethane - CHClF2	531	0.044	22.60	203		4.598	21.75	0.49
2	R134a	TetraFluoroethane - CH2FCF3	315	0.065	15.47	197		3.048	32.81	0.51
3	R407C	R32/125/134a (23/25/52)	605	0.031	31.94	204	Combined effect on C.O.P., ODP, GWP	6.515	15.35	0.49
4	R410A	R-32/125 (50/50)	850	0.029	34.55	219		7.567	13.21	0.46
5	R404A	R-125/143a/134a (44/52/4)	650	0.026	38.20	160		6.107	16.38	0.63
Natural Refrigerants							Figure each KPI (Weightage).			
6	R717	Ammonia - NH3	462	0.270	3.71	1,255		4.655	21.48	0.08
7	R744	CO_2	3,673	0.010	104.10	225		23.423	4.27	0.44
BHP	$144/33{,}000 \times (k/k\text{-}1) \times P_1V_1\ [(P_2/P_1)^{(K-1)/K} - 1]/(e_a \times e_v \times e_m)$							Heat exchangers	Compressor & piping	Compressor's motor
Formula for Torque at Compressor Shaft: T = 5250 x bhp / rpm										

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Sn.	Refrigerant		Press kPa	Sp Vol Mt^3/kg	Density kg/Mt^3	L heat kJ/kg	Comments and Clarifications	Affected system parts (Size and Cost)		
Chilled storage application to give Room temp between 0 & <10 °C - Saturated Suction conditions at -10 oC										
Man Made Refrigerants							Effect of each of the 4 Variables on equipment and material cost	KJ/Liter	L/S for 100 KW C C Sys	Kg/S for 100 KW C C Sys
1	R22	ChlorodiFluoromethane - CHClF2	355	0.065	15.32	213		3.263	30.65	0.47
2	R134a	TetraFluoroethane - CH2FCF3	201	0.1	10.04	206		2.068	48.35	0.49
3	R407C	R32/125/134a (23/25/52)	400	0.058	17.16	221	Combined effect on C.O.P., ODP, GWP	3.792	26.37	0.45
4	R410A	R-32/125 (50/50)	550	0.047	21.07	234		4.930	20.28	0.43
5	R404A	R-125/143a/134a (44/52/4)	440	0.045	22.36	174		3.891	25.70	0.57
Natural Refrigerants							Figure each KPI (Weightage).			
6	R717	Ammonia - NH3	291	0.418	2.39	1,297		3.100	32.26	0.08
7	R744	CO_2	2,649	0.014	71.17	259		18.433	5.43	0.39
BHP		$144/33{,}000 \times (k/k\text{-}1) \times P_1V_1\,[(P_2/P_1)^{(K-1)/K} - 1]/(e_a \times e_v \times e_m)$						Heat exchangers	Compressor & piping	Compressor's motor
Formula for Torque at Compressor Shaft: T = 5250 x bhp / rpm										

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Sn.	Refrigerant		Press kPa	Sp Vol Mt^3/kg	Density kg/Mt^3	L heat kJ/kg	Comments and Clarifications	Affected system parts (Size and Cost)		
Holding and blast freezing application to give Room temp between -20 & -25 °C - Saturated Suction conditions at -30 oC										
Man Made Refrigerants							Effect of each of the 4 Variables on equipment and material cost. **See R-134a pres.**	KJ/Liter	L/S for 100 KW C C Sys	Kg/S for 100 KW C C Sys
1	R22	ChlorodiFluoromethane - CHClF2	164	0.136	7.38	227		**1.675**	**59.69**	**0.44**
2	R134a	TetraFluoroethane - CH2FCF3	84	0.226	4.43	220		**0.975**	**102.61**	**0.45**
3	R407C	R32/125/134a (23/25/52)	180	0.125	7.97	238		**1.897**	**52.72**	**0.42**
4	R410A	R-32/125 (50/50)	260	0.098	10.2	253	Combined effect on C.O.P., ODP, GWP	**2.581**	**38.75**	**0.40**
5	R404A	R-125/143a/134a (44/52/4)	200	0.096	10.44	190		**1.984**	**50.41**	**0.53**
Natural Refrigerants							Figure each KPI (Weightage).			
6	R717	Ammonia - NH3	119	0.964	1.04	1,360		**1.414**	**70.70**	**0.07**
7	R744	CO_2	1,428	0.027	37.09	303		**11.238**	**8.90**	**0.33**
BHP		144/33,000 x (k/k-1) x P_1V_1 [$(P_2/P_1)^{(K-1)/K}$ – 1]/(e_a x e_v x e_m)						Heat exchangers	Compressor & piping	Compressor's motor
Formula for Torque at Compressor Shaft: T = 5250 x bhp / rpm										

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Sn.	Refrigerant		Press kPa	Sp Vol Mt^3/kg	Density kg/Mt^3	L heat kJ/kg	Comments and Clarifications	Affected system parts (Size and Cost)		
Air cooled Condensers at Ambient temperature of 46 °C - SaturatedSaturated condensing temperature 55 °C										
Man Made Refrigerants							Effect of each of the 4 Variables on equipment and material cost. See R-134a pres.	KJ/Liter	L/S for 100 KW C C Sys	Kg/S for 100 KW C C Sys
1	R22	ChlorodiFluoromethane - CHClF2	2224	0.01	100.503	145.9		14.663	6.82	0.69
2	R134a	TetraFluoroethane - CH2FCF3	1528	0.0128	78.2473	144.41		11.300	8.85	0.69
3	R407C	R32/125/134a (23/25/52)	2500	0.0083	120.919	139.46	Combined effect on C.O.P., ODP, GWP	16.863	5.93	0.72
4	R410A	R-32/125 (50/50)	3600	0.0056	180.18	115.34		20.782	4.81	0.87
5	R404A	R-125/143a/134a (44/52/4)	2600	0.006	165.563	92.65		15.339	6.52	1.08
Natural Refrigerants							Figure each KPI (Weightage).			
6	R717	Ammonia - NH3	2311	0.056	18.005	1024		18.446	5.42	0.10
7	R744	CO_2	Not applicable. Above Critical point							
BHP		$144/33,000 \times (k/k-1) \times P_1V_1 [(P_2/P_1)^{(K-1)/K} - 1]/(e_a \times e_v \times e_m)$						Heat exchangers	Compressor & piping	Compressor's motor
Formula for Torque at Compressor Shaft: T = 5250 x bhp / rpm										

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

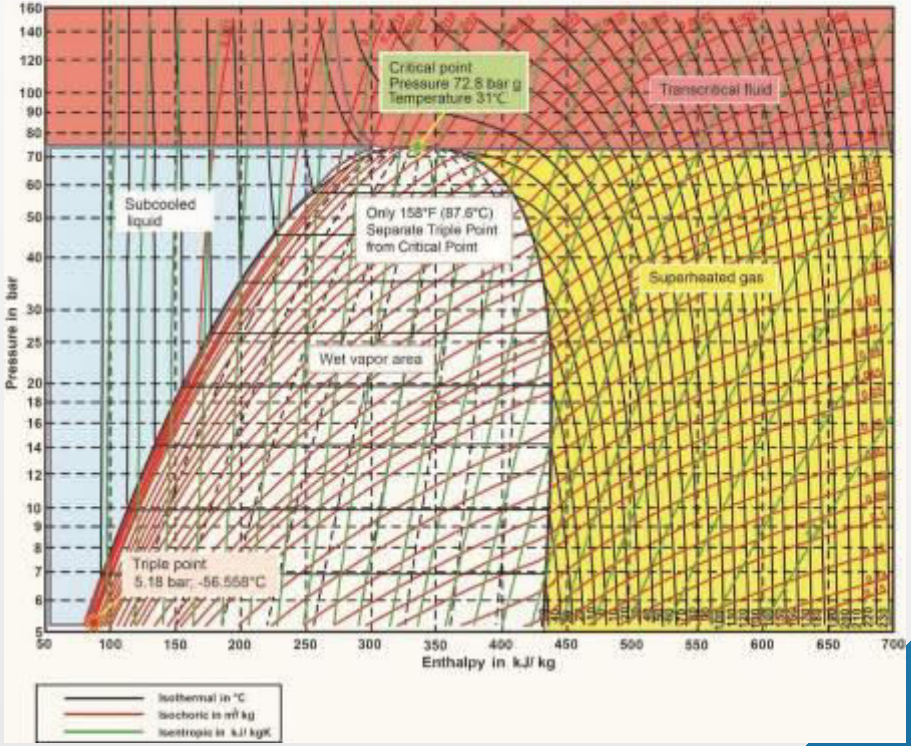
Sn.	Refrigerant		Press kPa	Sp Vol Mt^3/kg	Density kg/Mt^3	L heat kJ/kg	Comments and Clarifications	Affected system parts (Size and Cost)		
Air cooled Condensers at Ambient temperature of 46 °C - SaturatedSaturated condensing temperature 40°C										
Man Made Refrigerants							Effect of each of the 4 Variables on equipment and material cost. See R-134a pres.	KJ/Liter	L/S for 100 KW C C Sys	Kg/S for 100 KW C C Sys
1	R22	ChlorodiFluoromethane - CHClF2	1554	0.015	66.181	166.6		11.026	9.07	0.60
2	R134a	TetraFluoroethane - CH2FCF3	1017	0.02	50.075	163		8.163	12.25	0.61
3	R407C	R32/125/134a (23/25/52)	1800	0.012	81.235	162.8	Combined effect on C.O.P., ODP, GWP	13.228	7.56	0.61
4	R410A	R-32/125 (50/50)	2400	0.01	102.25	159.8		16.340	6.12	0.63
5	R404A	R-125/143a/134a (44/52/4)	1900	0.009	111.1	117.9		13.095	7.64	0.85
Natural Refrigerants							Figure each KPI (Weightage).			
6	R717	Ammonia - NH3	1555	0.083	12.034	1099		13.228	7.56	0.09
7	R744	CO_2	Not applicable. Above Critical point							
BHP		144/33,000 x (k/k-1) x P_1V_1 [$(P_2/P_1)^{(K-1)/K}$ – 1]/(e_a x e_v x e_m)						Heat exchangers	Compressor & piping	Compressor's motor
Formula for Torque at Compressor Shaft: T = 5250 x bhp / rpm										

NON-HFC COLD CHAIN

Technical and financial challenges facing NH3 & CO_2 refrigerants in food industry in GCC countries

Pressure Enthalpy Chart for CO_2. Watch the critical point and the Triple point

CO_2 application in GCC states requires Cascade system with medium stage side load at SST suitable for CO_2 SCT for optimum VE



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Cryogenics. Definitions (Low temp. is a relative term)

1. In Air conditioning, approaching zero degrees Celsius is considered low temp.
2. In industrial refrigeration, (-50) degrees Celsius is considered low temp.
3. In Cryogenics, zero degrees Kelvin (-273) degree Celsius is considered low temp.

Low temperature applications
تطبيقات درجات الحرارة المتدنية

- **Environmental test facilities**
  مختبرات البيئة
- **Cryogenics**
  علم فيزياء درجات الحرارة المتدنية
- **Low temperature refrigeration**
  علم تبريد درجات الحرارة المتدنية
- **Biomedical applications of Cryogenic refrigeration**
  التطبيقات الطبية الحيوية لعلم تبريد درجات الحرارة المنخفضة

NON-HFC COLD CHAIN

Cryogenics. Definitions (Low temp. is a relative term)

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Sn	Refrigerant			Cryogenics - low Temp. Application									
	Name	Source	Chemical Name or Composition (% by Mass).	Saturated suction conditions									
				Pressure kPa & Temp °C				Spec. Vol.		Density		Latent heat kJ/kg	
				P1	T1	P2	T2	S.V.1	S.V.2	Den. 1	Den. 2		
1	R-702	Natural Refrigerant	Normal Hydrogen	8	-259	90	-253	7.29	0.835	0.14	1.2	449	447
2	R-702 P		Parahydrgen	7	-259	93	-253	7.84	0.804	0.13	1.24	447	445
3	R-704		Helium	5	-271	47	-270	0.87	0.125	1.15	8.02	23	23
4	R-728		Nitrogen	13	-210	137	-193	1.48	0.164	0.67	6.11	215	195
5	R-729		Air	6	-213	150	-191	2.92	0.155	0.34	6.47	226	201
6	R-732		Oxygen	0.2	-219	254	-173	96.5	0.096	0.01	10.43	243	202
7	R-740		Argon	69	-189	324	-173	0.25	0.059	4.06	16.91	164	150
8	R-299		Propane	0	-150	"""	""	4341	""	0	"""	526	""""
9	R404A		Carbon Dioxide	518	-56.6	"""	"""	0.07	"""	13.76	"""	350	167
10	R717		Ammonia - NH3	6	-77.7	"""	"""	15.6	"""	0.06	"""	1,484	""""
Ref. ASHRAE (Fundamental Handbook)													

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Cryogenics – General applications

- The food industry uses large amounts of liquid nitrogen to freeze the more expensive foods like shrimp and to maintain frozen food during transport.
- Liquid nitrogen cooled containers are used to preserve whole blood, bone marrow, and animal semen for extended periods.
- Cryogenic surgery is performed to cure such involuntary disorders as Parkinson’s disease.
- Medical diagnosis uses magnetic resonance imaging (MRI), which requires cryogenically cooled superconducting magnets

NON-HFC COLD CHAIN

Cryogenics – General applications

- Finally, the **chemical processing industry** relies on cryogenic temperatures to recover the more valuable heavy components or upgrade the heat content of the **fuel gas from natural gas**, to recover useful components like **argon and neon from air,** to purify various process and waste streams, and to produce **ethylene** from a mixture of **olefin** compounds. An **alkene**, **olefin**, or **olefine** is an unsaturated chemical compound containing at least one carbon-to-carbon double bond. General formula **C_nH_{2n} . Ethylene C_2H_4**

Thank you