Sorption Refrigeration Systems & their Application to the Food Industry

Articles about Doug Marriott Associates

Doug Marriott

A PRESENTATION MADE AT BRUNEL UNIVERSITY IN THE UK AND 14 INDUSTRIAL PARTNERS
A NEW ENERGY SYSTEM FOR REDUCED ENVIRONMENTAL IMAPCTS IN SUPERMARKETS

11 November 2010

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Doug Marriott Associates Ltd Chartered Consulting Engineers

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- Sorption Systems
- Li/Br – Silica Gel – NH_3/H_2O
- Reduction in Energy Wastage
- Fuel Options
- Food Industry Applications
- Cold Store CHP
- Dairy
- Sub Zero Temp Freezing Plant
- Conclusion – Comparison VCR/CHRP

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Sorption Refrigeration Systems

Sorption

- **Absorption** is the incorporation of a substance into another of a different state.

  e.g. Liquids into Solids

  or Gases into Liquids

  Absorption is basically where a material takes in another substance.

- **Adsorption** is the physical adherence or bonding of ions and molecules onto the surface of another phase

  (e.g. reagents adsorbed to solid catalyst surfaces)

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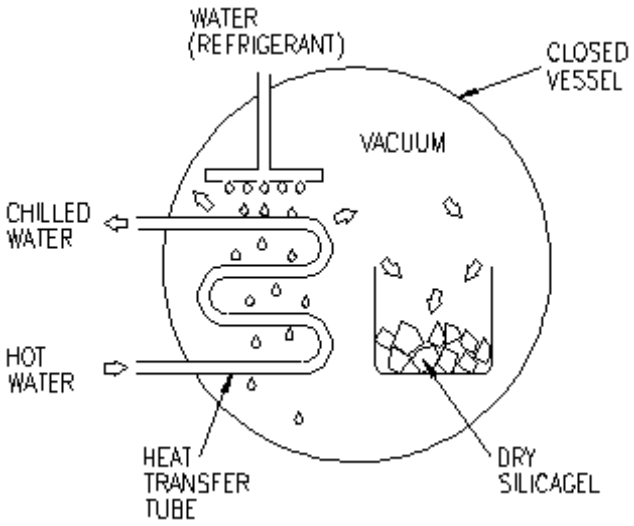
Simplified Silica Gel Schematic



- Water refrigerant
- Vacuum Vessel
- H_2O evaporates
- Chilled Water formed
- Silica Saturates
- Heat Regenerates Silica
- Cycle commences
- Adjacent chamber – typically 2 chambers
- Adjacent chamber with external thermal storage necessary

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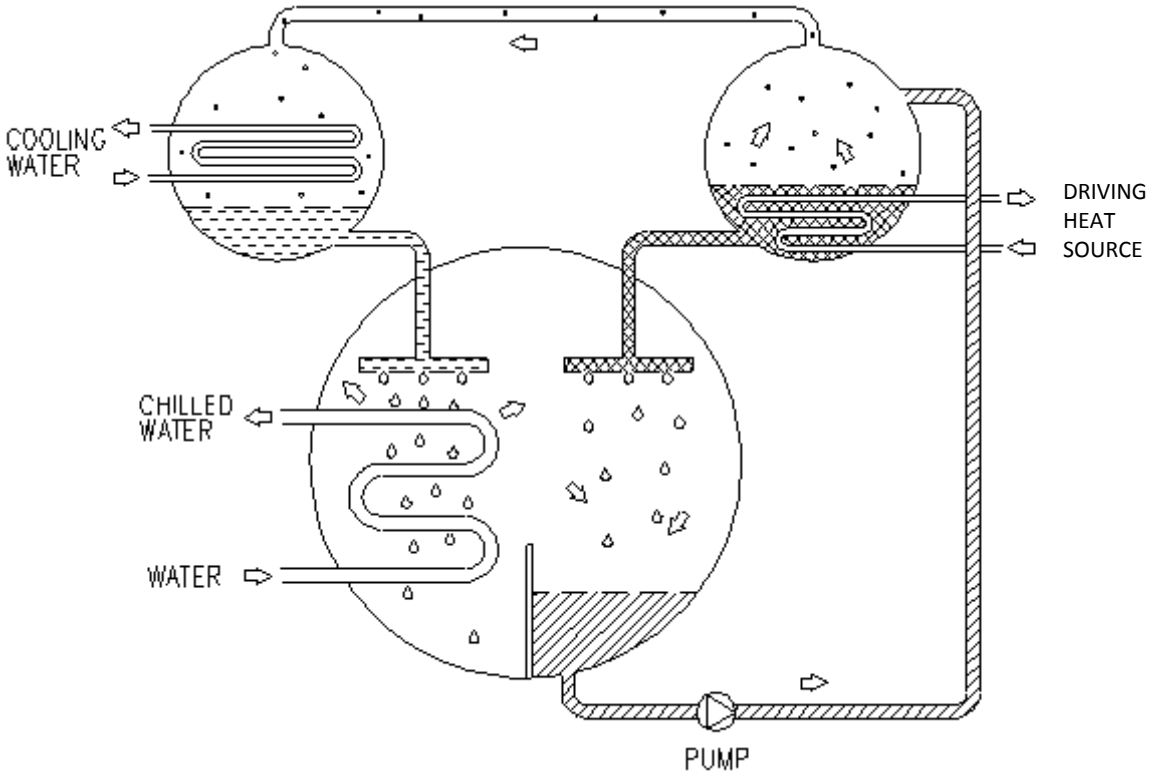
Simplified Lithium Bromide - Li/Br



- Water – Refrigerant
- Evaporator
- Pumps weak Sol'n
- Rectifier concentrates the solution
- Vapour driven off
- Liquefied – condensed
- Evaporates
- Care to avoid triple point solidification

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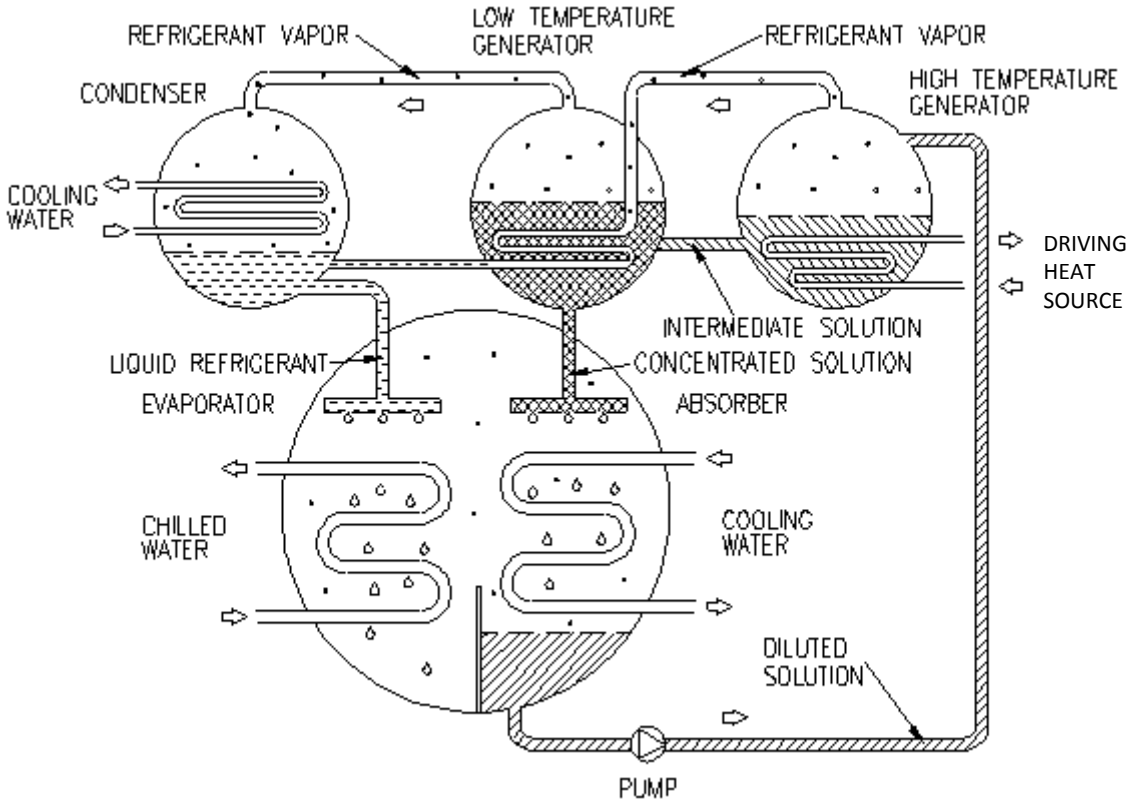
Simplified 2 Stage Li/Br



Compared with Single Stage

- **Higher Generator temperature input req'd**
- **Resultant higher COP**

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Pressure & Temperature Relationships Li/Br

Li / Br	Gauge Pressure (kg/cm² G)	Absolute Pressure (kg/cm² G)	Temp (°C)	Remarks
Pressure	10	11	183.2	Driving pressure for double effect type
	8	9	174.5	
	5	6	158.1	
	1	2	119,6	
	0.5	1.5	110.8	Driving pressure for single effect type
1 atm.		760 mmHg	100	Atmospheric Pressure
Vacuum		650.0	95.5	High Temp. Generator Pressure
		525.9	90.0	
		167.6	62.6	
		92.5	50.0	
		61.0	41.5	
		31.8	30.0	Condenser Pressure
		29.4	28.6	
		9.2	10.0	
		6.54	5.0	Evaporator Pressure
		5.68	3.0	

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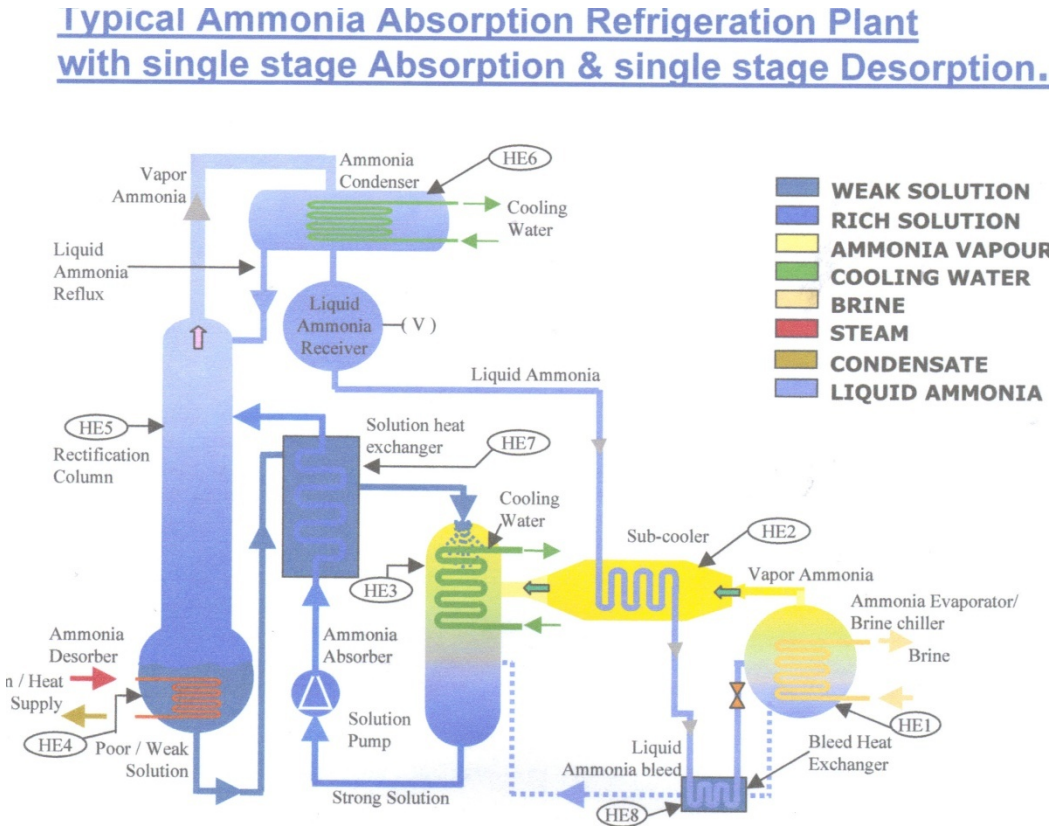
Simplified Ammonia Absorption Refrigeration Plant (AARP)



- Temp +5°C down to -60°C
- NH_3 refrigerant /H_20 absorbent
- Flexible and rapid temp adjustment/ start up
- Only one moving part (pump)
- No refrigerant losses
- Low Maintenance
- No Triple point issues
- Long Life >30 Years
- Performance a function of plant temperatures
- Fuels Cost Low Zero Negative Carbon/Cost – opportunity

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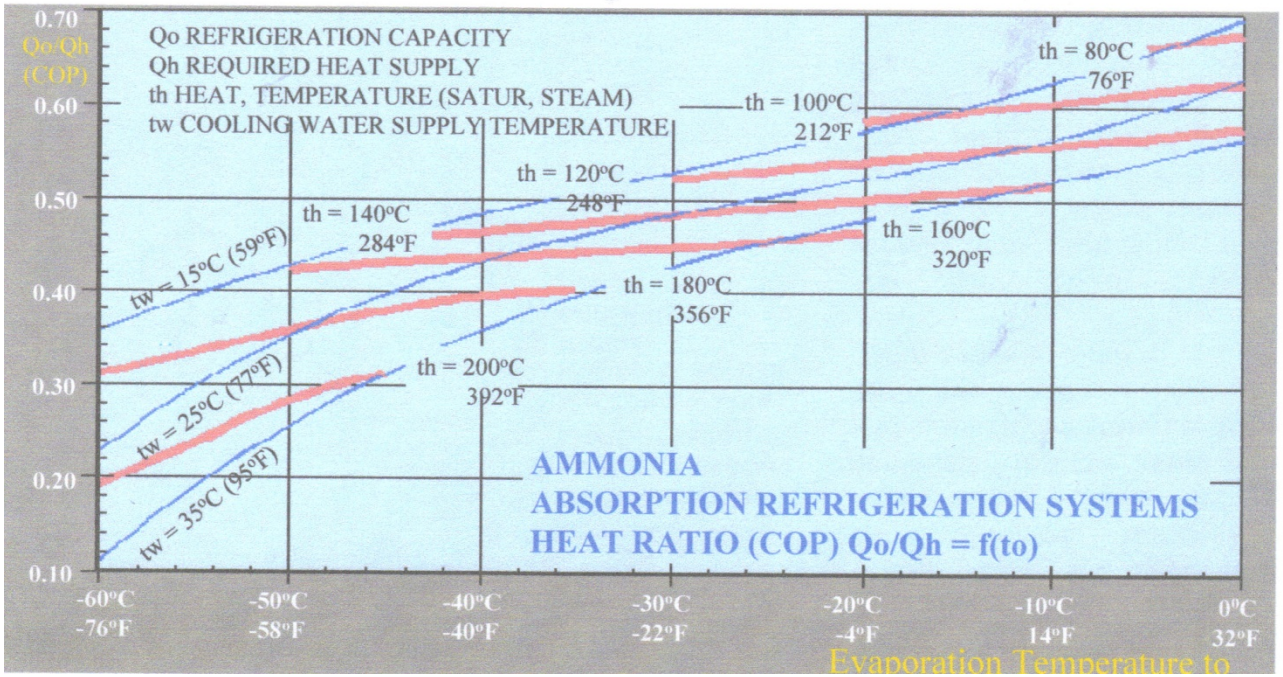
Zero or Negative Cost Fuels

Operation of Ammonia Absorption Refrigeration Plant (AARP)

AARP with single stage Absorption & single Stage Desorption.

Single stage Ammonia Absorption Refrigeration Plants are used for refrigeration temperatures ranging from +5 to –60 Deg.C, heat source temperature requirement varies from 95 Deg.C to 180 Deg.C.



- Evap +5 – 60^{0}C
- Gen heat +95 to 180^{0}C
- Various heating media
  - steam
  - hot oil
- Condenser low temp
  e.g. + 56% COP @ -50^{0}C
  +43% COP @ -40^{0}C
- Various cooling soln's
  - industrial brines etc

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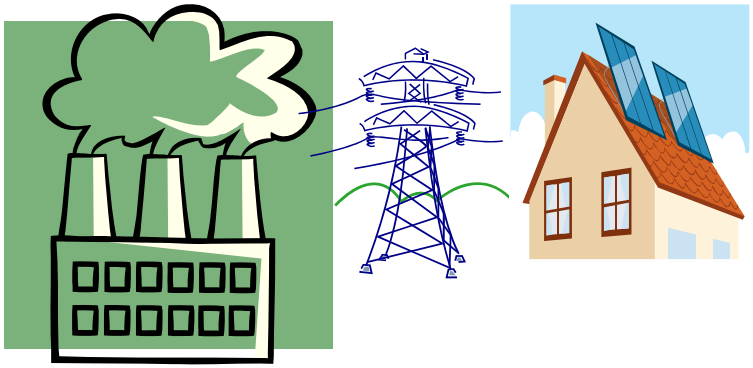
Why Sorption Anyway

Conventional Systems



- ή Power station 40-45%
- ή transmission = - 3%
- ή Power to site = 37-42%
- ή Loss = 63% – 58%

2/3 energy is lost

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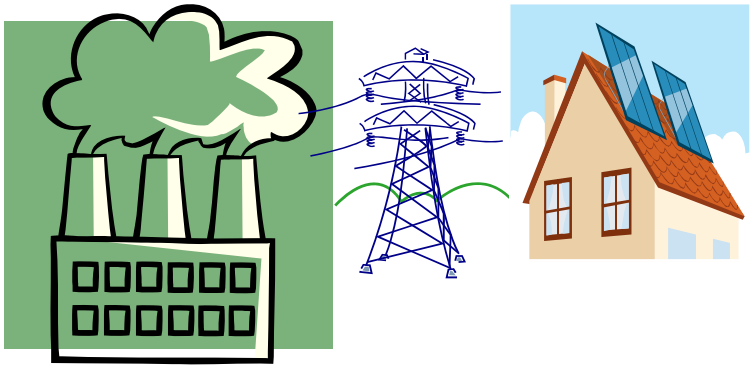
Conventional Systems



- ή Power station 40-45%
- ή transmission = - 3%
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2/3 energy is lost

Energy Act - 80% reduction in energy use by 2050

How can we achieve it !

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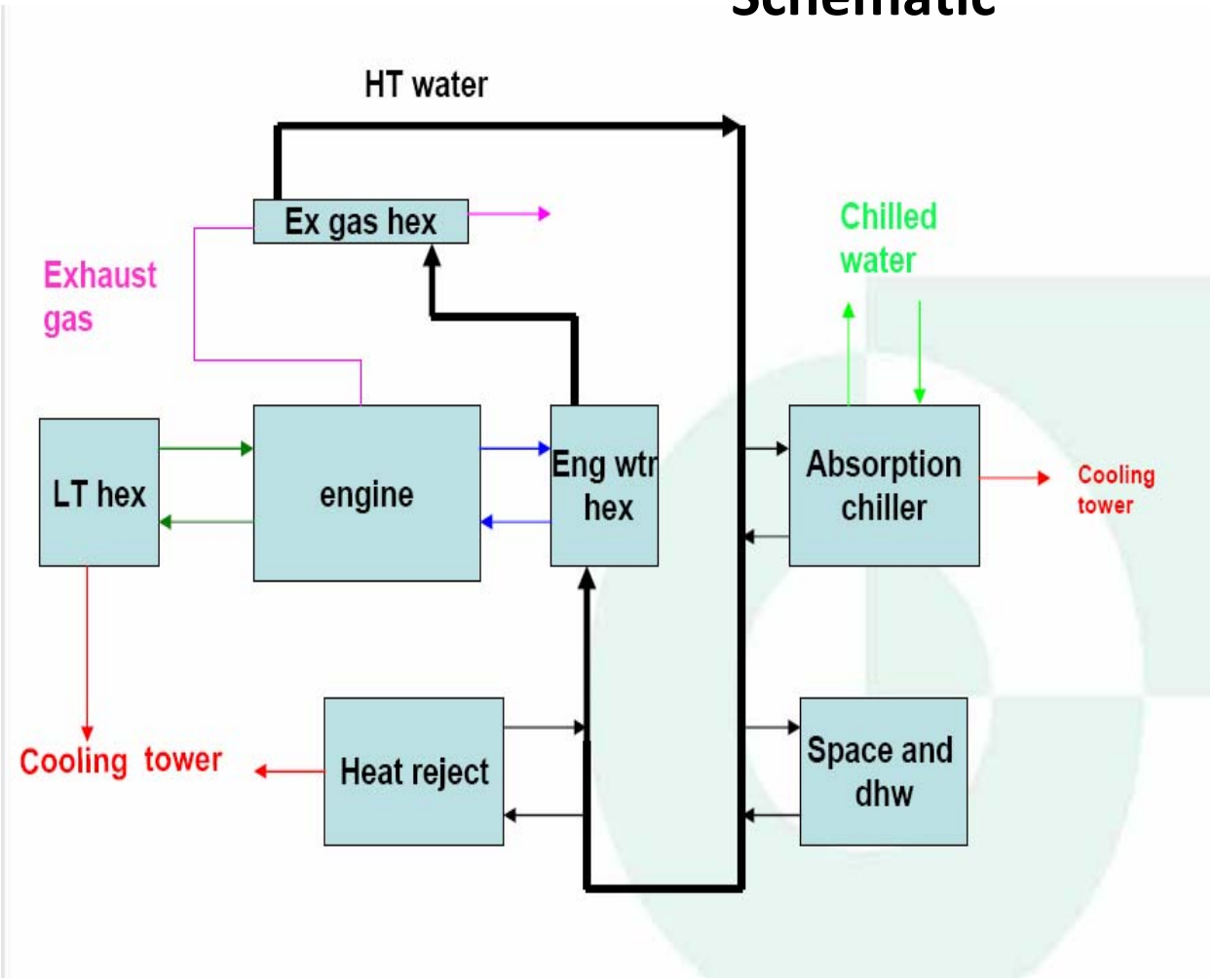
Trigeneration - Combined Heat Cooling/Refrigeration & Power Schematic



- Engine $\acute{\eta}_e$ = 28% to 45%
- Heat Recovery ~ 40%
- System $\acute{\eta}$ = 65% to 85%
  Losses = 35% to 15%
- Ability to use lower cost or waste fuel e.g Anaerobic Digester
- COP of AD/AB ~ 40% to 30 % conventional VCR. NH_3 plant typically at COP 0.6 to 0.4
- Li/Br COP ~ 0.7 – 1.1
- Silica Gel COP ~ 0.7
- Low maintenance
- High Reliability
- Rapid payback on suitable applications

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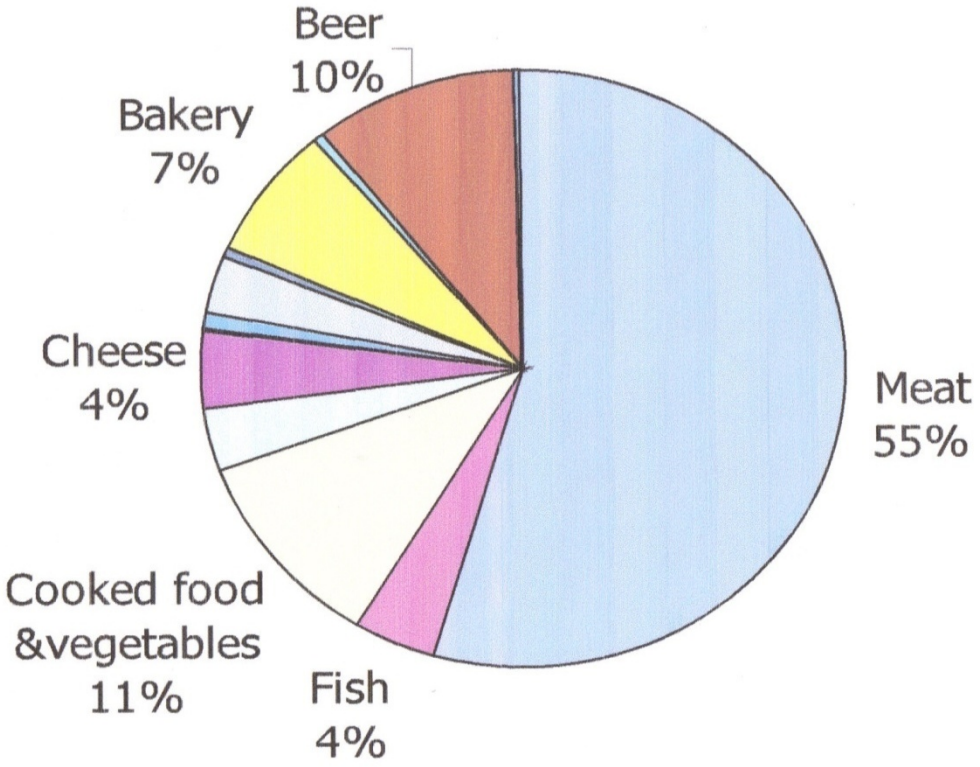
Trigeneration potential by sector

Total pure trigeneration potential: **15.3 TWh_{el}**

UK circa 13.7% 2 TWhel



- Meat
- Fish
- Cooked food &vegetables
- Consumer milk
- Cheese
- Butter
- Milk powder & Cond Milk
- Ice Cream
- Cultured Products
- Cereals
- Bakery
- Coffee
- Corn
- Beer
- Spirits
- Juice
- Cotton seed
- Ground-nut
- Rape-seed
- Saf- & Sun-flower
- Sesame
- Soyabean
- Virgin olive oil and refined oilve oil
- Sugar
- Chokolat

Source EU Contract No EIE/04/150/SO7.39553

M Whitley - Energy for Sustainable Development Ltd

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Food Industry Applications for Trigeneration

- Generally food process where CHRP is needed
- Ideal consideration on new investment
- Retrofit when considering time expired plant needing / or environmental upgrade
- It needs planning from conception

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Trigeneration Industrial Applications

Food & Pharmaceuticals

- Freeze Drying
- Food Refrigeration
- Cold Storage
- Dairies
- Ice Making Plants / Ice Storage.
- Ice Cream Plants
- Meat Processing
- Fish Processing Industries.
- Blast Freezing / Cold Stores
- Solvent Recovery
- Industrial Processes

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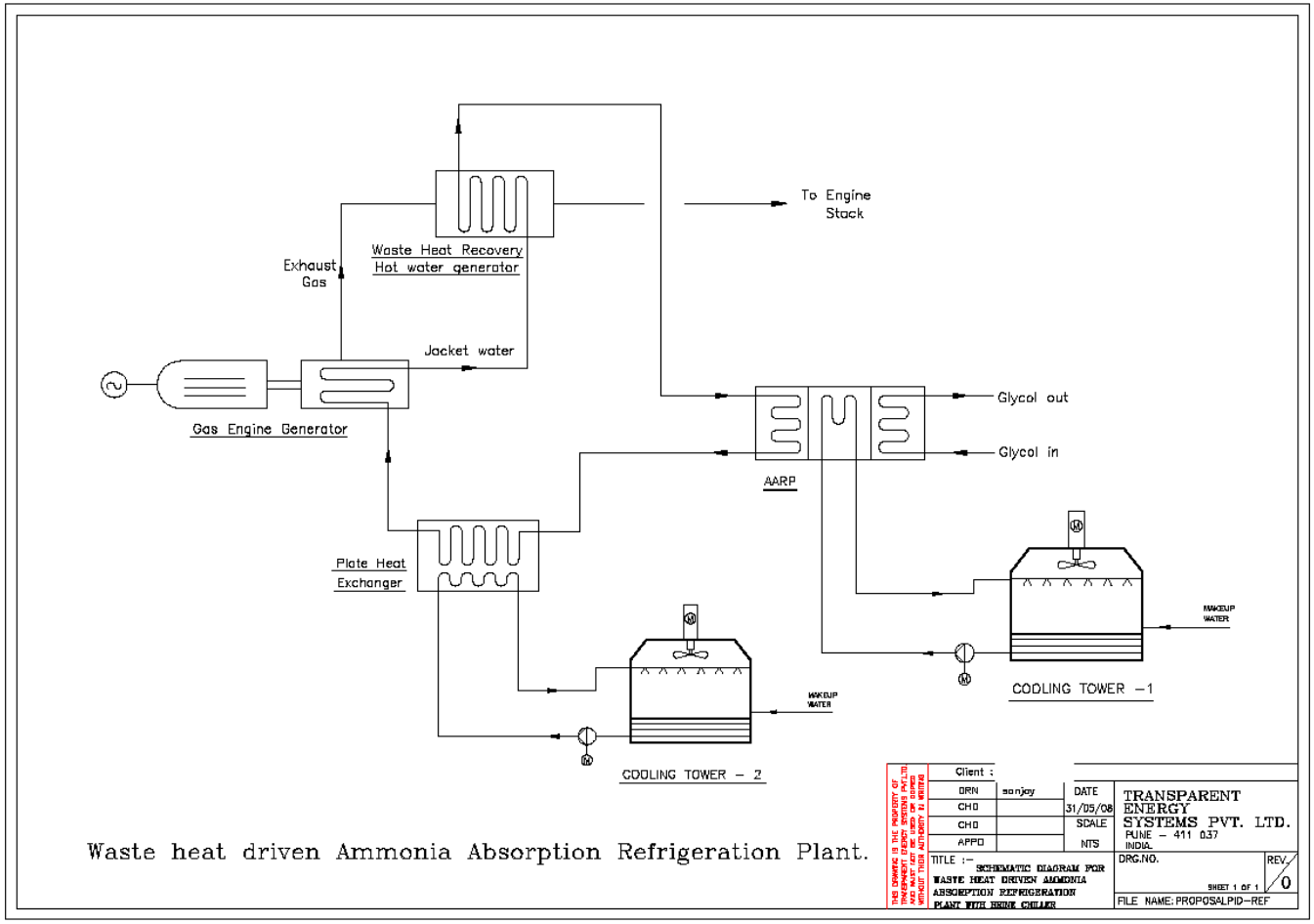
Ammonia Absorption Refrigeration Plant



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Polygeneration Dairy Complex in Govind Dairy India with Integral Block Ice Making Plant

- Fuel waste sugar cane husk, coal, wood, other waste fuel
- Steam @ 21 bar G
- Steam driven electrical turbine
- Steam exhaust powers AARP
- Complete cooling services
- Integral ice making plant

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Example of Relative Payback/ Cost Conventional vis CHRP

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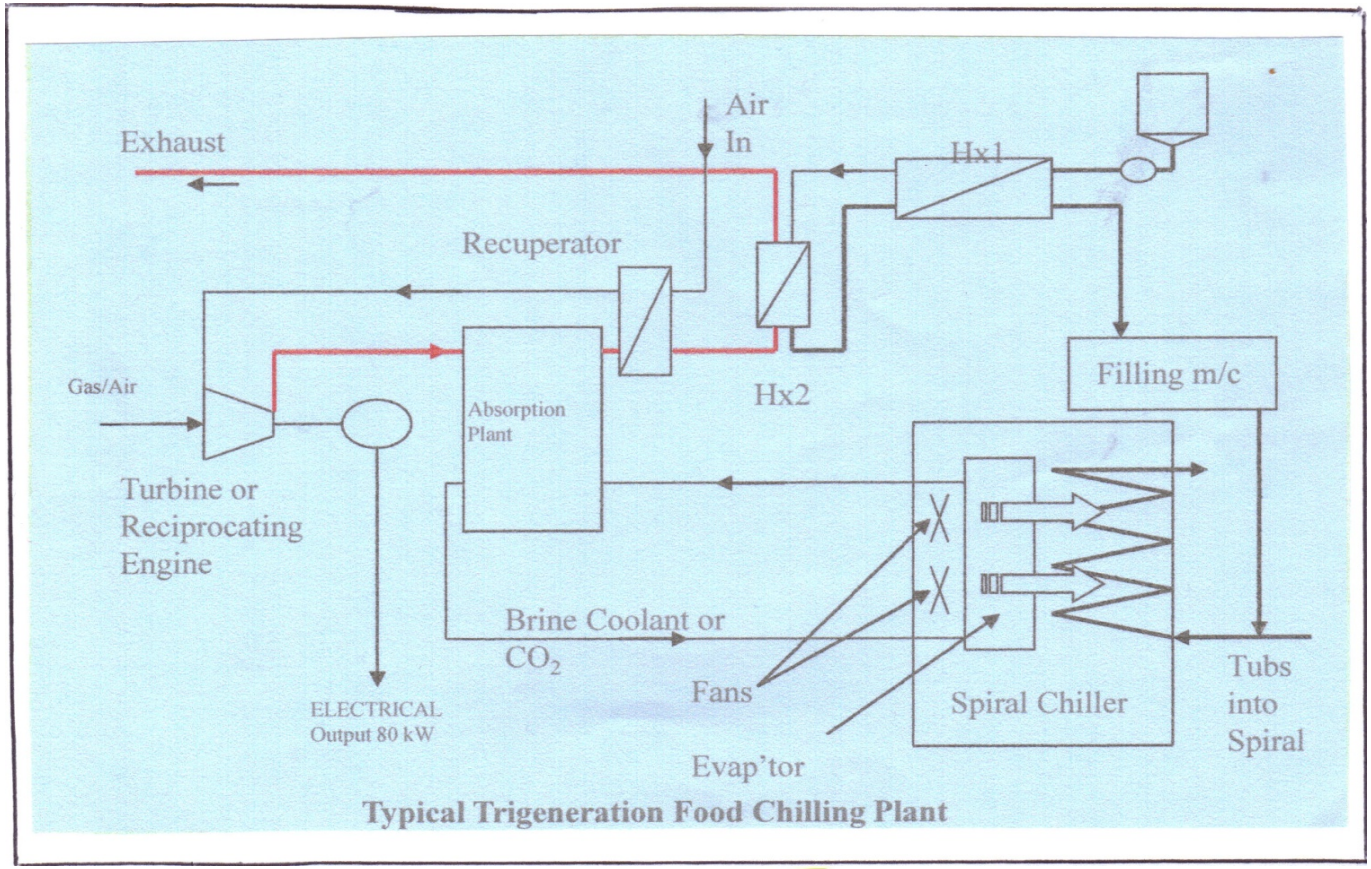
Chilled Food Application at 1 Tonne/hr
Dairy Produce Chilling Yogurt



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Assumptions for Comparisons

Tri-gen plant producing at 80kWe

Process heating Hx2 = 71 kW

Regenerative Hx1 = 45 kW

Spiral cooling duty = 55 kWr

6000 hrs p.a. production plan

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Economic Comparison of Conventional ~ Tri-generation

	Conventional Plant	Tri-generation Plant
Capital cost	**£ 35k (Refrigeration plant + heating)**	**£110k (Based on MGT)**
Electrical requirement	**52.5 kWe (Imported Main Grid)**	**25 kWe (to drive the fans, lights etc). (From the 80 kWe CHP plant)**
Exported electricity	**0 kWe**	**55 kWe**
Gas consumption	**88.75 kWf**	**285.7 kWf**
Running cost p.a.	**£ 38,513**	**£ 42,855**
Equivalent exported energy cost p.a.	**0**	**£26,400**
Net running cost p.a.	**£ 38,513**	**£ 16,455**
Relative maintenance	**similar for both installations**	
Capital cost difference	**+ £ 75,000**	
Net running cost difference	**-£ 22,058**	
Pay back on the difference	**3.4 Years**	

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Comparison Between Conventional and Tri-generation System

Conventional System

- Overall Efficiency: 51 %
- Running Cost: £800 p.w.
- CO_2 Emissions:12.6 t/day

Tri-generation System

- Overall Efficiency 73 % (COP=0.35)
- Running Cost: £440 p.w
- CO_2 Emissions: 5.3 t/day

Note: Efficiency and environmental performance of tri-generation system will increase significantly when low temperature absorption refrigeration systems with COP (Coefficient of Performance) close to 1.0 are achieved.

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