

# 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 IMPACTS IN SUPERMARKETS

11 November 2010



# Content

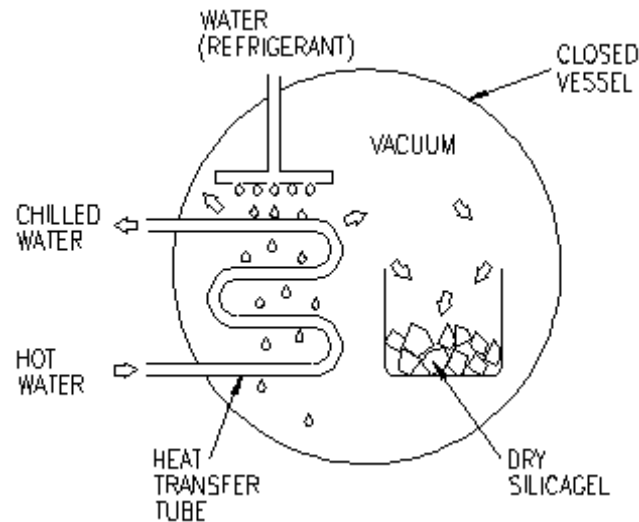
- Sorption Systems
- Li/Br – Silica Gel –  $\text{NH}_3/\text{H}_2\text{O}$
- Reduction in Energy Wastage
- Fuel Options
- Food Industry Applications
- Cold Store CHP
- Dairy
- Sub Zero Temp Freezing Plant
- Conclusion – Comparison VCR/CHRP

# Sorption Refrigeration Systems

## Sorption

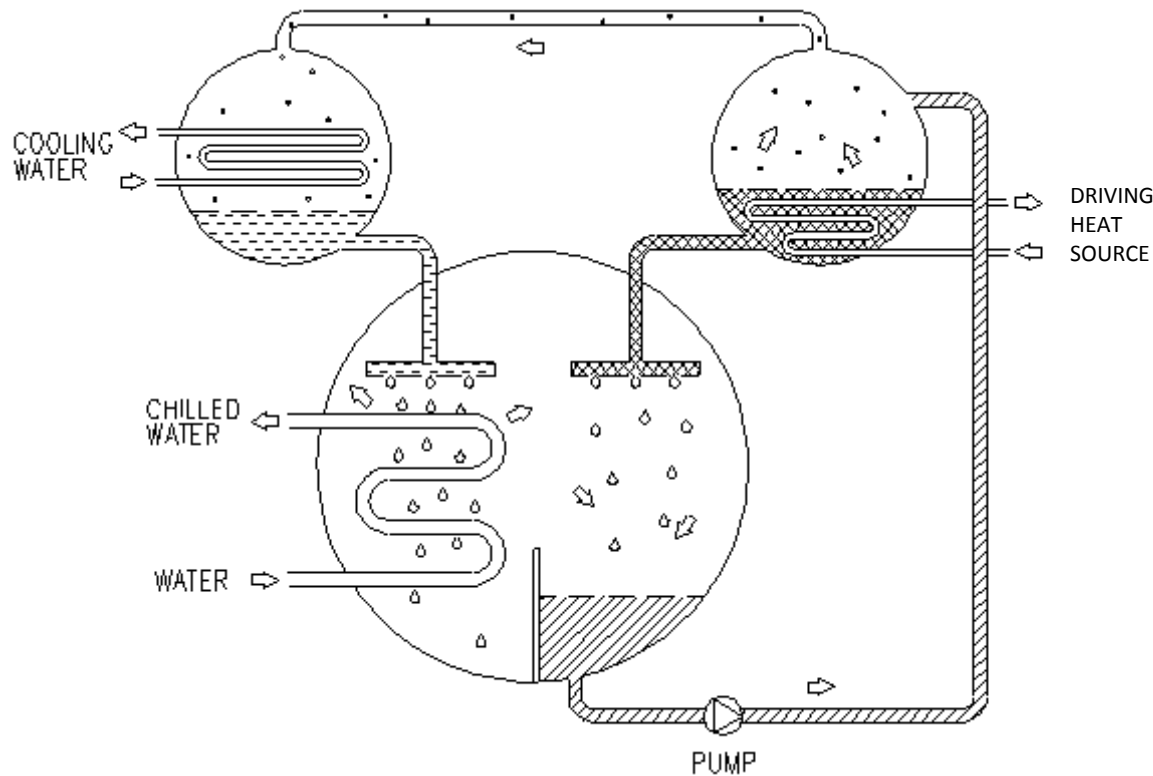
- **Absorption** is the incorporation of a substance into another of a different state.  
e.g. Liquids into Solids  
or Gases into Liquids  
Absorption is basically where a material takes in another substance.
- **Adsorption** is the physical adherence or bonding of ions and molecules onto the surface of another phase  
( e.g. reagents adsorbed to solid catalyst surfaces)

# Simplified Silica Gel Schematic



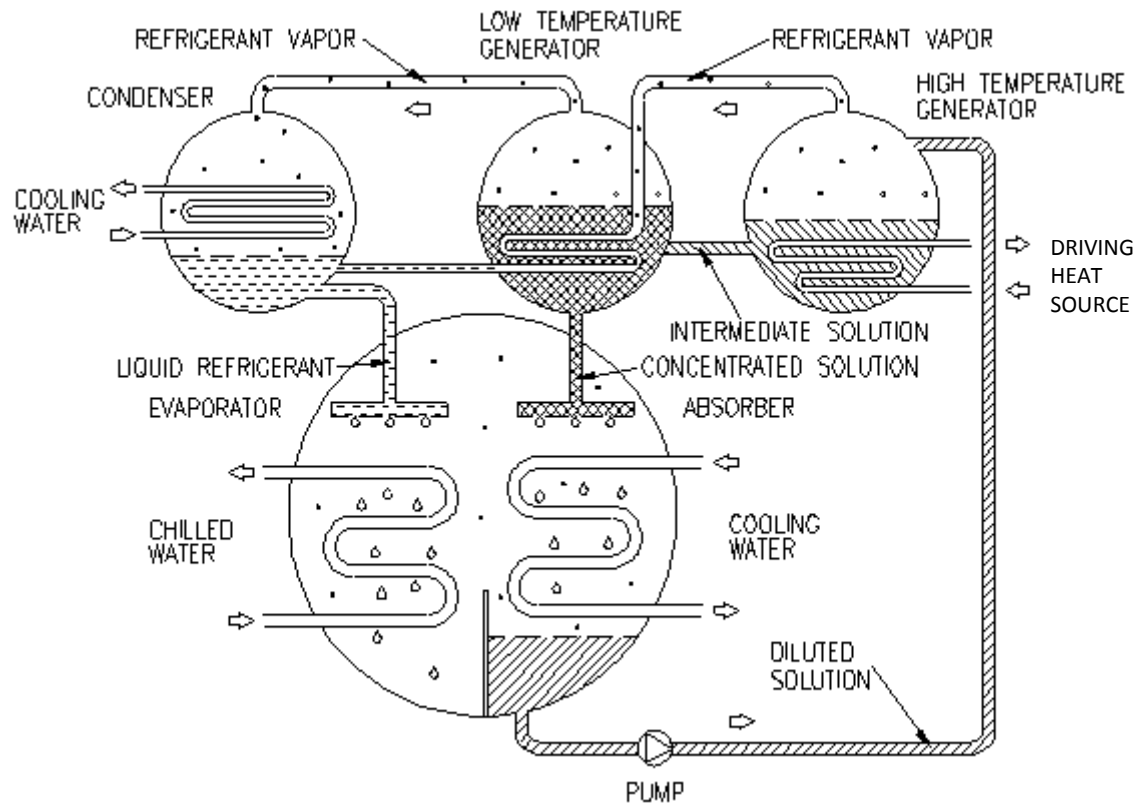
- Water refrigerant
- Vacuum Vessel
- H<sub>2</sub>O evaporates
- Chilled Water formed
- Silica Saturates
- Heat Regenerates Silica
- Cycle commences
- Adjacent chamber – typically 2 chambers
- Adjacent chamber with external thermal storage necessary

# 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

# Simplified 2 Stage Li/Br



## Compared with Single Stage

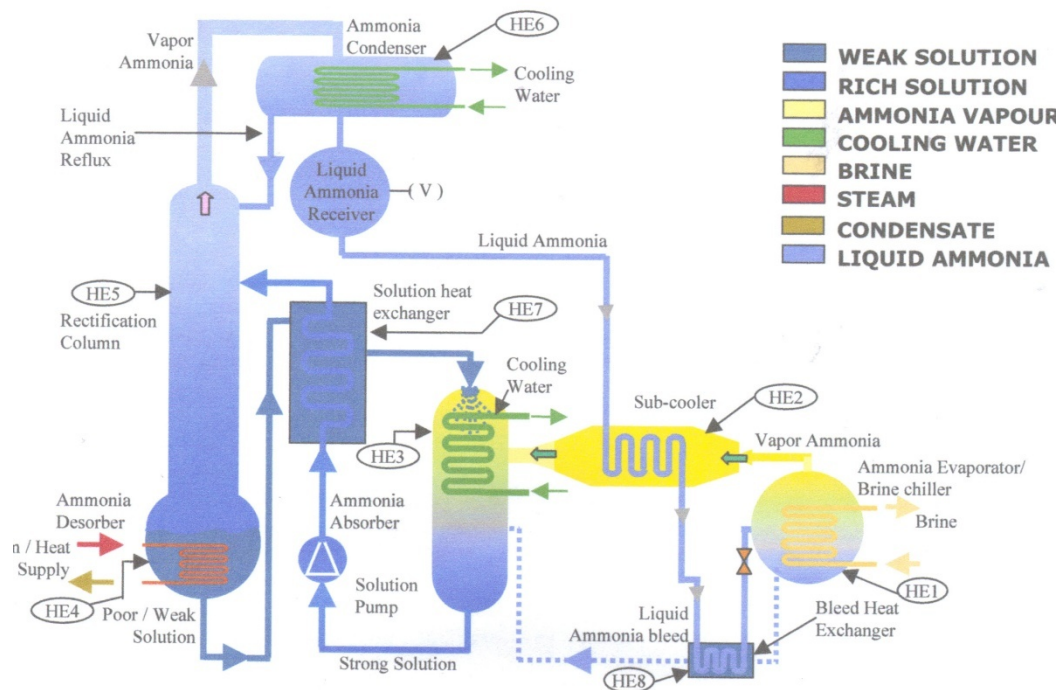
- Higher Generator temperature input req'd
- Resultant higher COP

# Pressure & Temperature Relationships Li/Br

Li / Br	Gauge Pressure (kg/cm <sup>2</sup> G)	Absolute Pressure (kg/cm <sup>2</sup> 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	Driving pressure for single effect type
	0.5	1.5	110.8	
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	Condenser Pressure
		61.0	41.5	
		31.8	30.0	
		29.4	28.6	
		9.2	10.0	Evaporator Pressure
		6.54	5.0	
	5.68	3.0		

# Simplified Ammonia Absorption Refrigeration Plant (AARP)

Typical Ammonia Absorption Refrigeration Plant with single stage Absorption & single stage Desorption.



- Temp +5°C down to -60°C
- NH<sub>3</sub> refrigerant / H<sub>2</sub>O 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

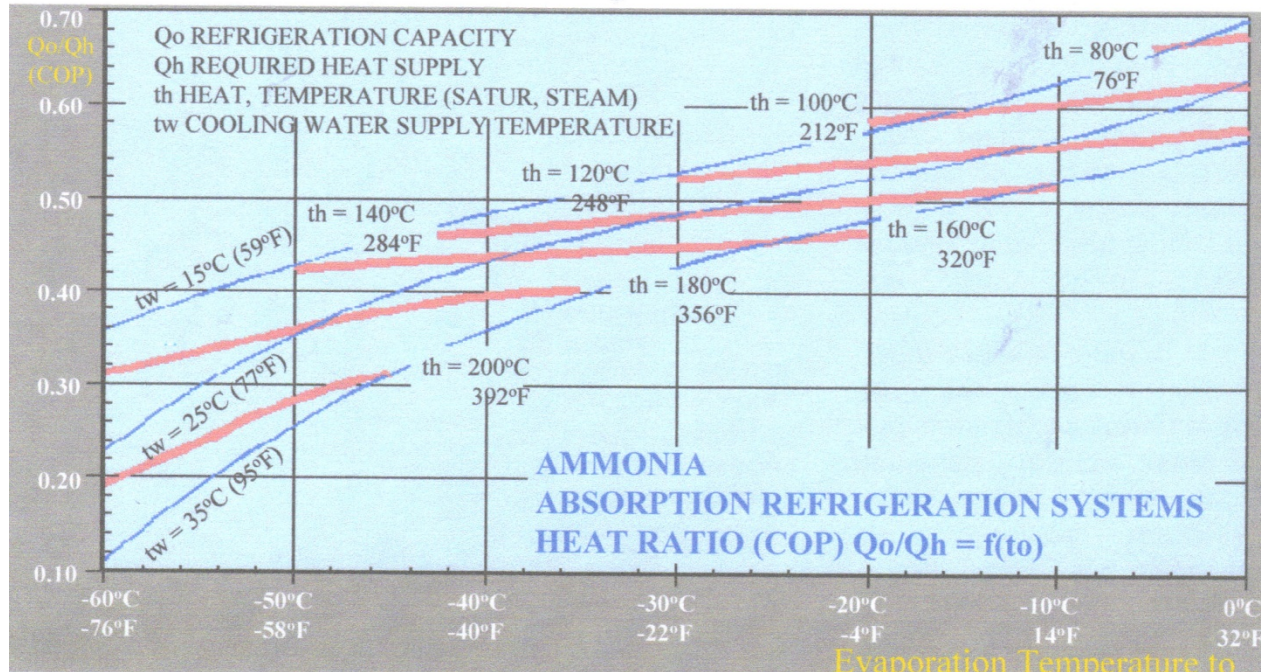
# Zero or Negative Cost Fuels



# 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°C
- Gen heat +95 to 180°C
- Various heating media
  - steam
  - hot oil
- Condenser low temp
  - e.g. + 56% COP @ -50°C
  - +43% COP @ -40°C
- Various cooling soln's
  - industrial brines etc

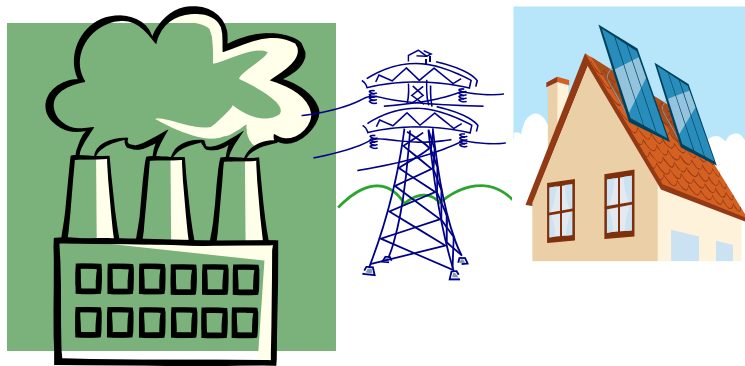
# Why Sorption Anyway

**Grid Power Conventional**

**Embedded Power is it Blue Sky ?**



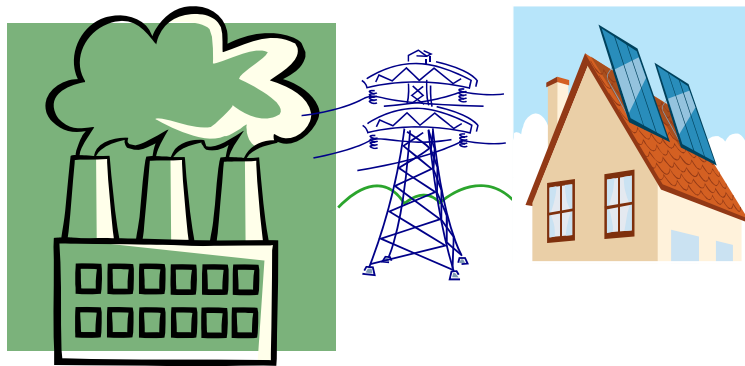
# Conventional Systems



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

**2/3 energy is lost**

# Conventional Systems



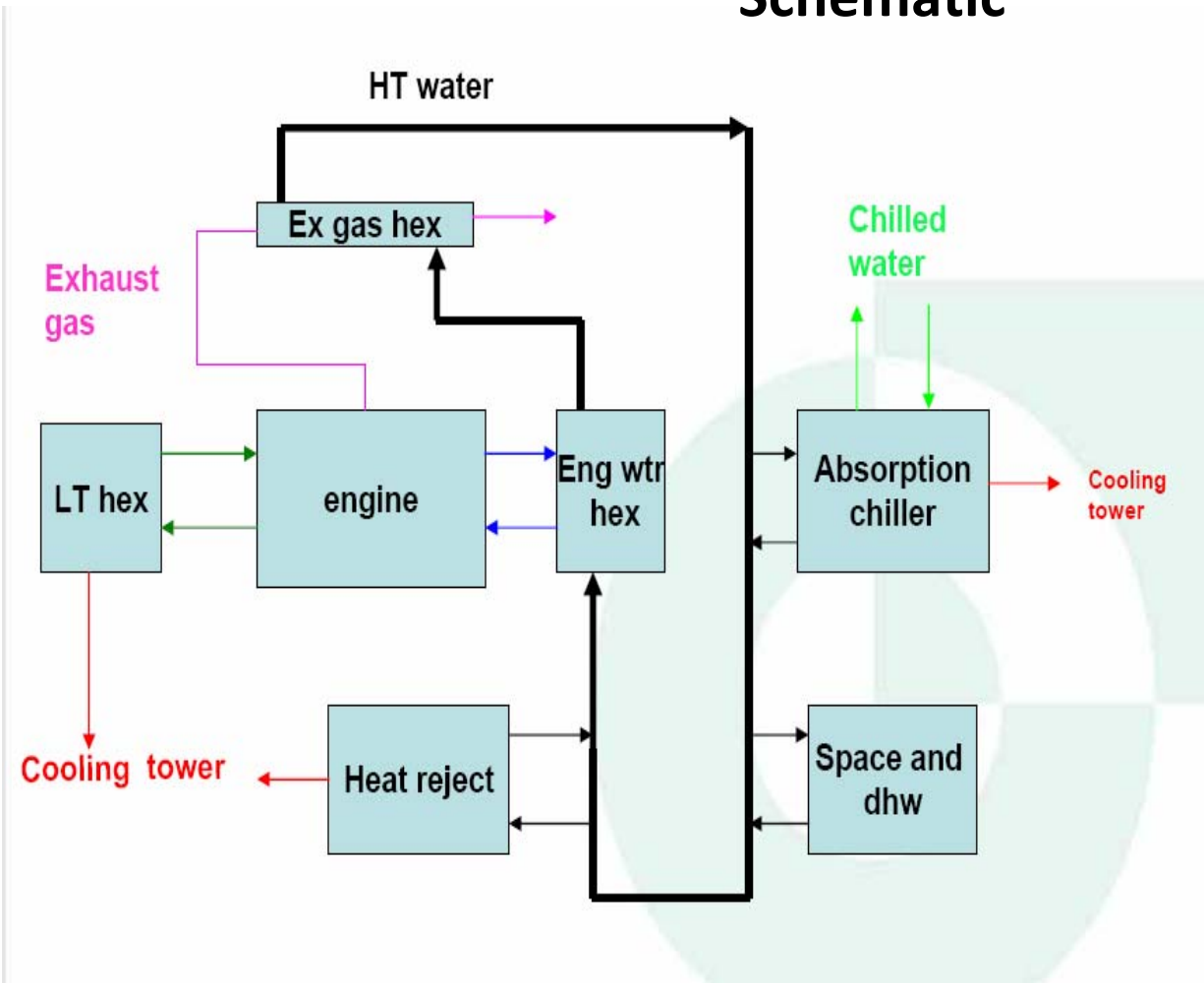
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**2/3 energy is lost**

**Energy Act - 80% reduction in energy use by 2050**

*How can we achieve it !*

# Trigeneration - Combined Heat Cooling/Refrigeration & Power Schematic

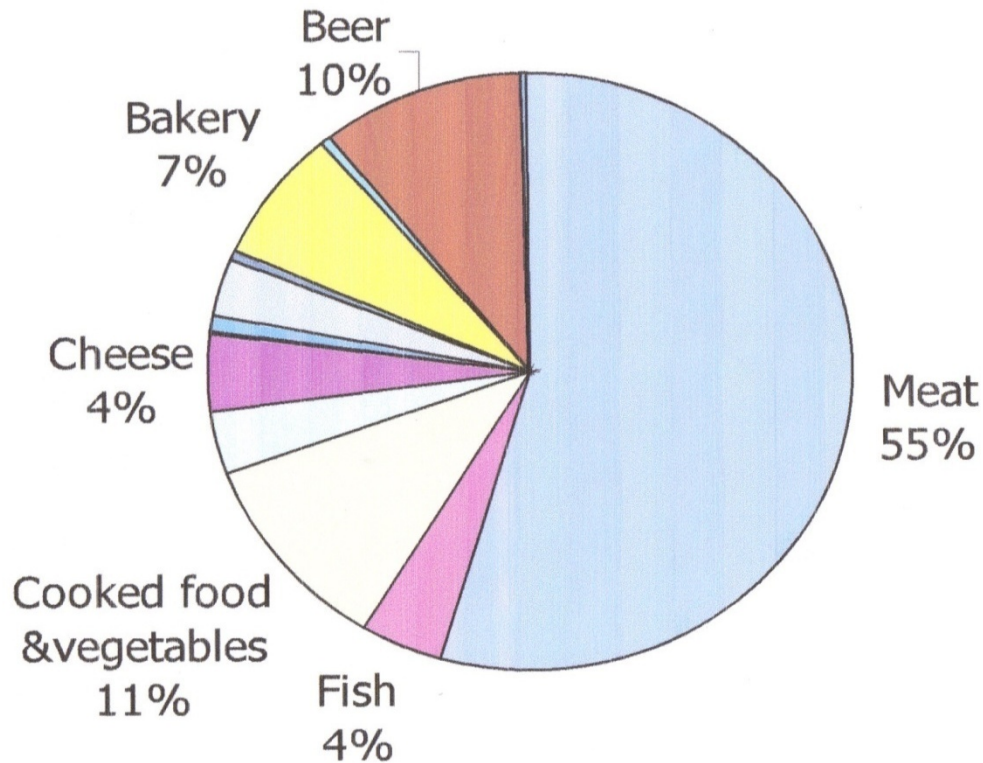


- Engine  $\eta_e = 28\%$  to  $45\%$
- Heat Recovery  $\sim 40\%$
- System  $\eta = 65\%$  to  $85\%$
- **Losses = 35% to 15%**
- Ability to use lower cost or waste fuel e.g Anaerobic Digester
- COP of AD/AB  $\sim 40\%$  to  $30\%$  conventional VCR.  $\text{NH}_3$  plant typically at COP  $0.6$  to  $0.4$
- Li/Br COP  $\sim 0.7 - 1.1$
- Silica Gel COP  $\sim 0.7$
- Low maintenance
- High Reliability
- Rapid payback on suitable applications

# Trigeneration potential by sector

Total pure trigeneration potential: **15.3 TWh<sub>el</sub>**

**UK circa 13.7% 2 TWh<sub>el</sub>**



- 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 olive oil
- Sugar
- Chokolat

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

M Whitley - Energy for Sustainable Development Ltd



# 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

# 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



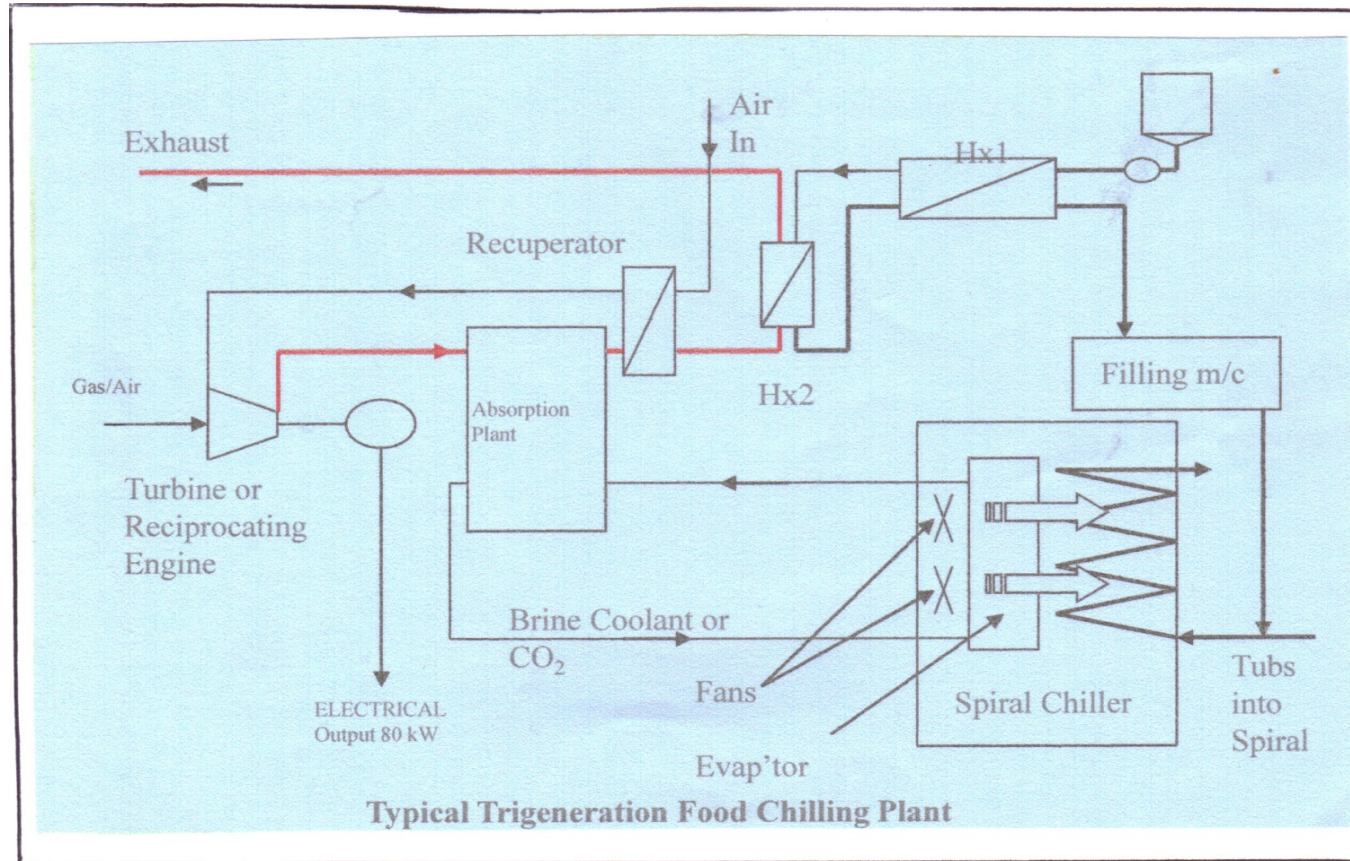
# Polygeneration Dairy Complex in Govind Dairy India with Integral Block Ice Making Plant



- 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

# Example of Relative Payback/ Cost Conventional vis CHRP

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



# Assumptions for Comparisons

Tri-gen plant producing at 80kWe

Process heating Hx2 = 71 kW

Regenerative Hx1 = 45 kW

Spiral cooling duty = 55 kW

6000 hrs p.a. production plan

## Economic Comparison of Conventional ~ Tri-generation

	<u>Conventional Plant</u>	<u>Tri-generation Plant</u>
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	

# Comparison Between Conventional and Tri-generation System

## Conventional System

- Overall Efficiency: 51 %
- Running Cost: £800 p.w.
- CO<sub>2</sub> Emissions: 12.6 t/day

## Tri-generation System

- Overall Efficiency 73 % (COP=0.35)
- Running Cost: £440 p.w
- CO<sub>2</sub> 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.

# Acknowledgements

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**The Consortium in the AFM project in addition to the above is:  
Tesco, Somerfield - Co-op, A&N Shilliday & Co Ltd, Cambridge Refrigeration Technology, Bond Industries Ltd, Bock Kaltenmaschinen GmbH, ACDP, Apex Air Conditioning Ltd, CSA, Bowman Power Group Ltd, Danfoss Ltd, George Barker & Co (Leeds Ltd) - part of the Elfi Group, Cogenco Ltd & Doug Marriott Associates**





### Who We Are

**Doug Marriott Associates Ltd** is a Team of Experts consisting of Chartered Engineers, Chartered Scientists and Environmental Practitioners specialising in Energy Management & Environmental Engineering for the Food & Allied Process Industries, Refrigeration and Logistics.

Energy Saving, Carbon Reduction and Renewable Energy is our main target activity area, working with some of the country's largest companies right down to the smallest business.

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- Integrated Power System Planning
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- 11 Power Support Infrastructure
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- Food Freezing Expertise and Solutions
- Contract Cost Reduction & Management
- Environmental Services
- Risk Planning & Reporting
- Expert Witness

**Zero - waste  
Re-use water**  
Homes-Housing-Communities

Eco-Bio process

**AMMONIA ABSORPTION REFRIGERATION PLANTS (AAR)**




Ammonia absorption refrigeration plants are used in a wide range of applications, including food processing, pharmaceuticals, and industrial refrigeration. They offer a sustainable and energy-efficient alternative to traditional vapor-compression refrigeration systems.

**Doug Marriott Associates Ltd**

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**Ammonia Water Absorption Refrigeration Typical Industrial Applications**




Ammonia water absorption refrigeration systems are ideal for industrial applications where low-temperature refrigeration is required. They are commonly used in food processing, pharmaceuticals, and industrial refrigeration.

**Doug Marriott Associates Ltd - Food Process Machinery**



Our experts provide comprehensive services for food processing machinery, including design, installation, and maintenance. We ensure your equipment operates efficiently and safely.

**AMMONIA ABSORPTION REFRIGERATION PLANTS (AAR)**



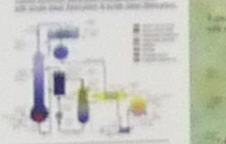
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**Advanced Waste Water Treatment**



Our advanced waste water treatment processes ensure compliance with environmental regulations while minimizing operational costs. We provide a comprehensive range of services for industrial and municipal waste water treatment.

Several brochures and documents are displayed on a table in the foreground, including one titled 'Zero-waste Re-use water' and another titled 'Advanced Waste Water Treatment'.

Doug Marriott Associates Ltd  
Exhibition Booth at Brunel University Trigeration 2010