Performance Analysis and Energy Benefits of a Commercial Scale Two-Rotor Solar Desiccant Trigeneration System in a Building

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Outline

- Project Overview
- Design considerations
- System design and components
- Operation/monitoring
- Performance
    - Domestic Hot Water Pre-Heat
    - Space Heating
    - Space Cooling
- Lessons Learnt and Summary

Hamilton TAFE NSW Project

- In April 2011, CSIRO and Air Conditioning Industries were commissioned to design and construct a combined solar cooling, heating and domestic hot water system at the TAFE NSW Hunter Institute at Hamilton in Newcastle.
- An innovative Two-Rotor Intercooled Solar Desiccant Evaporative Cooling (SDEC) system was implemented.
- Completed mid-2012, the system was to realise a net reduction in energy consumption and was integrated with the previous system components such as condensers, cooling towers, DHW Units and gas boilers.
- The installation was designed to pre-treat, in order to reduce the load and extend air conditioning for an ageing and undersized conventional system.

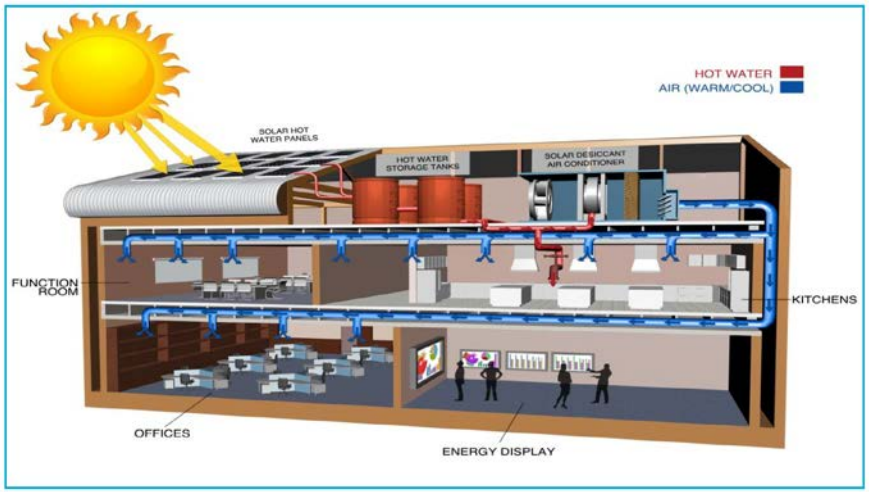
Building Layout and Design Considerations

Three main areas supplied by two TAC Units

- Teaching Kitchens (TAC Unit 7)
- Offices (TAC Unit 3)
- Campus Function Room

  (TAC Unit 3 on demand)

- Serviced area of 500m².



- Kitchen requirements made it the primary design consideration.
- Tightly controlled temperatures not needed for kitchens.
- Kitchens cannot recirculate air due to grease, combustible gases and contaminants.
- Latent heat removal of the desiccant enables good integration with conventional HVAC systems.
- Potable hot water in high demand for site for both cleaning and food preparation.
- Trigeneration system can provide for building requirements all year round.

Thermal Collection and Storage

- 400m² flat plate collectors
- Covers North-East facing roof at 18° tilt
- 79% Optical Efficiency, heat loss coefficient 3.875 W/m² (manufacturer's data)
- Chosen due to cooling and pre-heating requiring relatively low temperature up to 70°C
- Widespread, relatively inexpensive

- Two 4500L hot water storage tanks
- 4500mm (length) x 1000mm (wide) x 1350mm height with 50mm cool room panelling insulation.
- Volume representing 100kWh for 10 degree temperature increase in one hour considered adequate.
- Process water for TAC units drawn from top of tanks.
- Stratification key, however floor loading and height restrictions prevented high aspect ratio tank

Tempered Air Conditioner Units

- Two-Rotor intercooled design
- Silica gel desiccant wheels, 100mm thick, 1525mm diameter, 11 r/hr
- Desiccant cross section – 2/3 supply air side

  1/3 regeneration side
- Two rotor intercooled system enables greater dehumidification by keeping the air temperature lower on the supply side and reduces the temperatures required for regeneration.
- Altering flow paths to produce cooling or heating.

Operating Modes

Ventilation Mode

- Fans operate 7am to 10pm, Mon to Fri

Desiccant Cooling Mode

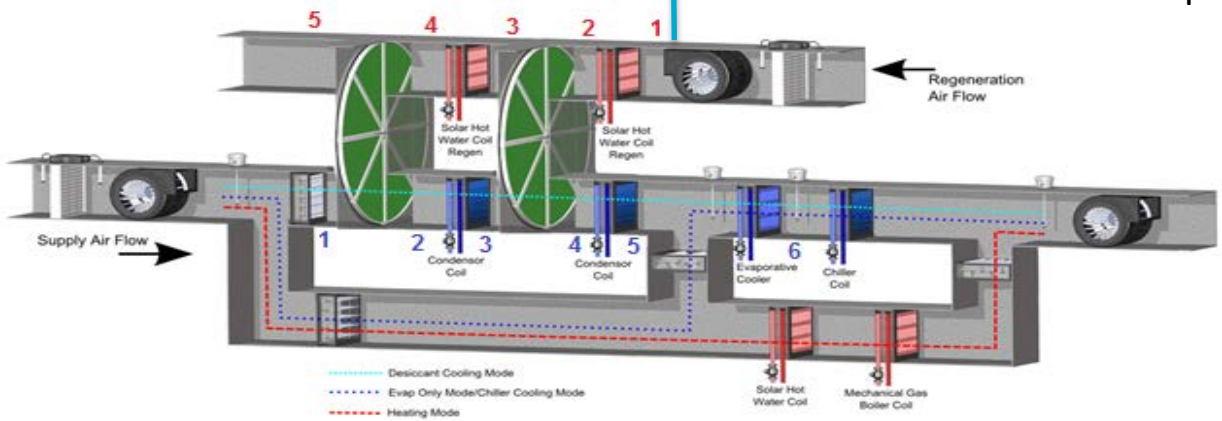
- Cooling Demand (Room above 21.5°C)
- Tank top above 70°C (operates till 60°C)
- Ambient RH above 50%
- Backup chilled cooling if fan speed reaches 100%

Evaporative Cooling Mode

- Cooling Demand (Room above 21.5°C)
- Desiccant conditions not met
- Backup chilled cooling if fan speed reaches 100%

Heating Mode

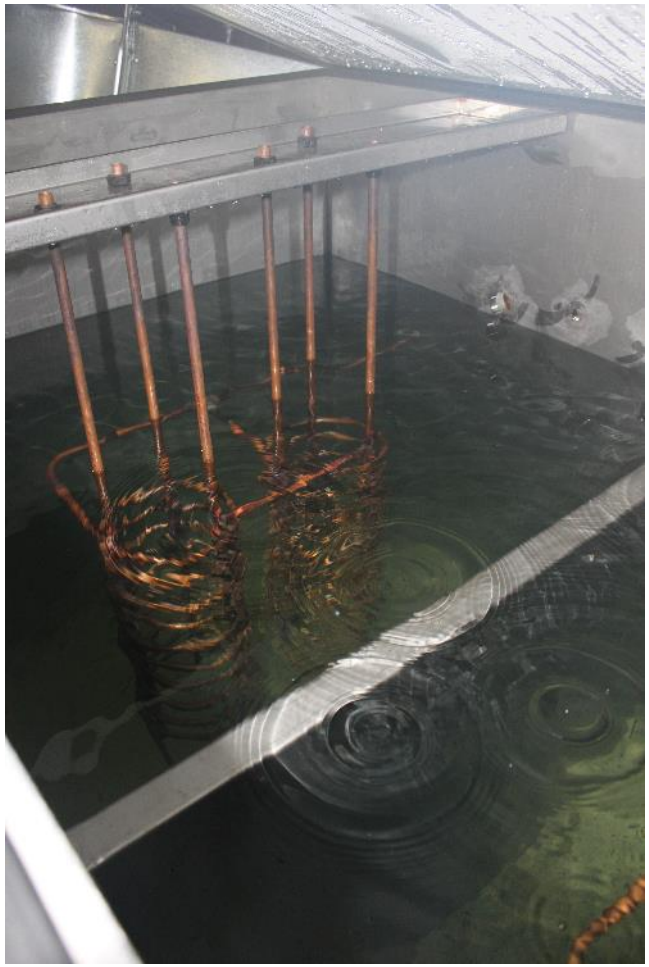
- Service room is below 18°C
- Tank top above 40°C (operates till 35°C)
- Backup gas boiler heating coil if demand reaches 100% of solar capacity



Domestic Hot Water PreHeat

- Two rings servicing east and west sections of the building.
- Six DHW units supplied by one mains gas supply.
- Solar Desiccant arrangement integrated to pre-heat the mains water prior to entering supply rings.
- Mains pre-heated from 16-23°C to 30-70°C
- Backup gas boilers heat to 70°C if needed

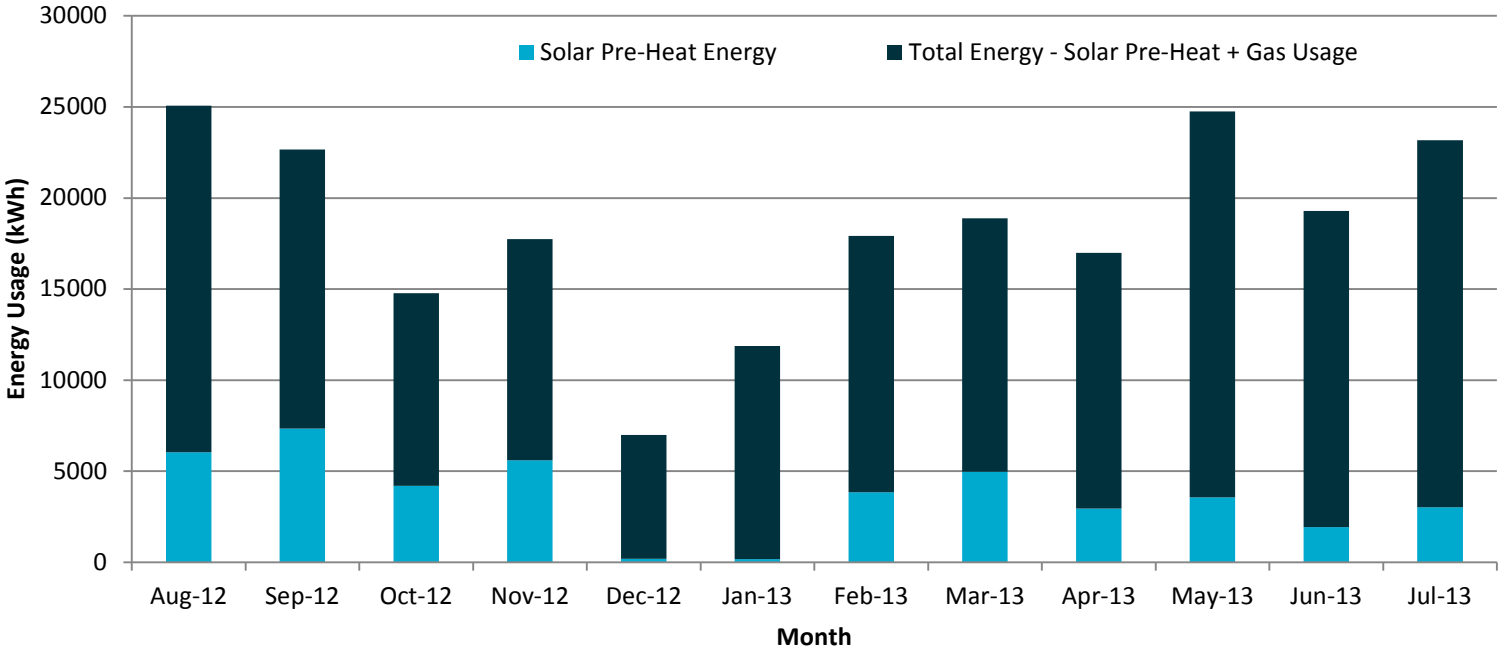
- PreHeating is enabled:
  When the tank is above 25°C
- PreHeating is bypassed:
  When the tank drops below 20°C



Building Management System

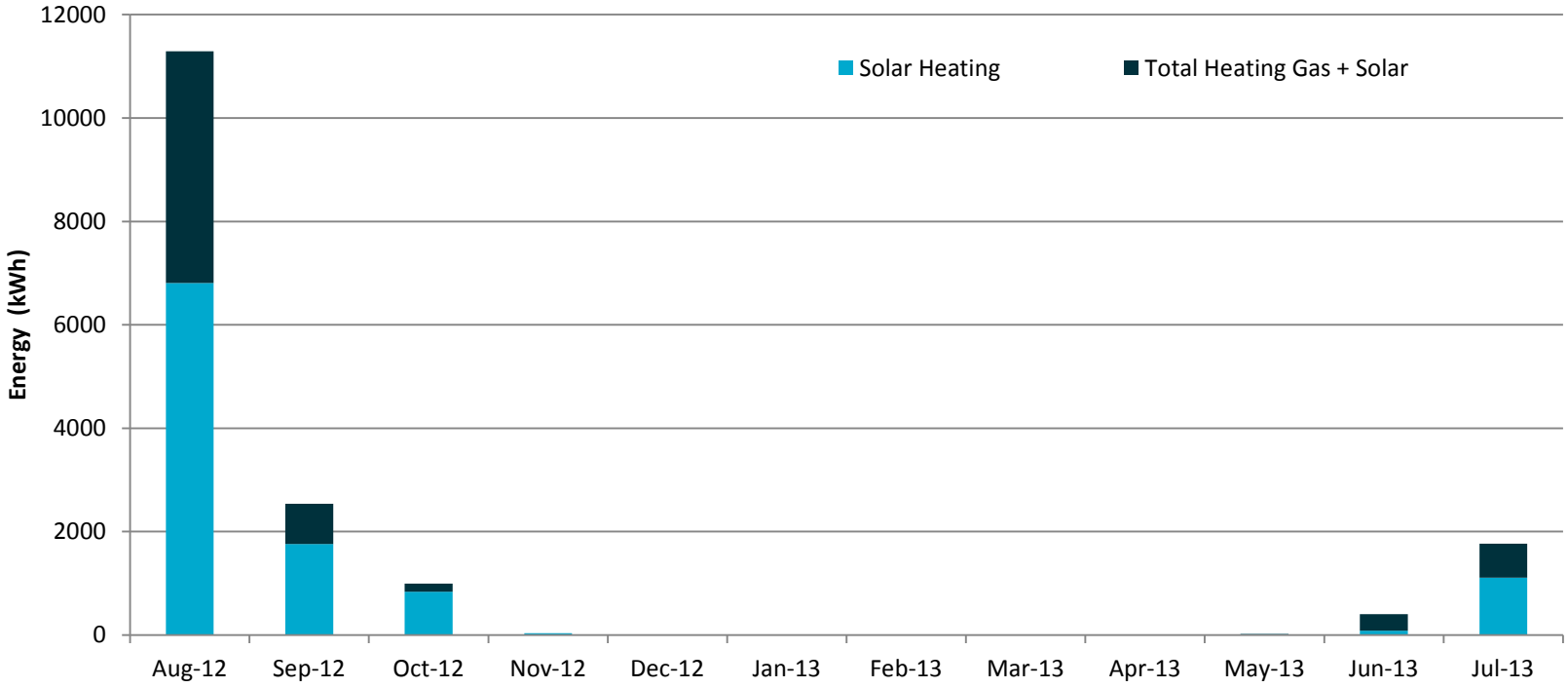
- Entire system monitored and controlled by a Building Management System (BMS).
- Data logged at 15min intervals.
- System allows user to adjust operating setpoint and deadband parameters.
- BMS monitors: Air Temperatures/RHs at key system points
  Water flow rates
  Coil inlet/outlet temperatures
  Tank temperatures
  Solar Panels temperatures
  Fan Speeds
- Logged parameters allow calculation of system performance.

Domestic Hot Water Performance



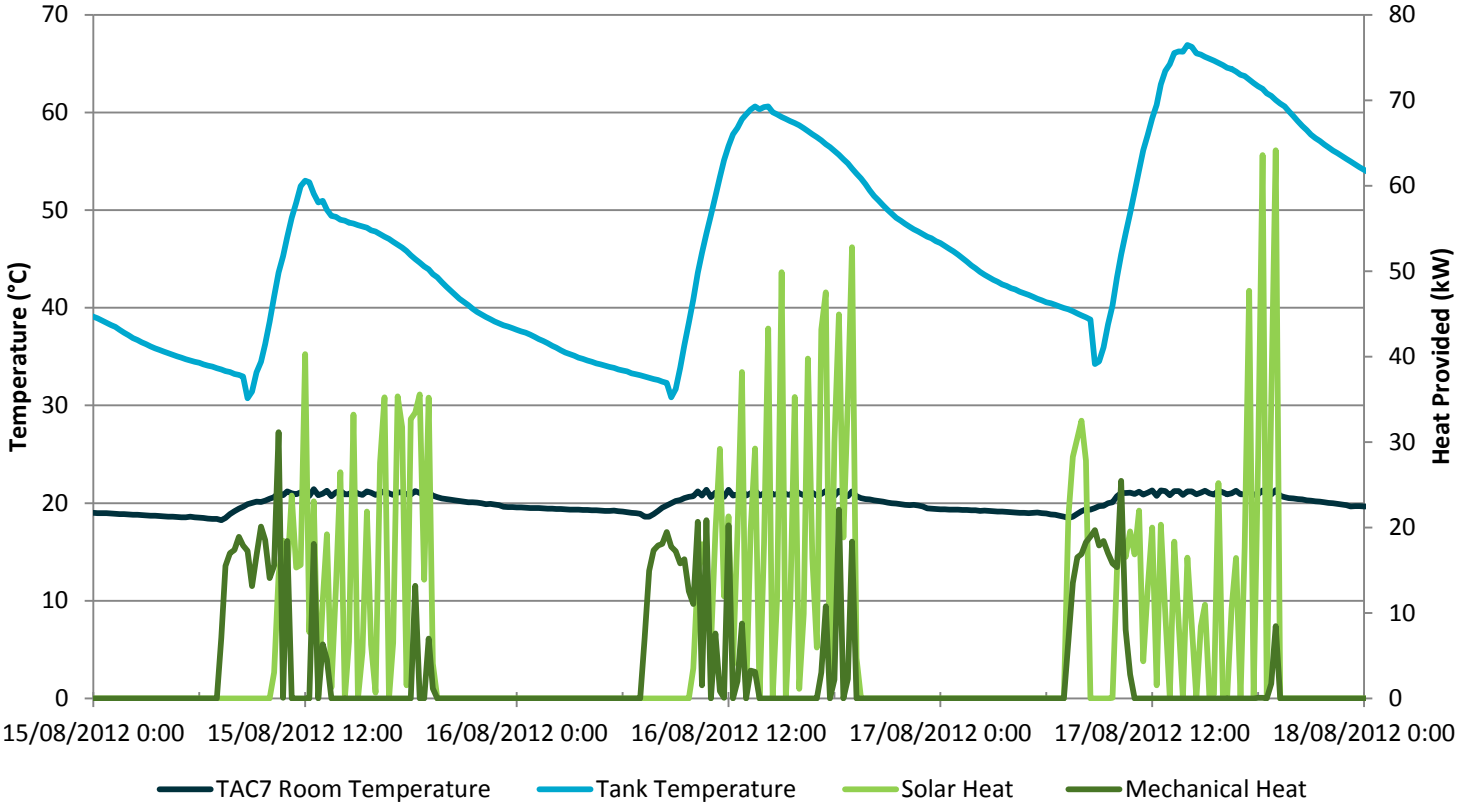
	Total PreHeat Provided (kWh)	Solar Energy (kWh)	Gas Use (kWh)	Gas Saved (m^3)	Volume of Water Used (kL)	Solar Fraction (%)
Average per day	604	121	483	13	5	20
Total Annual	220 122	43 829	176 294	4 577	1 787	20

Space Heating Performance



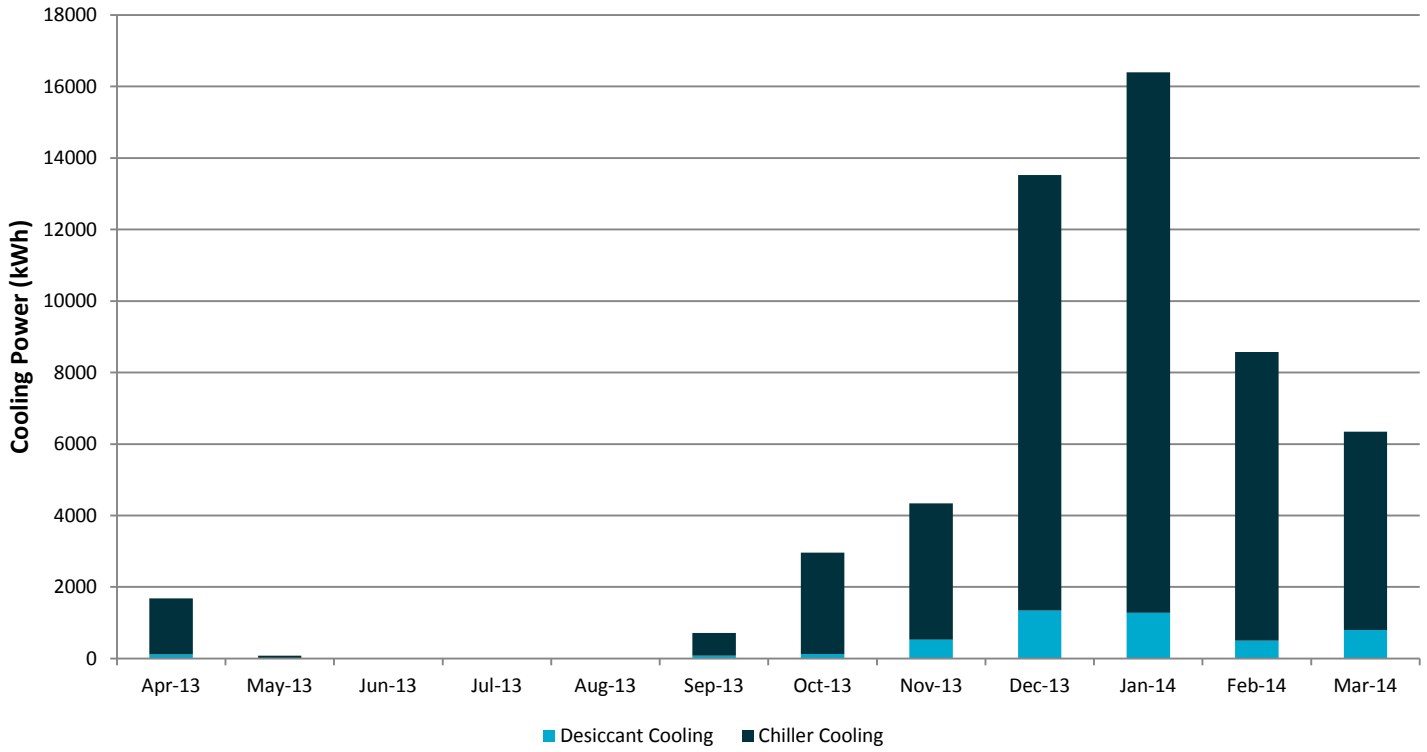
Total Heating Provided (kWh)	Solar Heating (kWh)	Boiler Heating (kWh)	Gas Saved (m^3)	Solar Fraction (%)
15 067	9 306	5 761	787	62

Space Heating Performance



Space Cooling Performance

Total Combined Cooling



Total Cooling Provided (kWh)	Solar Cooling (kWh)	Chiller Cooling (kWh)	Solar Fraction (%)
51 000	4 450	46 550	9

Space Cooling Performance

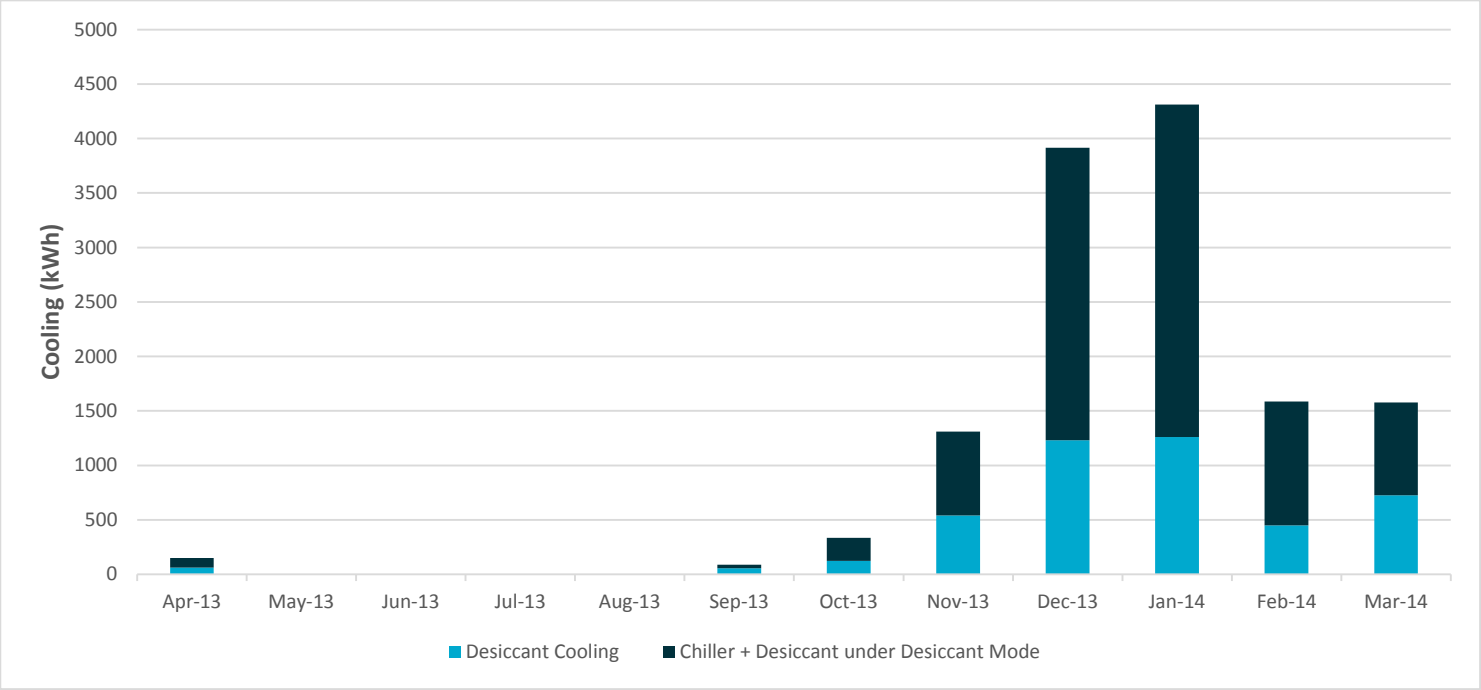
Evaporative Cooling

- From April 2013 to March 2014, 27% of cooling hours was spent in evaporative cooling mode, 815 of total 2960 hours.

- 1440 kWh of sensible cooling provided under evaporative cooling mode only.

Space Cooling Performance

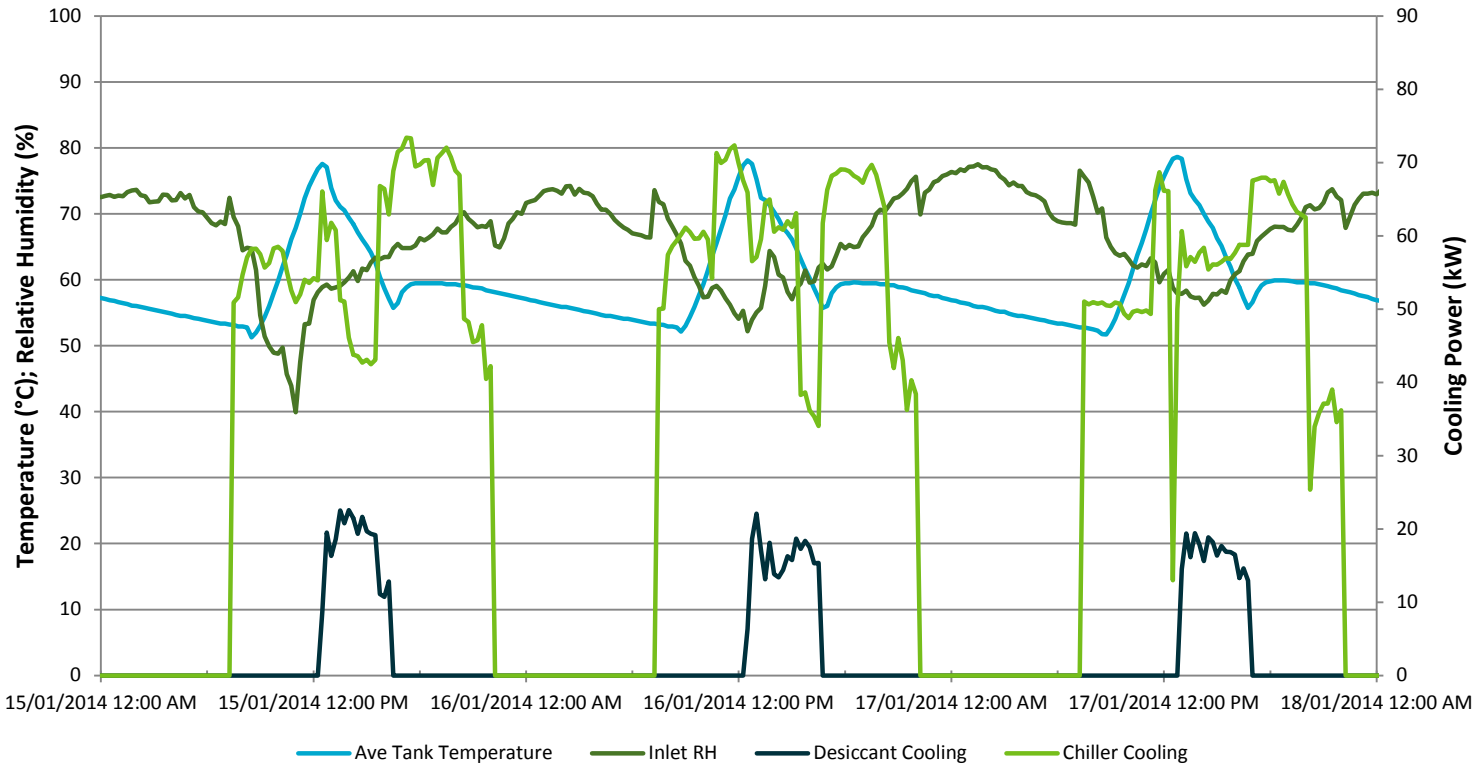
Desiccant Cooling Mode



Total Cooling Provided (kWh)	Solar Cooling (kWh)	Chiller Cooling (kWh)	Solar Fraction (%)
13 280	4 450	8 830	34

Space Cooling Performance

Desiccant Cooling Mode



Lessons Learnt

- There is still a need to share design learning and outcomes for industry to progressively identify issues and improve designs.

- The design has many best practice features:
  - Design avoids gas backup for low efficiency desiccant cooling cycle
  - Takes full advantage of solar resource during part load by doing only preheating/precooling
  - This reduces the temperatures required from solar collectors during part load operation while reducing backup fossil fuel energy sources
  - Trigeneration system enables solar usage all year round for cooling, heating and DHW.
  - Two rotor intercooled system enables greater dehumidification by keeping the air temperature lower on the supply side and reduces the temperatures required for regeneration.

Lessons Learnt

- However, further improvements could be achieved:

  - By reducing heat losses between collectors and storage tanks
  - Using an indirect evaporative cooler to provide genuine enthalpy reduction rather than swapping sensible for latent cooling
  - The benefit of the two rotor with intercoolers was less effective than thought at design stage as the temperature of the cooling water was kept higher in the demonstration system in order to maintain head pressure on the existing chillers.
  - Vertical storage tank would have been preferable for improved stratification, reduced thermal losses and possibly increasing hours of operation.

Performance Summary

- Reduction in DHW gas usage by 20%.
- Reduction in space heating gas usage by 62%.
- Evaporative cooling provided cooling requirements for 27%of time cooling was required.
- Desiccant unit for provided 9% of total cooling requirements.
- During Desiccant mode the desiccant provided for 34% of cooling.

Acknowledgements

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Thank you

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