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Solar Desiccant Cooling for Commercial Buildings

Background

Most building air conditioning systems use electrically driven compression chillers to deliver cooling. These systems run on electricity that can be expensive and also contribute to the network peak demand during summer months.

Thermal cooling can be a lower cost alternative to electrical cooling. Thermal cooling systems utilise solar thermal energy or waste heat to deliver cooling with minimal electricity usage.

The use of solar energy for cooling makes intuitive sense due to the high alignment of solar radiation availability with typical building cooling requirements. Moreover, these systems aid in the decrease of carbon emissions due to reducing fossil fuel based electricity and gas usage.

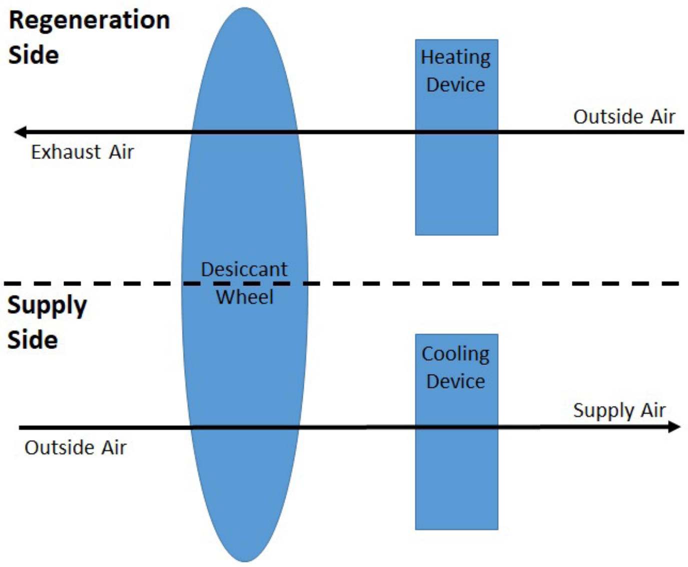
Desiccant based solar air conditioning systems fall under the category of open cycle solar cooling systems. In this technology, ambient air (mixed with recirculation air) is conditioned and delivered into the building instead of using chilled water to deliver cooling to a building in other known solar cooling systems.

Desiccant cooling system operating principle

Desiccant cooling systems use a combination of air dehumidification by a desiccant and evaporative cooling using water as the refrigerant in direct contact with air in a thermally driven cycle.

A desiccant unit consists of two distinct air streams, the supply air stream and the regeneration air stream. In this configuration, warm and humid ambient supply air is passed through a rotating desiccant wheel which dehumidifies the air stream. The supply air then passes through a direct or indirect evaporative cooler, providing a reduction in the air temperature. This air is then directly delivered into the building for cooling and ventilation. As a result of the adsorption of moisture by the desiccant wheel, the temperature of the air increases at the outlet of the desiccant wheel. A heat recovery wheel can be used to remove this heat and use this heat in pre-heating the regeneration air stream.

The final stage of the process is to regenerate the desiccant wheel. Heat is sourced from solar collectors and applied to the regeneration air stream. The higher temperature air stream passes through the desiccant wheel and removes moisture. The hot and humid regeneration air is then exhausted in order to allow the supply side of the desiccant wheel to continue a cycle of dehumidification, enabling the system to continuously provide cool air.



Configuration of simple desiccant cooling system

The thermal versatility of a solar desiccant cooling system

Heat can be sourced by solar panels and stored in thermal storage tanks which function to extend the use of solar heat in a building throughout the entire year. The heat from the storage tank can be fed to coils within the air handling unit to provide space heating. The tank can also be used to provide pre-heating to domestic hot water (DHW). Hence, a solar desiccant system typically consists of solar collectors, storage tanks, desiccant dehumidifiers and direct or indirect evaporative cooling units.

Benefits and considerations of desiccant air conditioning systems

- Simple design, low installation cost.
- Handles fresh air, suitable for high ventilation requirement applications.
- Low temperature heat requirement makes integration with space heating and domestic hot water feasible.
- Active moisture control, suitable for humid environments.
- Can be integrated with existing air conditioning systems.

Case study

TAFE solar assisted cooling system

Motivation

- Deliver cooled ventilated air to teaching kitchens.
- Reduce high gas usage due to hot water and space heating. Reduce carbon footprint, use roof space for generating solar heat.

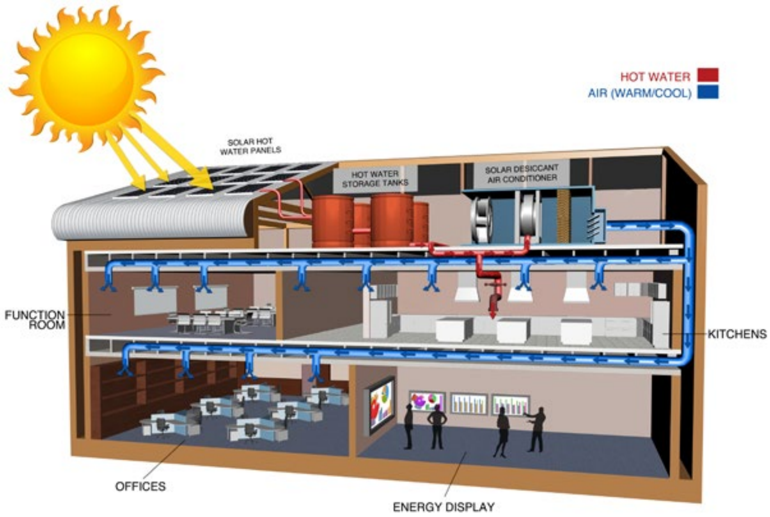
Project details

In 2012, a solar assisted desiccant air conditioning system was installed as a retrofit to an existing compression air conditioning system at TAFE Hamilton campus in Newcastle, NSW.

The primary design consideration was the high fresh airflow requirements of the site due to the working kitchens used for training and education throughout the year. Air conditioning the kitchens with conventional systems could be energy intensive due to these fresh air requirements.

Solar desiccant TAC unit and evaporative cooler

Flat plate solar panels installed on TAFE site roof



Conceptual design of the TAFE site installation

The installed desiccant system consists of solar collectors, thermal storage tanks and two tempered air conditioning units (TAC units). The solar system also delivered heat for space heating and domestic hot water (DHW) to the facility.

The desiccant system incorporated a novel two rotor intercooled design to maximise the dehumidification and use the heat available from low cost flat plate collectors. Intercooling was achieved using water-air heat exchangers with water from the site cooling towers.

The TAC units have various operation modes controlled by a Building Management System that are implemented depending on the ambient conditions, tank temperature and building load requirements.

System Specifications Summary

Year of installation	2012
Location	Hamilton, NSW ≈32.9 °S, 151.7 °E
Collector type	Glazed flat plate
Total Collector Area	≈400m²
Orientation	North-East, ≈18° tilt
Desiccant Type	Metallic silicate on inorganic substrate
Volume of Hot Water Tanks	2 x 4500L
Supply Air Flow Rate	3250 L/s (split into two TAC units)
Regen Air Flow Rates	1850 L/s (split into two TAC units)
Serviced Area	~500m²

System benefits

- Reduced chiller usage time, savings on electrical energy costs. Delivers tempered fresh air to the building.
- Replaced gas used for space heating and DHW with solar heat. Consistent energy cost savings for the site.
- Two annual cycles of operation for the system provided below.

System benefits for various modes of operation

DHW (ANNUAL PERFORMANCE)	
Total DHW Heating (kWh)	220 000
Solar Energy (kWh)	43 800
Gas Use (kWh)	176 300
Gas Saved (kWh)	44 000
Volume of Water Used (kL)	1 800
Solar Fraction (%)	20
HEATING (ANNUAL PERFORMANCE)	
Total Heating Provided (kWh)	17 000
Solar Heating (kWh)	10 600
Gas Boiler Heating (kWh)	6 400
Gas Saved (kWh)	900
Solar Fraction (%)	62
COOLING IN DESICCANT EVAPORATIVE COOLING MODE (ANNUAL PERFORMANCE)	
Total Cooling Provided (kWh)	14 000
Solar Cooling (kWh)	4 724
Chiller Cooling (kWh)	9 300
Solar Fraction (%)	34

The performance and cost numbers provided in the brochure are indicative. Actual values may vary depending upon location, type of collector etc. This work is supported by the Australian Renewable Energy Agency (ARENA).

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