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Assessment of potential energy and greenhouse gas savings in the commercial building sector by using solar energy for air-conditioning purposes

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Abstract

Australia currently faces significant increases in electricity prices. The owners and occupants of buildings are influenced by this change and alternative technologies are being investigated to reduce outgoing costs. The adoption of renewable and alternate solar technologies is gaining favour as reductions in technology component prices occur. The increase in population density and societies increasing expectation of conditioning spaces requires the continued investment in air-conditioning plant and equipment, generally at the expense of greenhouse gas emissions and high electricity consumption. This paper reviews the current potential of energy and greenhouse gas savings by using alternative solar-energy technologies for air-conditioning in commercial buildings. The economics of solar thermal and solar photovoltaic cooling systems will be discussed by calculation of the Levelised Cost of Cooling (LCOC) i.e. $/kWh of cooling. The paper will conclude the economic viability of solar thermal cooling in 2015 and provide comparison to findings based on 2011 economics to demonstrate the improving financial viability of solar-energy usage for air-conditioning. The paper further outlines constraints for adoption of solar thermal cooling in the commercial market and provides predictions on the potential greenhouse gas emissions savings that can be achieved from the adoption of alternate energy sources for air-conditioning.

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1. Introduction

Solar cooling and solar air-conditioning are generic terms for a process that uses solar energy to drive a cooling or refrigeration process. Two commercially available solar cooling technologies exist: solar thermal and solar-electric cooling.

Solar thermal cooling systems utilise heat from the sun as the main driving source for a cooling or refrigeration process. These technologies include absorption, adsorption, desiccant-evaporative, ejector and liquid sorption cooling. On average, these systems require approx. 50% less electrical energy than conventional vapour-compression systems. Solar thermal systems are available 'off-the-shelf' and are a mature technology. The technology has been proven feasible worldwide but global sales are still orders of magnitude lower than of conventional cooling/refrigeration systems.

Solar electric cooling is to combine photovoltaic panels with a vapour-compression cooling or refrigeration system and to use the electricity generated from the sun, not the heat. It is possible to use the electricity generated from photovoltaic (PV) modules directly in a vapour-compression chiller, e.g. via a direct power cable link between PV generator and chiller. However, more often these solar electric systems are used based on an annual balance, where the annual electrical energy required by the chiller is covered by the annual PV power generation. This means there are times during the year where the actual PV power is not sufficient to cover the momentary chiller power demand (hence additional grid power is being drawn by the chiller).

It is estimated that the installed base of non-residential air-conditioning systems in Australia [6]:

- Consumes 9 per cent of electricity produced in Australia, representing more than 3.6 per cent of Australia's greenhouse gas emissions.
- Creates more than 55 per cent of electrical peak demand in commercial business district (CBD) buildings.
- Consumes billions of litres of water per annum in cooling towers.
- Is part of an industry worth $7 billion per annum that employs more than 95,000 people.

Residential systems have not been investigated in this paper. Cost figures on residential solar cooling systems can be found in [1]. Economies of scale make larger units more economic and the hours of operation are usually much greater in an industrial/commercial application compared to residential. At the time of writing this paper approx. 1,200 solar thermal cooling systems have been installed globally, with the majority of those operating in Europe [2].

2. Methodology

The air-conditioning, cooling and refrigeration markets in the states of Australia differ significantly from each other. The climatic differences across Australia result in solar applications having quite variable annual outputs. The approach of this paper is to compare solar thermal versus solar electric cooling in a commercial air-conditioning application; hence a location had to be chosen where both solar resource and air-conditioning demand are of suitable magnitude. The city of Sydney was chosen for this purpose. Three air-conditioning systems have been compared:

A. Solar thermal parabolic trough collectors and a double-effect absorption chiller (STAC)
B. Photovoltaic panels and a scroll type vapour-compression chiller (PVAC)
C. Reference case: Grid-connected scroll type vapour-compression chiller (REF)

The systems are illustrated in Fig. 1 to Fig. 3.

The solar thermal system (STAC) uses parabolic trough collectors with an annual average efficiency of 40% and a peak efficiency of 58%. A chilled water storage tank of 23,000 litres is used as a buffer tank. The absorption chiller is a water-cooled double-effect chiller with an annual average COP of 1.1. The solar thermal system yield has been calculated using Meteonorm data for the climate zone of NSW [3].

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