

# **DEVELOPMENT OF A SOLAR AIRCONDITIONING AUSTRALIAN STANDARD**

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## **ABSTRACT**

Solar airconditioning is an emerging renewable energy technology that is technically proven and suitable for wide scale deployment. Unfortunately, solar airconditioning cannot compete on a level playing field with other renewable energy technologies because it is not eligible for government rebates such as those awarded to solar photovoltaic electricity or solar hot water systems. In addition, the potential complexity of solar air-conditioning systems, and the lack of a clearly defined and readily comparable method of assessing their performance under typical operating conditions, are both likely to make the process of selecting a solar air-conditioner difficult for the consumer in the future marketplace.

Both these factors point to the need for the development of a solar air-conditioning standard which can be used to both benchmark competing solar a/c products, and to provide a realistic measure of any energy savings in comparison to maintenance of the 'status quo'. No such standard exists at present. Thus, Standards Australia have supported the development of "AS5389 Solar cooling and heating systems – calculation of energy consumption", which is expected to be released as a provisional standard in the first quarter of 2013. Presently this document considers only solar desiccant based cooling and solar air heating systems, though inclusion of other technologies is expected in the future. Here an overview of the technical development of this standard is described.

## **INTRODUCTION**

In many parts of Australia, summer cooling, or indeed year round cooling in the tropics, and winter heating of residential buildings, are becoming increasingly desirable. The home office is likely to further increase this desire for residential air-conditioning. This places an ever growing demand on the electricity infrasture, which for Australia, is dominated by long distance connections servicing comparatively small populations. Peak electricity demand, driven by concurrent usage of large numbers of air-conditioners, drives expenditure on electricity infrastructure. A reduction in peak demand, without an increase in discomfort, requires air-conditioning driven by an alternative energy source.

The idea of using energy from the sun to condition indoor spaces for comfort is long established. Indeed passive systems in which wind and bouancy forces are used to induce air-flows have been used for many centuries. Active cooling using mechanical ventilation to drive air-flows is a relatively recent phenomena stemming from the industrial revolution. Active solar building air-conditioning uses energy from the sun to drive either a thermally driven chiller such as those based on absorption or adsorption processes, or an electrically driving vapour compression chiller via photovoltaic panels.

Since the 1960's, interest in thermally driven chillers has been largely tied to the fluctuations in electricity and gas prices; when heat is available at low cost over an extended time, the thermal chillers have tended to become more attractive. (Though concerns over CFC's relaxed by electrical driven chillers which arose after the 1987 Montreal Protocol also had an influence.) The steady reduction in the price of photovoltaic panels in recent times has led to renewed interest in conventional vapour compression chillers designed for use with photovoltaic panels.

Presently there a number of mature solar air-conditioning technologies which could be readily deployed in private residences across Australia. These are; i) adsorption chillers, ii) desiccant air-conditioners, iii) absorption chillers, and iv) vapour compression systems with PV panels. However while there are a handfull of these systems in operation in commercial installations (e.g. (White, et al., 2012) (Kohlenbach & Dennis, 2010)), they have made no measurable penetration into the residential air-conditioner market. This is almost entirely due to the capital cost of the solar systems, which ranges from 10 to 20 times that of comparable vapour compression system driven by mains electricity (Otanicar & Taylor, 2012). Furthermore, the environmental benefits are not apparent to potential buyers because there is no established method of estimating the savings.

Thus, whilst there is a clear need to reduce Australia's reliance on grid connected vapour compression cooling, increasingly favourable operating economics due to rising electricity prices, and increasing public interest in environmentally friendly technologies, at present there are no incentives for consumers or businesses to invest in solar air-conditioning.

### 1.1 The Australian solar hot water industry

It is natural to seek parallels between solar cooling and the development of the solar hot water industry in Australia. The latter grew out of an idea which was first demonstrated in the early 1940's, with the fundamentals published in a series of CSIRO reports made available to the public between 1954-1964 (Morse, 1988). Large scale uptake of solar hot water was greatly assisted by the Australian Government which installed solar hot water systems in 1000's of government houses in the Northern Territory. As shown in Figure 1, the national percentage of solar water heaters installed in residential buildings increased rapidly during the 1980's to 5% of all households in Australia (data from (Department of Environment, Water, Heritage and the Arts, 2008)). However, this initial success did not continue.

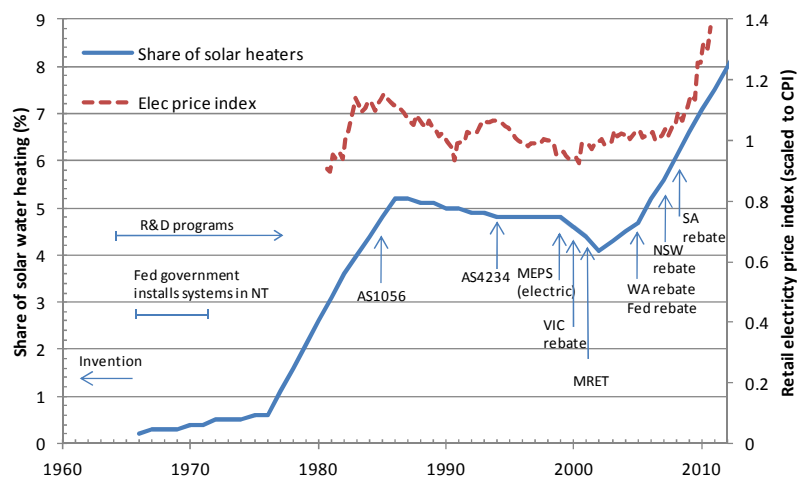


Figure 1 Uptake of solar hot water heaters in Australia with selected key dates depicted.

A combination of a decline in the real price of electricity, subsidies made by energy companies for off-peak electric resistance heaters, the high capital cost of solar systems, and misconceptions of the reliability and performance, both real and perceived, led to a steady 16 year decline in the percentage of households with solar hot water systems. During this period, a minimum allowable heat loss Australian Standard for electric storage hot water systems was developed (AS1056.1-1985 though now defined in AS4692.2 (AS/NZS 4692, 2005), as well as a method of performance testing solar hot water systems (AS/NZS 4234, 2008)). The former was enforced through national Minimum Energy Performance Standards (MEPS) which were introduced in 1999, shortly after which there was actually a reduction in the share of solar water heaters due to a resurgence of gas storage systems.

The performance test standard for solar hot water systems entered regulation via the national Minimum Renewable Energy Target (MRET) which introduced a mechanism for cash rebates for solar hot water systems based on their performance as determined using a computer modelling procedure. Only after these rebates began to be understood by customers, did the uptake of solar hot water systems begin to increase. The introduction of various state based rebates (Guthrie, 2009), sometimes in addition to the national rebate, as well as a rapidly increasing real cost of electricity (ABS, 2010), has led to a renewed rapid growth in the solar hot water industry throughout the last decade.

## 1.2 Lessons learned

What then can be learned from this 50 year history of the solar hot water industry in Australia? The presence of rebates at point of sale is an important factor in attracting customers to buy solar. Reputation must also be maintained through quality standards. Therefore we can avoid the downturn period which resulted from a combination of economics and the reputation/consumer understanding of the solar hot water systems. From an electricity price perspective the conditions are increasingly favourable for solar air-conditioning. Thus, to be viable, solar air-conditioning must compare favourably from an economic stand-point to vapour compression systems operated with mains electricity. Secondly, it is critically important, that every solar cooling system installed and purchased by the consumer, functions, not as the designers expect, but rather as the *customer* expects.

A method of reliably assessing the performance of solar cooling systems, and, of communicating this performance in a clear fashion to consumers, are both the pervue of Australian Standards. The development of the solar hot water performance rating standard AS/NZS 4234 enabled rebate systems to be introduced which paved the way for sustained growth. Hence it is clear that the development of a Solar Air-Conditioning Australia Standard, which in the future might be backed by regulation, is a key component for the development of the solar air-conditioning industry in Australia.

Standards Australia have thus supported the development of a draft solar air-conditioning performance rating standard; “AS5389 *Solar cooling and heating systems—Calculation of energy consumption*” using the solar hot water standard AS/NZS 4234 as a basis. In its present form, this standard applies only to desiccant based cooling systems and solar air heaters using a fan-coil unit. It is anticipated that the draft document will be released as a provisional standard in the first quarter of 2013 for a period of 2 years during which time it will be open to public comment. Here the basic outline of the standard is described.

## OVERVIEW OF THE STANDARD

The purpose of the standard is to provide manufacturers, regulators and Conformity Assessment Bodies with a means of evaluating the annual energy performance of solar cooling and/or heating systems as compared to a reference baseline cooling and/or heating system. The standard applies to systems delivering;

- i. Space cooling only
- ii. Space heating only
- iii. Space cooling and space heating
- iv. Space cooling and water heating
- v. Space heating and water heating
- vi. Space cooling, space heating and water heating

For systems which provide only water heating, AS4234 applies. The standard is intended to apply to systems with cooling and heating capacities typical of single household space conditioning loads, and uses the domestic hot water loads as defined in AS/NZS 4234. Presently the systems must be capable of being separated into;

- a solar collector component, evaluated in accordance with (AS/NZS 2535.1, 2007)
- a storage tank component, evaluated in accordance with (AS/NZS 4692, 2005)
- a fan-coil heat exchanger component (if providing space heating), evaluated in accordance with (I.S. EN 1397, 1999) (or else with default performance parameters)
- a desiccant airconditioner component (if providing space cooling), tested according to the modified (ASHRAE Standard 174, 2009) procedure specified in the standard.

It is anticipated that other solar cooling technologies, for example adsorption or absorption chillers, will be added in the future.

The standard uses test results for these individual components to provide parameters for mathematical models of each component. These models are then combined with a reference building model to evaluate the annual performance of the system in up to 6 climate zones (as shown in Figure 2) using the TRNSYS simulation program (version 16 or later) with extensions. All TRNSYS model extensions necessary to model the solar cooling and heating systems will be supplied with the standard.

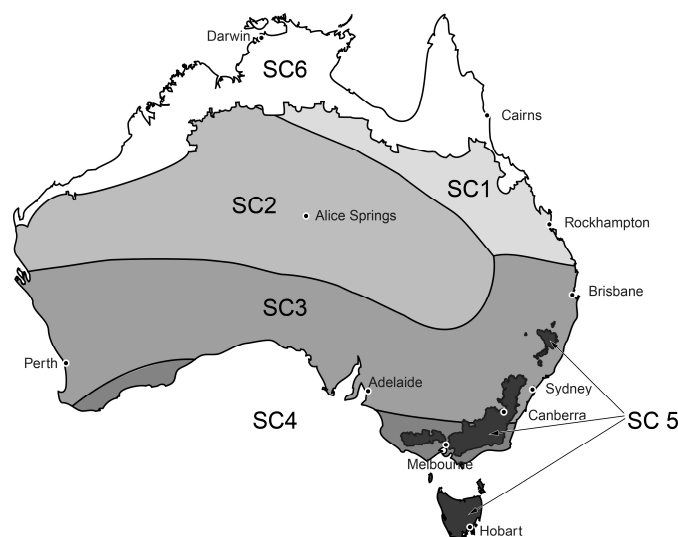


Figure 2 Climate zones for use in estimating solar air-conditioner annual performance.

## 2.1 Formulation

The energy displaced by the solar air-conditioning system is calculated by determining the amount of energy that a reference system would require to perform *exactly the same function*. A TRNSYS building model for a single story free standing house is used to quantify the space cooling and heating loads based on prescribed comfort conditions. The procedure then applies a fixed (i.e. once off) scaling of these loads throughout the annual simulation so that the equipment under test satisfies the following constraints on the comfort conditions inside the modelled building;

- i. for a cooling-only system the building size/cooling load is set so that both the dry bulb temperature in the building is below 26°C, and the dew point temperature is between 2°C and 17°C for more than 95% of the specified operating time;
- ii. for a heating-only system the building size/heating load is set so that both the dry bulb temperature in the building is above 20°C, and the dew point temperature is between 2°C and 17°C for more than 95% of the specified operating time;
- iii. for a combined cooling and heating system the cooling and heating loads are determined from the requirement that the temperatures in the building must stay between 20°C and 26°C dry bulb temperature and 2°C and 17°C dew point temperature for 95% of the specified operating time.

At each interval in time, the amount of energy that the reference system would consume to provide the same comfort conditions is calculated. This calculation takes account of the instantaneous indoor and outdoor conditions, and the part load performance of the reference air-conditioner. The reference air-conditioner part load performance is scaled according to a baseline ACOP (space cooling) or AEER (space heating for systems without gas boosting) (as defined in AS3823.2). The baseline ACOP and AEER values are taken to be 3.1 to reflect the current MEPS level for ducted vapour-compression air-conditioners (AS/NZS 3823.2, 2011). (Note: for systems which use gas boosting for space heating the reference heating system is an indirect ducted gas heater.)

For systems which do not have a backup, the reference reverse cycle air-conditioner may be used to meet the comfort criteria, for example, during periods of low solar availability. The energy use of this backup system is subtracted from the displaced energy. These systems must achieve a minimum of 50% annual energy savings in zone 3 relative to the corresponding reference system.

The building model includes internal loads representing typical occupancy and activities in residential buildings. For a single family dwelling the internal sensible and latent loads are as defined in the NatHERS software accreditation protocol (Nationwide house energy rating scheme - software accreditation protocol, 2012).

The space heating/cooling load size can be independently sized regardless of the hot water usage load size (which is defined in AS/NZS 4234). However, if the system provides hot water for domestic usage, the modelled hot water delivery must satisfy the minimum temperature delivery and solar performance limits as specified in AS/NZS 4234 for the selected hot water load size.

## 2.2 Calculating the displaced energy

The annual amount of energy that the solar cooling, heating and hot water system would save if it were used in place of the reference system in a given climate, is referred to as the 'displaced energy'. This includes both electrical and gas energy use with equal weighting. This equal weighting was chosen for simplicity since the relative cost and emissions intensity of gas and

electricity varies with location and changes over time. The displaced energy is calculated according to;

$$\text{Displaced energy} = B_r - (B_s + B_e) \quad (\text{MJ/yr}) \quad (1)$$

where

$$B_s = \text{annual supplementary electrical and gas energy use} \quad (\text{MJ/y})$$

$$B_e = \text{annual auxiliary (i.e. parasitic) electrical energy consumption} \quad (\text{MJ/y})$$

$$B_r = \text{annual purchased energy use of reference system} \quad (\text{MJ/y})$$

The annual purchased energy use of the reference system is calculated according to;

$$B_r = (B_{rc} + B_{rh} + B_{rw}) \quad (2)$$

where

$$B_{rc} = \text{annual electrical energy use of reference cooling system} \quad (\text{MJ/y})$$

$$B_{rh} = \text{annual electrical and gas energy use of reference heating system} \quad (\text{MJ/y})$$

$$B_{rw} = \text{annual electrical and gas energy use of reference water heating system} \quad (\text{MJ/y})$$

### 2.3 Calculating the specific carbon dioxide equivalent emissions

The annual specific carbon dioxide equivalent emission is defined as the grams of carbon dioxide equivalent (GHG) produced per megajoule of heat added to the building by the space conditioning system and heat added to the water by the water heating system. The specific GHG is calculated according to;

$$\text{Specific GHG} = \frac{(B_e + B_{s,elec})EF_{elec} + B_{s,gas} \times EF_{gas}}{\text{Annual load}} \quad (\text{gCO}_2\text{-e/MJ}) \quad (3)$$

where

$$EF_{elec} = \text{emission factor for electricity} \quad (\text{g/MJ})$$

$$EF_{gas} = \text{emission factor for gas} \quad (\text{g/MJ})$$

$$B_e = \text{Total annual auxiliary electrical energy consumption} \quad (\text{MJ/y})$$

$$B_{s,elec} = \text{electrical energy used to provide the annual supplementary boosting for a solar cooling and heating system} \quad (\text{MJ/y})$$

$$B_{s,gas} = \text{gas energy used to provide the annual supplementary boosting for a solar cooling and heating system} \quad (\text{MJ/y})$$

$$\text{Annual load} = \text{Total energy delivered to load in form of space heating plus total energy extracted for space cooling plus energy delivered in form of hot water during annual energy use evaluation} \quad (\text{MJ/y})$$



## DISCUSSION & CONCLUSION

The Solar Air-conditioning Standard provides the methodology that allows calculation of the Displaced Energy and the Specific GHG emissions of a particular system operating under a specific climate and given representative residential building loads. To be effective the standard must be supported by legislation. This process might involve, for example, providing an up-front rebate for the installation of solar air-conditioning systems based on their estimated displaced energy subject to a minimum specific GHG emissions performance. The exact details such as which particular installations were eligible would be determined by the legislating authority. Such a scheme would be similar to the Victorian Solar Hot Water Rebate which in part uses the annual purchased energy savings (analogous to the displaced energy defined above), as calculate using a similar performance modelling procedure (as described in AS4234), to determine the rebate.

It is important to bear in mind that like the solar hot water performance modelling standard, the purpose of the solar air conditioning standard is to determine indicative energy savings under representative conditions. The building space conditioning loads are chosen so that the savings are calculated subject to the requirement that the modelled system provide minimum levels of comfort inside the modelled building. The standard cannot and does not ensure either that a particular solar air-conditioner is sized appropriately in a given real installation, or that the installation is carried out correctly. The latter task might be the role of a separate design standard coupled with a certification procedure.

The story of the solar hot water industry in Australia has shown that while economics are a strong driver in the adoption of new technology, the true cost is not always seen by the consumer. Furthermore, a regulated industry can lead to more sustained growth, particularly when the technology is not well understood. The challenge for the solar air-conditioning industry is that the technology is arguably more complex, the benefits less apparent, and the operating performance subject to a greater number of variables. It is worthwhile noting that solar hot water systems must displace electric resistance heating, not much more efficient vapour-compression heat pumps. Yet despite these challenges, solar air-conditioning can be part of the solution. A standardised method of assessing their performance as described here will be a world's first and is a key step in the development of an Australian solar cooling industry.

## ACKNOWLEDGEMENTS

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