Convincing Aquatic Centres in Victoria to Use Solar Energy for Pool Heating

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Abstract

There are approximately 1900 aquatic centres in Australia, according to the database of Aquatics and Recreation Victoria (ARV) and 500 of these are located in Victoria. These centres are also large users of energy and water. However, a survey of a sample of these centres reveals that few use solar energy for water heating. Of 22 centres participating in an energy audit conducted for a larger research project, only one was using solar water heating to heat its outside pools. None used solar heating for its indoor pools. Five centres used solar for non-pool heated water and four centres used a solar photovoltaic system. Outside pools only represent 25% of the total number of pools in the surveyed centres. This failure to use solar energy, which is ideally suited and proven to heat water to 30°C, represents a lost opportunity for the renewable energy industry. One aquatic centre that is successfully using a solar system to heat its two indoor pools is that run by the Australian Institute of Sport in Canberra. Two solar systems, 520 m^2 and 1040 m^2, were designed and installed to give approximately 40 and 50% solar contributions for the 25 m and 50 m pools respectively. Data from these pools was used to validate the simulation program RETScreen, which was then used to predict solar contributions for a typical aquatic centre in different locations in Victoria. Solar fractions and payback periods were calculated for this hypothetical aquatic centre. Barriers to adopting solar systems in Victorian aquatic centres and the challenges to overcoming these are also discussed. It was found that RETScreen predictions of solar fraction and gas heater use were within 10% of previous modelling with a different more comprehensive program. These results verified the use of RETScreen for predicting the performance of a typically-sized aquatic centre in five different locations around Victoria. It was found that solar fractions of between 53% and 70% could be achieved for 1500 m^2 roof mounted system. Simple payback periods of between 6.5 and 5 years for these respective solar fractions were calculated. A number of possible arguments against solar systems are discussed and a possible dissemination pathway involving key industry stakeholders is also proposed.

1. Introduction

Growing populations and their desire for year-round facilities in which to exercise for their health has seen increased popularity of aquatic centres. According to the Aquatics and Recreation Victoria (ARV) database, there are 500 aquatic centres located in Victoria (ARV, 2009). A recent survey showed that there are around 110 council-owned facilities in Victoria which include a number of amenities such as indoor and outdoor pools, gymnasiums, fitness centres, saunas and spas, stadiums, childcare facilities, cafés and offices. Many councils in Victoria have recently produced aquatic strategies. These include, for example, Mitchell, Yarra Valley, Macedon, and Wyndham (Mitchell Shire, 2014; Yarra Ranges, 2010; Macedon, 2011; Wyndham 2015). Rising energy costs are becoming a concern because aquatic centres are energy-intensive compared to other commercial buildings (Rajagopalan, 2014). This concern is not just limited to Victoria. In WA, a 2015 report for the gas industry entitled "Reducing Energy Expediture in Western Australian Aquatic Centres" has canvassed various energy supply options for current and future aquatic centres (Simons Greens Energy, 2015).

These developments take place against a backdrop of the need to urgently reduce carbon emissions, particularly using renewable energy. Solar energy is ideally suited to heat water to low temperatures, and has been used for decades to heat swimming pools, particularly in Australia. Recent data, however, suggests that unglazed solar collector sales, the traditional technology used for pool heating in Australia, have declined (Mauthner et al. 2016). Survey data (Fuller and Rajagopalan 2015) suggests that there is a poor acceptance of solar energy as a heating source for modern aquatic centres due to perceived barriers such as lack of roof space, poor contribution of solar energy and high construction costs. There is a need to counter these misconceptions, particularly for environmental reasons.

This paper examines the misconception that solar energy is not able to make a significant contribution to pool heating in aquatic centres in Victoria. This is achieved by simulation using the program RETScreen. Initially, the broad capabilities of RETScreen are explained, particularly in relation to its swimming pool model. The solar system at the Australian Institute of Sport (AIS) is then briefly described, followed by previous modelling of the AIS system by the University of New South Wales, which is used to verify the RETScreen approach. The RETScreen model parameters and the results obtained are then presented. The final part of the paper discusses some possible barriers that need to be confronted to convince operators/owners of aquatic centres to embrace solar technology.

2. RETScreen

The software programme, RETScreen V4, has been used for the simulations in this paper. This version of the software has recently been replaced by RETScreen Expert. The software has been developed by the Government of Canada and is downloadable free and is available in 35 languages. This simulation programme includes the model of a swimming pool and allows a variety of scenarios to be modelled, including with and without a pool cover and the addition of a glazed or unglazed solar collector system using manufacturers' technical product data. It contains an extensive climate database covering 6500 ground stations around the world.

The swimming pool model in RETScreen offers the user a number of options. An indoor or outdoor pool can be selected but not a combination of both. When an outdoor pool is selected, wind attenuation and solar shading may be defined to define the particular location. Indoor pools are assumed to have a relative humidity of 60%, indoor air speed of 0.1 ms^{-1} and normal pool activity. The area of the pool water surface is entered by the user, from 20 m^2 to 1000 m^2 or more. The hours of pool cover use per day can be specified, providing a useful way to assess the impact of this conservation strategy. The desired minimum pool temperature set point is defined. The percentage of pool water that is renewed each week is set by the user. It includes water lost by swimmers exiting the pool, backwash and for hygiene reasons. It is suggested that the value should be between 5% and 10% with the lower value representative of a low activity pool, such as a home system, while the higher value is for public pools with high activity. Higher values for therapeutic pools may be set.

RETScreen compares a ‘base case’ i.e. a pool in its current mode with a proposed case in which the effects of changes are investigated. This might include use of a cover, changes in pool water temperature and the addition of solar heating system. When the addition of a solar system is selected, a product is selected from the data base. Fourteen commercial options are available and once selected technical data for the product is displayed. Such factors include the optical efficiency ($F_R\tau\alpha$) and the heat loss coefficient (F_RU_L). Pumping and miscellaneous losses in the system can be defined, as can the heating system efficiency, cost of fuel and fuel type, although not electricity. Since this fuel type is rarely, if ever used, it is not considered to limit the use of RETScreen. Results of the simulation are displayed in terms of annual fuel consumption for the base and proposed cases, heat supplied by the solar system and the solar fraction. In addition to energy, RETScreen enables cost, financial, risk and emission analysis to be performed with suitable inputs from the user.

3. AIS Aquatic Centre

The Australian Institute of Sport’s aquatic centre is located in Canberra. It contains two indoor heated pools, a 25 metre pool heated to 28.5°C and a 50 metre pool heated to 26°C. The centre is open from 6.15 am until approximately 10 pm to the public, as well as clubs and sporting organisations. The current solar heating system was installed in 2011, replacing a solar system which had lasted 28 years. The new system comprises 1560 m^2 of unglazed solar collectors covering the multi-tiered roof (Figure 1) and required approximately 5000 m of pipework (ALM, 2011). According to the operator, the system is shut down in the winter and shoulder months, and only operated when collector outlet temperatures above 28°C are achieved (Seal, 2016). When the solar system is shut down, natural gas is used to heat the pool water. The solar system reportedly saved about $105,000 in the first year of operation and had a simple payback of less than two years (Lovegrove, 2015). No details of the energy-saving calculation are provided.

Figure 1 AIS 1500 m^2 unglazed solar heating system (source: Lovegrove 2016)

4. Sunbather/UNSW Modelling

Modelling of the AIS aquatic centre and possible solar systems was conducted for the installer (Sunbather) by the University of New South Wales (UNSW) to determine performance and optimum collector array size. A gas heating system in combination with an unglazed solar system was modelled. The results of the simulations were kindly made available to the authors of this paper by Sunbather. The simulation results are far more comprehensive than those produced by RETScreen V4. For example, air heating requirements for the pool hall are calculated and include relative humidity levels, monthly summaries of pool temperatures, heat transfer modes and losses, as well as solar contributions. The solar collector output was calculated using a second order equation unlike RETScreen which uses a linear equation. Although fuel costs were included, no financial analysis was provided to the authors. Despite the difference in complexity of the models, at least at the user interface, key results from both sets of modelling are comparable and enable an assessment of the validity of the RETScreen calculations. These key results include energy required with and without solar system, and solar fraction (defined below).

5. Verification of RETScreen

The verification of the RETScreen results was conducted by modelling the two AIS pools using identical parameters in the software to those used in the more comprehensive Sunbather/UNSW model. These parameters included: pool water surface, absence of pool cover, percentage of pool back-flush water to waste, solar collector area, pool water temperature and boiler efficiency. Table 1 shows a comparison of the RETScreen modelling for both pools with those from the more comprehensive model. Note that solar fraction is defined as the proportion of load supplied by solar compared to load without solar. In other words, this is the difference between the system performance, before and after the addition of the solar system divided by the pre-solar gas use.

Table 1 Comparison of Sunbather and RETScreen modelling for 25 m and 50 m pools

Sunbather/UNSW 25 m			RETScreen 25 m		
Gas pre-solar (GJ)	Gas post-solar (GJ)	Solar Fraction (%)	Gas pre-solar (GJ)	Gas post-solar (GJ)	Solar Fraction (%)
3569	2120	40.6	3969	2495	37.0
Sunbather/UNSW 50 m			RETScreen 50 m		
Gas pre-solar (GJ)	Gas post-solar (GJ)	Solar Fraction (%)	Gas pre-solar (GJ)	Gas post-solar (GJ)	Solar Fraction (%)
6904	3433	50.3	6577	3306	49.7

Assuming that the Sunbather/UNSW modelling is more accurate because it is far more detailed in terms of input and outputs, it can be seen that RETScreen over-predicts gas use for the 25 m pool by 11% and under-predicts gas use for the 50 m pool by 5%. Verification of RETScreen against the performance of these two AIS pools and the use of RETScreen worldwide instils confidence in its use. Despite the differences in the predictions of the two models, the solar fraction is within 10% for both pools. These results effectively verified the RETScreen results and gave confidence that this model could be used to predict the performance of a typical aquatic centre in various locations within Victoria. Ideally, actual gas consumption figures pre- and post-installation of the AIS solar system would be used to verify the veracity of both models, but these figures were not available.

6. Modelling Aquatic Centres in Victoria

A survey of 17 aquatic pools in Victoria indicated that the average pool surface area (indoor and outdoor) was just over 1400 m^2. Pool water temperatures vary depending on the pool's use but 27°C is the normal setting for a recreational pool. Assuming that the pool is in use between 6 a.m. and 6 p.m., the pool cover will be in use for 12 hours per day. The percentage of make-up water varies depending on the pool's use, but is typically between 5% and 10% (RETScreen). Natural gas and electricity prices of $12/GJ and 15 c/kWh, taken from an industry report by Simons Greens Energy (2015), have been used in financial calculations. Using the above assumptions, a typical aquatic centre has been modelled, located in five locations around Victoria in order to assess its performance in different climatic conditions. These locations are: Melbourne, Bendigo, Ballarat, Mildura and East Sale in Gippsland. Table 2 shows the values of the parameters used to define this typical centre.

Table 2: Parameters used in RETScreen modelling a typical aquatic centre

Parameter	Value
Pool water surface area (m^2)	1400
Pool water temperature (°C)	27
Hours of pool cover use (hr)	12
% make-up of total pool water per week	7
Make-up water temperature	varies according to ambient temperature
F_R U_L coefficient ($W/m^2/°C$)	15.76
$F_R\tau\alpha$ coefficient	0.82
Collector area (m^2)	1500
Collector slope (°); north facing	5
Natural gas boiler efficiency (%)	80
Natural gas cost ($/GJ)	12
Electricity cost (c/kWh)	15
Collector cost ($\$/m^2$)	150
Fuel cost escalation rate (%/a)	5
Inflation rate (%/a)	3
Discount rate (%)	5
System lifetime (yrs)	25

7. Results and Discussion

Table 3 shows the results of the simulations for each location.

Location	Av. Daily Horizontal Radiation (MJ/m^2)	Average Ambient Temp (°C)	Annual Gas Saved (GJ)	Solar Fraction (%)	Simple Payback Period (years)
Ballarat	15.2	11.8	3148	53	6.5
Bendigo	16.6	14.0	3541	61	5.7
East Sale	15.6	13.6	3434	59	5.9
Melbourne	14.8	15.5	3480	61	5.9
Mildura	18.7	17.0	3989	70	5.0

Unsurprisingly, Mildura outperforms all other locations because of the superior solar radiation levels and higher average ambient air temperature. Ballarat, despite higher solar radiation levels than Melbourne, is the worst performing location because of the low ambient temperatures. The influence of ambient temperatures on unglazed solar collector performance can be seen in the case of Melbourne, which despite the lowest solar radiation levels of the five locations, has the second highest average ambient temperatures and consequently achieves a solar fraction equal to other locations with higher solar radiation.

8. Barriers to Implementation

The results described in the previous section indicate that significant solar fractions and energy paybacks can be achieved by installing solar systems on aquatic centres in all locations in Victoria. The evidence to date, reported in a previous paper (Rajagopalan and Fuller, 2015), indicate that there has been little uptake of active solar systems in Victoria. Survey results indicated that perceived barriers were lack of roof space, a poor payback period and an inability of solar to meet the pool heating needs of aquatic centres. The sections below discuss these issues further.

8.1. Is a high solar fraction enough?

The solar fractions that can be achieved are impressive. Meeting between 50% and 70% of any energy requirement with solar energy cannot be easily dismissed. However, pool water heating is just one of the many energy uses of a modern aquatic centre. The heating of the air consumes more energy than pool water heating (Trianti-Stourna 1998). Estimates vary of the fraction of the total energy requirements of an aquatic centre that are attributable to water heating. Trianti-Stourna (1998) estimate that pool water heating makes up 33% of the energy budget, although the Sydney Water Corporation (2011) estimate the percentage to be much higher (64%) from an audit of ten aquatic centres in Sydney. The operator of one of Melbourne’s largest aquatic centres estimated that 35% of their energy use was for pool water heating, tending to confirm the lower figure (Anon, 2015). If pool heating is only one third of the total energy requirements of an aquatic centre, then the impact of the solar fraction is much reduced i.e. energy savings from the solar system are reduced to approximately 20%, for a solar fraction of 60%. Is this enough to convince an aquatic centre to invest in solar water heating or are they likely to believe that bigger savings are possible by concentrating on other energy usage at the centre?

8.2. Are large roof-mounted solar water heating arrays practical?

Large collector arrays are required for an unglazed solar water heating system on an aquatic centre. The AIS, for example, has over 1500 m^2 of solar collector. Given that there is adequate roof area for the solar system, does a large area of water-filled tubing on the roof of their complex create negative perceptions to an operator? One advantage of an unglazed water heating panel is that it is usually in strip form, minimising connection points and thus the potential for leakage and maintenance, although this does not necessarily guarantee trouble-free operation. The AIS system, for example, has experienced tube splitting due to frost (Seal, 2016). This problem is overcome by draining the tubes when the system is not in use. Glazed solar water heater panels are limited in size (4-6 m^2) meaning that multiple interconnections are required, increasing the risk of leakage. Operators are interested in ‘set-and-forget’ systems and the prospect of roof-based maintenance will be viewed negatively. Most roofs are not designed for the addition of solar systems and glazed systems, while outperforming the unglazed units, do require roofs that are strong enough to support the solar units. Aquatic centres sometimes have roofs with high levels of glazing to create an attractive environment and this might limit the practicality of a solar system.

8.3. Can simple and complex systems be blended?

Aquatic centres are complex facilities. Apart from air handling, the water handling equipment will consist of sand and UV filters, multiple heat exchangers, tanks and pumps, boilers, heat recovery equipment and more. Their design is a world apart from a basic outdoor pool, typical of those built in many country areas in the past. Solar heating systems could be combined relatively easily into the latter with the pool itself often an integral part of the heat storage system and with simple controls. Even the control system at the AIS pool is very basic (Seal 2016). Multiple pools at different temperatures, as found in the modern aquatic centre, require different heat exchangers supplying hot water at different temperatures. While not impossible the integration of a large solar system will require complex controls and reliable control strategy. It is not yet clear whether the blending of these simple and complex technologies can be achieved and at what cost. Although the AIS solar system is a recent installation, its control system is simple and the solar heating system is turned off during the winter and shoulder months of the year, indicating that the solar fraction might be improved. However, a more complex control system is likely to increase system costs. Further detailed modelling and demonstration is therefore required to determine the viability of a solar heating system, both technically and financially.

8.4. Gas price or carbon price?

Traditionally, in the commercial market place, the driver for solar systems has been a financial one. If the cost of fuel becomes significant, alternatives will be explored. The natural gas price in Australia is rising, largely due to the price now being linked to the international market. For large gas users, the contract price is hard to determine. Wholesale prices have doubled to an average of \$6-7 per GJ, but sometimes can be as high as \$20 per GJ (ABC, 2016). The modelling for an industry report focusing on reducing energy expenditure in Western Australian aquatic centres used a figure of \$12 per GJ, and, as stated earlier, this figure has been used in this research (Simons Greens Energy, 2015). Undoubtedly, rising gas prices will continue to force operators of aquatic centres to consider energy efficiency measures and alternative forms of heating. These price rises, however, take place at a time when rising carbon emissions are now a major concern and various government strategies to reduce emissions are either in place or likely in the coming years.

The average cost of carbon abatement after the first round of the Federal Government’s ‘reverse auction’ was calculated to be approximately \$14 per tonne of CO_2 (Christoff 2015). By comparison, the annual gas savings from the AIS solar system are estimated to be 4920 GJ and therefore 7405 tonnes of CO_2 will be avoided, assuming a system lifetime of 25 years and 60.2 kg CO_2 per GJ. If the system cost is \$150 per m^2, then the abatement cost from the solar system is approximately \$32 per tonne. Although this figure is more than double the ‘auction’ price, this price is likely to rise indicating that carbon abatement may yet play a part in convincing centre operators to consider solar energy, particularly in a different legislative environment.

9. Key Stakeholder Collaboration

There are various players involved in the aquatic centre industry and different management models. Although most large aquatic centres are owned by individual councils, the management of these facilities varies. Some centres may be the responsibility of an external body such as the YMCA or Belgravia Leisure, and respectively these two organisations manage approximately 33 and 19 centres of council-owned aquatic centres in Victoria. Management may be either partial (i.e. day-to-day non-financial running) or total, including the paying of energy and water bills, but not offering engineering services. Some councils run their own facilities. Aquatics and Recreation Victoria (ARV) is the peak body for the industry and sees its role to provide “strategic services, the delivery of industry seminars and development of innovative projects and programs.” As such, it will play a key role in promoting solar energy to the aquatics industry.

Once further research has established the viability of integrating a solar system into a modern aquatic centre, a possible technology transfer pathway is to organize an industry seminar through the ARV and to promote this event through the main management players, the

YMCA and Belgravia Leisure, as well as through individual councils. Solar swimming pool system manufacturers would also be invited. Depending on the level of interest, a commitment will be sought from the various players to integrate a solar heating system into an existing aquatic centre. Funding contributions will also have to be secured from these players, as well as seeking external (i.e. state or federal government) funding. The demonstration will be used as the focus of future seminars to spread the technology.

10. Conclusions

Low temperature water heating is the natural province of solar thermal systems and aquatic centres should use this technology to reduce their energy consumption and financial costs. It is also vital that carbon emissions are reduced in every sector of human activity. Over the lifetime of a solar system at a typical aquatic centre it was found that over 5000 tonnes of emissions could be avoided. Previous research work by Rajagopalan and Fuller (2015) has shown that a government incentive scheme failed to provide sufficient impetus to create a sustained uptake of solar systems for pool heating. This scheme, however, occurred over 30 years ago before the growth in the modern aquatic centre and certainly before the task of reducing carbon emissions was an urgent priority. The task of persuading aquatic centres to adopt solar energy for pool heating therefore needs to be revisited. This paper has demonstrated that significant solar fractions and reasonable simple payback periods can be achieved by a solar system in a typical aquatic centre located in five locations across Victoria. Some of the concerns and perceived barriers to solar heating are explored and a technology transfer pathway involving the key stakeholders is proposed.

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