SOLAR WATER HEATERS - MARKETS AND NEW DEVELOPMENTS

Graham L. Morrison
School of Mechanical and Manufacturing Engineering
The University of New South Wales
Sydney, Australia 2052

ABSTRACT

The status and scale of the International and Australian solar water heater markets are outlined. Factors effecting adoption of solar water heaters are presented with a discussion of the impact of market promotion programs. A range of new products being developed in Australia and as part of an International Energy Agency program are described.

INTRODUCTION

The market for active solar thermal energy products in Australia includes domestic solar water heating, swimming pool heating and limited commercial and industrial heating applications. The solar water heater industry is well established with companies exporting a significant share of their production. There have been few large applications in industry or commercial buildings. Although interest in the application of solar energy for drying agricultural products and heating large aquaculture systems is high there are no companies specialising in the this area. Active solar space heating systems are seldom used since passive building design can satisfy most domestic heating requirements.

Currently solar water heaters are installed in 350,000 to 400,000 households. The annual solar water heater production dropped to 27,000 in 1992 however, production has steadily increased over the past four years. Cumulative production of solar water heaters over the last 25 years in Australia is approximately 600,000 systems with a cumulative glazed solar collector production of more than 2,500,000 m^2. The mid-day power output of the systems installed in Australia is more than 800 MW and the annual energy saving is more than 1000 GWhr. Adoption of solar water heaters in different states ranges from 40 to 50% in the Northern Territory to only 3 to 4 % in the eastern states.

Solar pool heating systems are estimated to be installed in more than 50% of new domestic swimming pools and it is estimated that 20% of existing domestic swimming pools use active solar heating. This would correspond to an installed absorber area of more than 1 million m^2. Detailed statistics on solar pool heating installations are not available as most of these systems are constructed on site.

SOLAR WATER HEATER CONFIGURATIONS USED IN AUSTRALIA

The most common solar water heater in Australia is a closed loop thermosyphon system with a mantle heat exchanger around a horizontal storage tank. As there are few areas with major freezing problems many solar water heaters use direct circulation between the tank and collector with freeze protection provided by drain valves or an electric heater in the collector. Auxiliary boosting of solar water heaters is generally integrated into the solar tank, two tank systems are not commonly used. Recently a number of manufacturers have developed in-tank gas boosting for solar water heaters. The development of single tank gas boosted systems was driven by pressure to market ultra low pollution water heaters, however these systems are very expensive and have not achieved a significant market share. In 1995 there were nine manufactures of solar water heaters. Two of these manufacturers also produce integral collector-tank systems however, these systems are not sold in Australia.

Thermosyphon systems: The majority of domestic solar water heaters manufactured in Australia are thermosyphon systems based on externally mounted horizontal tanks. The collector-tank configurations used include:

- thermosyphon flat plate collectors with direct connection to a horizontal tank or connection through a heat exchanger for freeze protection.
- thermosyphon evacuated tubular collectors with direct connection to a horizontal tank.
- heat pipe energy transfer from parabolic trough concentrating collectors with the heat pipe condenser inserted directly into the base of a horizontal water tank.

Integral tank-collector systems : Integral tank-collector systems are made by a number of manufacturers, the systems include

- one piece plastic moulded systems
- integral tank-collector systems with an enamelled steel pillow shaped tank.

These systems and the production facilities for the plastic system are exported in substantial numbers however, there are few sales of such systems in the local market. The main problem with this system concept for the local market is that they are only a pre-heater and hence must be connected in series with a conventional water heater.

Pumped circulation systems : Until the mid 1980's pumped circulation systems held a significant share of the market. These systems were primarily based around conventional enamelled steel hot water tanks. The market share of such systems has dropped significantly due to the lower cost of externally mounted horizontal tank systems. However the market share of pumped systems has started to increase in recent years, possibly due to the acceptance of SDHW systems by consumers who do not want the visual impact of an external roof mounted tank.

Heat pumps - solar boosted : Two types of solar boosted heat pump water heaters are manufactured in Australia. One type uses a roll-bond construction unglazed collector as the evaporator which is fully exposed to the sun, the condenser is a wrap-around heat exchanger on the tank. To reduce the cost of connecting refrigerant lines to the evaporator on the roof a compact model has been developed with the evaporator wrapped around the outside of the tank. This configuration can also provide solar boosting if it is installed outdoors against a north facing wall. The advantage of the

compact system is that all the refrigerant connections are made in the factory. Due to the low power demand of the compressor the site installation costs of these systems are low as they can be powered from a standard power point. The tanks used in Australia are enamelled steel tanks with a wrap-around tubular heat exchanger, in New Zealand a low pressure copper tank is used with a wrap-around heat exchanger.

Commercial Building/Industry applications : Solar water heating for small commercial applications such as restaurants and commercial laundries is often provided by integrating a large number of domestic thermosyphon solar water heaters. This is not a desirable design in terms of thermal efficiency however, it is often the most economic approach. There are many commercial and industrial solar water heating systems in the range of 50 to 100 m^2 collector area. The largest solar installation in Australia is in a hotel complex at Yulara. This system uses 4000 m^2 of flat plate collectors to supply domestic hot water and winter space heating for this remote tourist centre. The space heating system is based on a combination of water heating solar collectors, an ice storage tank, a series of large hot water tanks and two 400 kWe heat pumps. The market for solar heating systems in the commercial - industrial area has not developed due to the very low price of natural gas for large energy users.

Solar swimming pool heating : Application of active solar heating for domestic and public swimming pools is widespread. The most common form of solar pool heating is a plastic strip incorporating 4 to 6 parallel tubes mounted directly on a roof. The strip absorbers are spaced one or more widths apart in order to gain a heating effect from the roof. Glazed flat plate collectors are used for heating some indoor pools. The area of the roof covered by the collector is typically 50% to 100% of the pool surface area. A solar boosted heat pump powered by a gas engine was tested successfully on two large pool heating systems however, the heat pump swimming pool heating market has now shifted to air source systems as the standard product configuration.

MARKET SCALE

The solar water heater market in many parts of the world was recently surveyed by IT Power for the CEC Directorate General for Energy [1] and the IEA CADDET Renewable Energy review [2] in 1994-1995. The findings of these studies are summarised in table 1. Comparison of markets in different countries is difficult due to the wide range of designs used for different climates and demand requirements. In Scandinavia and Germany a solar heating system will typically be a combined water heating and space heating system with 10 to 20 m^2 collector area. In Japan the number of solar domestic water heating systems being installed is large however most installations are simple integral preheating systems. The market in Israel is large due to the favourable climate and due to regulations requiring installation of solar water heaters.

The largest exporters of solar water heaters are Australia, Greece and the USA. The majority of exports from Greece are to Cyprus and the near Mediterranean area, the majority of US exports are to the Carribean area. Australian exports approximately 50% of local production to most areas of the world that do not have hard freeze conditions. Australian products are renowned for high material and construction quality and good performance. High quality products were developed by Australian manufacturers

initially in response to the extreme conditions of climate and water quality that are experienced in the local market. Although Australian products have gained acceptance in most of the growing markets there is now a need to develop more focussed products for specific markets, this is particularly the case in the rapidly growing European market.

Table 1
Solar water heater markets

Country	Number of SDHW systems in use.	Number of SDHW systems produced in 1994	Total glazed collector area installed m^2	Glazed solar collector area produced in 1994 m^2
Australia	350,000*	30,000*	1,400,000*	140,000*
Austria			400,000+	100,000o
Cyprus			600,000+	30,000+
Denmark	14,000*	2,000*		8,000 o
France				18,000+
Germany				40,000+
Greece				170,000+
Israel			2,400,000+	300,000+
Japan	3,800,000*	150,000*	7,000,000*	?
Korea				50,000+
Netherlands	10,000*	3,000*		9,000 o
New Zealand	10,000*	750*		3,000*
Norway	100*	20*		200 o
Portugal				13,000+
Spain				12,000+
Sweden		2,000*		20,000 o
Switzerland	9,300*	1,300*		6,000 o
UK	45,000*	1,821*		7200 o
USA	1,200,000*		4,000,000*	70,000*

* CADDET survey, + CEC survey, o Estimated,

MARKET DEVELOPMENT

A problem highlighted by a recent consumer study [3] was the difficulty obtaining independent information on solar products. Potential customers require information from an authoritative source in order to assess what is still seen by many as an innovative technology and to reduce the perceived risk of purchase. In general consumers are more receptive to energy efficiency information provided by energy utilities rather than special energy information centres. The consumer survey found that potential purchasers had a preference for energy related information presented in a readily digestible form, such as an energy rating label. At present the introduction of an integrated water heater energy

rating label covering all forms of water heaters is being opposed by both the gas and electric industries.
Information on solar products is available from some state government energy information centres but these centres are generally poorly funded and are limited to responding to individual inquires (NSW has recently closed its Energy Information office). A survey [4] of consumers has shown that the primary sources of information used by potential purchasers assessing solar water heaters were newspapers 28%, television 29%, previous purchasers 27% and government bodies 2%. This survey also indicated "the sources of information consumers would choose to use differ markedly from the sources that have been used. In particular the consumer expects the government to play a much more active role in giving out information". The Department of Primary Industries and Energy distributed a substantial booklet on domestic energy conservation and renewable energy products to all households in 1990 and some electricity utilities have included pamphlets on solar water heating with quarterly bills however, often with notices of discount or "cash back" promotions for conventional off-peak water heaters. The main source of information that consumers said they would like to have is "information from satisfied purchasers" [4]. Clearly distributors of solar products must ensure that each purchaser is happy with the product - perhaps by an early maintenance visit. Most owners of solar water heaters in Australia are highly satisfied with the operation of their systems and thus could have a significant influence on the future adoption of solar water heaters. A non-commercial document on the relative economics of solar and conventional gas and electric water heaters, published by the Solar Energy Industries Association, would be a useful document to aid satisfied owners in their discussions with potential adopters.

Public perception : "Consumers are generally not well informed as to how solar water heaters work. Marketers of solar water heaters have been unable to communicate the fact that their product is an integrated device" [5]. The media message regarding solar is very confusing, many consumers do not understand the difference between solar thermal collectors and photovoltaic panels. The Australian media has reported extensively on the development and use of photovoltaic systems for optical fibre communication links and public telephones in small remote towns, however many consumers have been left with the impression that this is the technology they can expect to see in solar water heaters in the future.

Renewable Energy Market Promotion : Solar domestic water heaters are economically viable in the northern latitudes, the west coast area and in all inland areas. These areas have good solar conditions and high energy cost due to small electricity grids and the lack of natural gas distribution systems. However in many locations the cost of electricity is heavily subsidised. In the east coast cities the economics of solar water heaters are marginal due to the artificially low cost of off-peak electricity.

Purchasers of solar heating equipment are confronted with significantly higher capital costs than required if they chose to use a conventional water heater and purchase energy from the utilities. A purchasing decision is influenced not only by economic rate of return but also availability of funds. Consumers who do not have the cash to finance the up front purchase renewable energy products now have the option of borrowing through the EnergyCard scheme at the lowest available interest rate (house mortgage interest rate). Federal government support was provided to establish the EnergyCard scheme

however the scheme is now operating as a normal bank loan but with a lower loan threshold for the lowest interest rate. This scheme has been very successful in promoting solar water heaters in the replacement market where consumers are making urgent decisions about replacing a failed conventional hot water system. Prior to the EnergyCard scheme the penetration of solar water heaters into the urgent replacement market was small, now a consumer can be offered a solar replacement for a failed conventional product at essentially the same up front cost. The maintenance and improvement of this type of financing scheme will be an essential element in future promotion of the renewable energy market.

Direct subsidy of the purchase of conventional water heaters has been an essential feature of past competition between gas and electric utilities. A solar subsidy program is being used in Queensland to develop an energy conservation and greenhouse gas abatement program. This scheme has been very successful as it was coupled with a discounted price negotiated with participating suppliers. A subsidy scheme cannot be a long term market promotion tool (unless the cost benefit of greenhouse gas abatement is included) however, a subsidised interest rate with a revolving capital fund would be a possible way of reducing the initial cost barrier. Under such a funding program the capital would be repaid as part of the utility bill with the benefit to the consumer being an immediate small reduction in utility charges. Rental of conventional water heaters through the utility with no capital input by the consumer has been the practice in Canada in the Ontario Hydro Utility area for many years. This scheme is now being extended to include for solar water heaters [6].

Certification : The success of any renewable promotion program is contingent upon the availability of reliable products and a process to assess all products covered by the program. Certification of solar collectors and domestic water heaters is managed by Standards Australia. There are three performance rating standards and one design and construction standard for solar water heaters.

AS2813 - Method of test for thermal performance - simulator method
AS2984 - Method of test for thermal performance - outdoor test method
AS4234 - Solar water heaters and heat pump - calculation of energy consumption
AS2712 - Solar water heaters - design and construction

The design and construction standard AS2712 specifies material quality and operational safety requirements for tanks and solar collectors. The simulator and outdoor test standards AS2813 and AS2984 treat the solar water heater as a black box and do not require prior knowledge of the performance of the components of the system however, the experimental procedures are not as flexible as the simulation load cycle standard AS4234. Australian standard AS4234 is a performance rating procedure based on a combination of component tests and a computer simulation model. The procedure is applicable to solar water heaters with integral boosting, preheating systems and to solar boosted heat pump water heaters. The procedure defines a means of evaluating the annual task performance using a short time step mathematical model of the system and hourly environmental data for the area of interest.

There are a range of material and operational test standards for solar thermal collectors and systems however, there are no performance targets required for certification. To ensure consumer satisfaction with a promotion or subsidy program all products should be required to meet a verified minimum performance target before they can be included in the program.

TECHNICAL DEVELOPMENTS

There are a range of developments currently under way to reduce the cost and improve the performance of SDHW systems. Development of new product configurations other than the standard external tank thermosyphon systems could open new opportunities in the expanding overseas markets.

Seasonally biased collectors : From the mid to southern latitudes of Australia a major operational problem with domestic solar water heaters is over heating in summer and insufficient capacity in winter. The summer over temperature problem is due to the practice of mounting collectors flush with low inclination roofs. The over temperature problem can be easily overcome by using a valve to dump water however most water supply authorities will not allow water dumping as a standard operational feature. There is an apparent conflict between restrictions on water use in summer and a steaming and bubbling solar water heater tank on the roof. Manufacturers go to considerable trouble to incorporate over temperature control without excessive water dumping, this requires considerable ingenuity in thermosyphon systems.

An alternative approach to over temperature control and improved winter performance is to use a collector design that can be mounted on a standard roof pitch and yet give a winter biased performance. Such a collector was originally developed for a solar cooking system and then adapted to a solar water heating application. The original design employed a series of low profile reflectors in the collector that give a winter bias to the system performance. The first product evolving from this work is a flat plate collector with a near vertical reflector mounted above the absorber panel. The reflector shades the collector slightly in summer (depending on the roof pitch) but significantly improves the winter performance. A field trail of 50 systems incorporating such a reflector booster is currently in progress around Australia. A fully integrated reflector absorber design is also being developed.

Plastic tanks : A low cost plastic tank with a steel support band has been developed and commercialised. These tanks are corrosion resistant and are projected to be much cheaper than metal tanks. A local company commenced production of a low cost solar water heater incorporating this innovative tank configuration however, the company was recently taken over and the product is now being developed for other applications.

Heat pumps - air source : The heat pump market has recently expanded to include three air source heat pump products for domestic water heating. These systems were first used in Australia in the 1970s but were displaced by the solar boosted configuration. The new air source systems are primarily directed at markets in humid regions where the latent heat input from condensation on the coil gives excellent performance. One of these systems is designed as an add-on unit to be fitted to a conventional hot water tank the other configurations require specially configured tanks with refrigerant to water heat exchangers.

Pumped circulation systems : During the last ten years most Australian manufacturers have stopped producing pumped circulation systems while other countries have been introducing innovative pumped circulation system designs based on the low flow

concept. A significant contribution to this development was an International Energy Agency program to develop and test a range of new system configurations. Australia did not participate in this IEA program hence Australian manufacturers have missed out on the chance to lead the commercialisation of these new products. The eight countries that participated in the IEA program each developed a system configuration that was considered the "Dream System" for the market in each country. Some of the "Dream Systems" have be so successful that they have reached commercial production before the IEA report has been published. The concepts incorporated in the "Dream Systems" include

- Low flow rate working fluid circulation in the collector
- Integration of supply and return liquid lines and sensor leads in one flexible bundle (figure1).
- Efficient natural circulation heat exchangers to remove the need for two pumps in freeze protected systems.

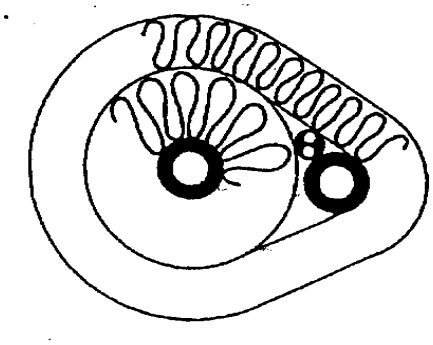

Fig. 1 Cross section of flexible integrated collector-tank interconnection

If the low flow rate concept is adopted as a design principle then a range of systems cost reductions can be achieved at the same time as the system performance is improved. A low flow rate system incorporating the integrated collector/tank connection system developed in Switzerland is shown in figure 2. The features of this system are reduced installation costs due to the ease of installing the flexible "life-line" between the collector and the tank. The single run "life-line" replaces two hard pipes and the controller sensor wire used in standard pumped circulation system designs. The low flow rate design enhances performance as a result of improved thermal stratification in the storage tank. The Swiss system uses a vertical tank with a manifold heat exchanger around the bottom 2/3rds of the tank. This tank configuration is being widely adopted by European manufacturers.

Another outcome of the IEA program was the commercialisation of a cheap and compact heat exchanger designed for low collector flow rate (pumped) in one stream and thermosyphon flow between the other side of the heat exchanger and the tank. This heat exchanger is based on a simple small diameter multi-strand spiral tube construction and is now manufactured in Germany and Canada.

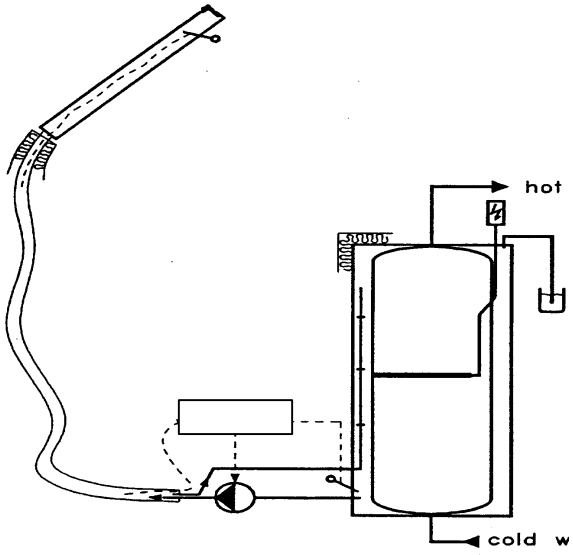

Fig 2 Swiss Dream system (Solkit).

A combination of low flow rate collector circulation with a compact heat exchanger fitted to a low cost standard water heater tank has been developed in Canada. This system has the benefit of easy installation and low shipping cost as the solar components can be fitted to any locally available hot water tank.

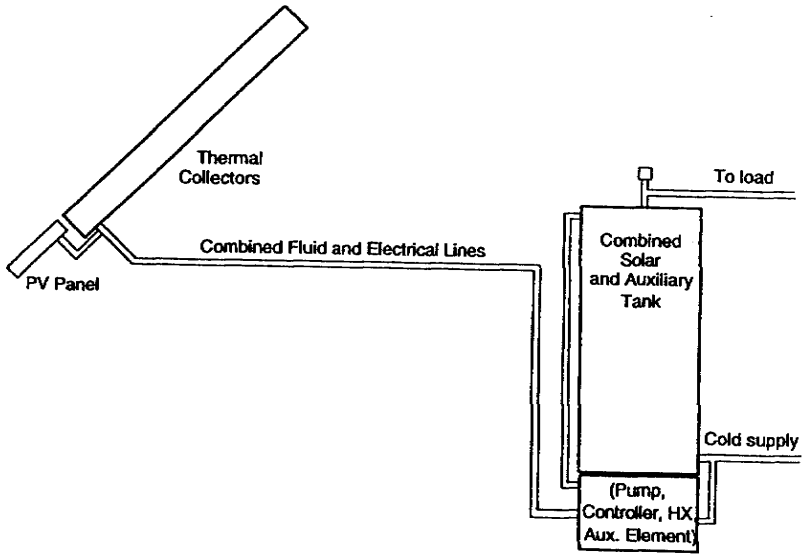

Fig 3 Canadian Dream System (Thermodynamics)

Evacuated tubular absorbers : There has been extensive development of evacuated tubular absorbers in Australia. This work has led to the development of a range of selective surfaces for use in all glass evacuated tubes. These absorbers have not been produced commercially in Australia but are manufactured under licence in Japan and a design based on Australian developments is manufactured in very large quantities in

China. Overheating of solar water heaters in summer is a problem in most parts of Australia and is a particular problem with evacuated tubular absorbers due to their good efficiency at high temperatures. Temperature dependent gas desorption materials have been developed to introduce a high temperature switch in the heat loss from evacuated tubes however, these devices have not gained commercial acceptance. An unusual evacuated tube system using air in the tubes rather than water was developed by a local manufacturer to overcome the two extreme problems of overheating in summer and freezing in winter. This system uses a fan to circulate air through the tubes and then through a manifold heat exchanger around a close coupled tank. Using air as the working fluid overcomes freeze problems in the collector and the fan controller can be used to avoid tank overheating in summer. The tubes can operate safely under stagnation conditions in the non-concentrating configuration that was adopted for this system. Commercialisation of this system has not proceeded due to the high cost of evacuated tubes manufactured under licence in Japan, however with low cost tubes now available from China this system could be commercialised in the future.

CONCLUSIONS

Australian solar water heater manufacturers have established a sound reputation world-wide for high quality products and have a significant presence in most markets except Greece and Israel. Due to past distortions in the Australian east coast electric and gas utility markets, solar water heaters have not achieved a significant market penetration in the major capital cities. With new investment in solar water heater development and fresh interest in marketing renewable energy products by the new energy retail companies formed out of the break up of the utility monopolies, the local solar water heater market appears to have entered a new period of expansion.

REFERENCES

1. I.T Power Pty Ltd. “The development of renewable energy manufacturing facilities”. CEC Directorate General for Energy, contract No 4.104/91-44, 1993
2. Mini-review of Active (Thermal) Solar Energy; International Energy Agency, CADDET Renewable Energy Technologies, 1995
3. Solar and Heat Pump Hot Water Systems. Considerations for proposed financing program. ERDC project report Feb 1994.
4. Guthrie K., Shaw. M.R. and Mendelsohn. H.R. Marketing Solar Water Heaters. ANZSES, Annual conference, Auckland 197-204, 1990
5. Verslius P. Marketing of solar water heaters. National Agricultural and Resources Outlook Conference, (ABARE), Alternative Energy Symposium, 5-9, 1992.
6. Solar Innovations, International Energy Agency Workshop, Toronto, 1996
7. Kline S.A. et al, TRNSYS 14.1 - A Transient Simulation Program. Solar Energy Laboratory, University of Wisconsin 1994.