SOLAR WATER HEATER CONTRIBUTION TO GREENHOUSE GAS ABATEMENT

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SUMMARY

The Australian solar water heater industry has established a worldwide reputation for high quality innovative products and has achieved a significant presence in most of the major world markets. The displaced power output of locally installed solar water heaters reaches 800MW during the peak solar periods with annual conventional energy displacement approaching 1000GWhr. Energy displacement could be significantly increased if the market penetration in the populous eastern states was increased above the current penetration level of approximately 5%.
Analysis of the Australian solar water heater market presented in this submission demonstrates that 2/3rds of the objective of 2% new electricity generation (or displacement) from renewable energy sources by 2010 could be achieved by a relatively minor expansion of the market for solar water heaters.
The impact of solar water heaters on displacement of electricity is evaluated for two expansion programs. Extrapolation of recent market growth (10%) through to 2010 indicates that the displacement of electricity would reach 2045 to 2310 GWh/annum compared to the current 980 GWh/annum displacement. If a five year expansion program was implemented to double the solar water heater installation rate over the period 2000 to 2004 then the displacement of electricity in 2010 would be 2870 to 3140 GWh/annum. The increase over current displacement would then be more than 2/3rds of the objective for new electricity substitution or displacement in this program.

A procedure for evaluating the actual electricity displaced by solar water heaters in the market area or customer base of a particular electricity utility is outlined.

This submission also includes a summary of solar and heat pump water heating technology currently available in Australia.

BASELINE STATISTICS

The achievement of the Australian solar water heater industry is clearly demonstrated in the ABARE statistics published in table 1 of the background papers for this program (extract below).

Table 1: Background statistics on the share of renewable energy in Australian electricity production (Source: ABARE Energy Database)

Source	**Generated 1995-96 GWh**
Hydro	16000
Wind	8
Landfill (grid based)	300
Sewage gas (grid based)	25
Solar hot water	**980**
Solar photovoltaics	26
Bagasse total	495
(supplied to grid)	(95)
Wood	225
(supplied to grid)	(0)
TOTAL renewables	18059
Total grid based renewables	16420
TOTAL ELECTRICITY (Incl. solar hot water)	177833
less private generators own use	15394
less remote communities	407
less wind, solar hot water and PV	1314
TOTAL GRID BASED ELECTRICITY	**160718**
% Total renewable of total electricity	10.2
% grid based renewable of grid based electricity	10.2

Excluding the government funded hydro program, solar water heaters currently generate more energy than all other forms of renewable energy combined. This contribution to energy supply has been achieved with an Australia wide water heater market penetration of the order of 5%. A market penetration of the order of 40% could be achieved without the need to develop products for difficult installations such as high rise apartments, although such systems are feasible if included at the building design stage.

The ABARE statistics in table 1 show that the existing solar water heater stock contributes 0.61% of total grid based electricity generation (through displacement). Hence the target of a further 2% of grid based electricity from new renewable sources could eventually be achieved solely through development of the solar water heater market. The total target for new electricity generation could be achieved by raising the national penetration of solar water heaters from the current 5% to 16%. As solar water heaters have 100% Australian content an expansion program for electricity displacement based on expanded solar water heater use would also have a significant impact on local manufacturing, employment and exports.

AUSTRALIAN RENEWABLE WATER HEATING TECHNOLOGY

The Australian solar water heating industry has historically concentrated on the production of flat plate solar collectors and thermosyphon solar water heaters. The high quality and low installation cost of Australian thermosyphon products has resulted in Australian products being highly regarded and very successful in most markets around the world. In recent years there has been considerable investment in the development of new products and improved manufacturing processes. Australian manufacturers now produce renewable energy water heaters such as thermosyphon systems with a guarantee period of 12 years, a range of pumped circulation systems and in recent years a range of heat pump water heaters with solar-boosting or air-source energy input. A summary of Australian renewable energy water heating technology is given in appendix 1.

AUSTRALIAN MARKET FOR SOLAR WATER HEATERS

Australia has been a leader in solar energy development for over 30 years. This has resulted in the establishment of a substantial manufacturing industry that is renowned for producing the highest quality and most reliable solar water heaters in the world. This industry exports more than 40% of production to Asia, the Pacific Islands, Europe and the USA. Although the industry has a range of high quality products that compete successfully on the international market, the Australian market has been stagnant over the last five years. Production statistics for solar water heater production in Australia are shown in fig 1. Since 1995 production data has not been published by the ABS however manufacturers have indicated growth of the order of 10%/annum from 1995 to 1998.

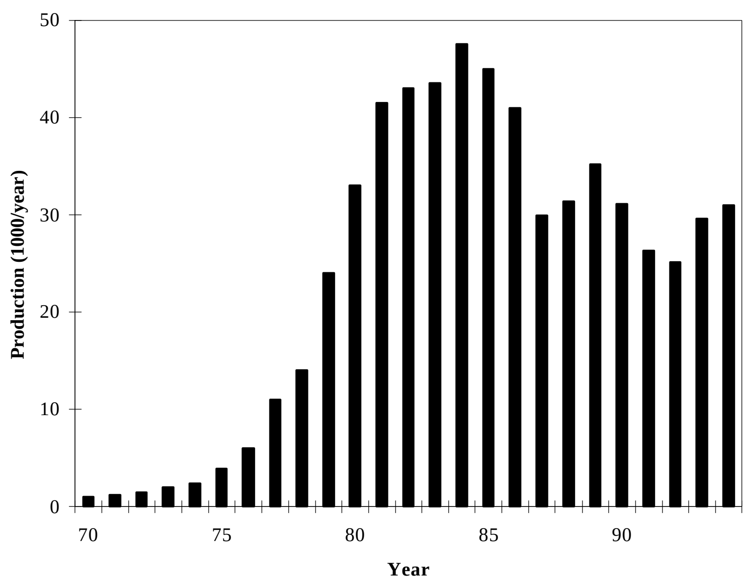


Fig 1. Australian solar water heater production.

The annual solar water heater production dropped to 27,000 in 1992 however, production has steadily increased since then. Cumulative production of solar water heaters over the last 25 years in Australia is more than 700,000 systems with a cumulative glazed solar collector production of more than 3,000,000 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 less than 5% in the eastern states, with a national adoption of less than 5%.

POTENTIAL CONTRIBUTION OF SOLAR WATER HEATERS

Solar water heaters currently displace 0.61% of total grid electricity (see table 1). To achieve the additional 2% renewable electricity supply required under the greenhouse gas abatement program a simple response would be to increase the number of solar water heaters from the current 350,000 systems to 2/0.61*350,000 = 1,147,000 systems. This would not be possible within the time frame of the current program since new production would be required to expand the installed number of systems and also to supply replacement systems reaching the end of their service life. Two market expansion scenarios are presented for evaluation of the potential expansion of the level of electricity that could be displaced by solar water heaters.

Product life

Product life has a major effect on the extent to which solar water heaters can displace electricity, as a substantial part of current production is required for product replacement. In the major population areas of Australia conventional electric water heaters have a guarantee of 5 to 7 years and a typical life of 12 to 15 years. Solar water heaters have a tank life that is generally better than conventional electric water heaters and the solar collector life is longer than the tank life, particularly for copper absorber collectors. Since 1997 solar water heaters have been sold with a guarantee of 12 years and are expected to have a life approaching 20 years. Outside of the hard water areas in central Australia a large proportion of solar water heaters installed in the 1980's are still operating. A thermosyphon system operated and monitored at the University of NSW since 1978 is still achieving 85% of the original performance. The only maintenance performed on this system was replacement of the electric booster element. Thus product life can be expected to approach 20 years for systems installed after 1997. In the analysis presented in this paper product lifetimes of 15 and 20 years are used.

Maintenance of the current market expansion (10%/annum growth)

If the estimated market growth of 10%/annum experienced over the last three years was maintained and the export volume remained at the current 40% of production the expansion of the number of installed systems and net displacement of electricity that would result is shown in figures 2 & 3.

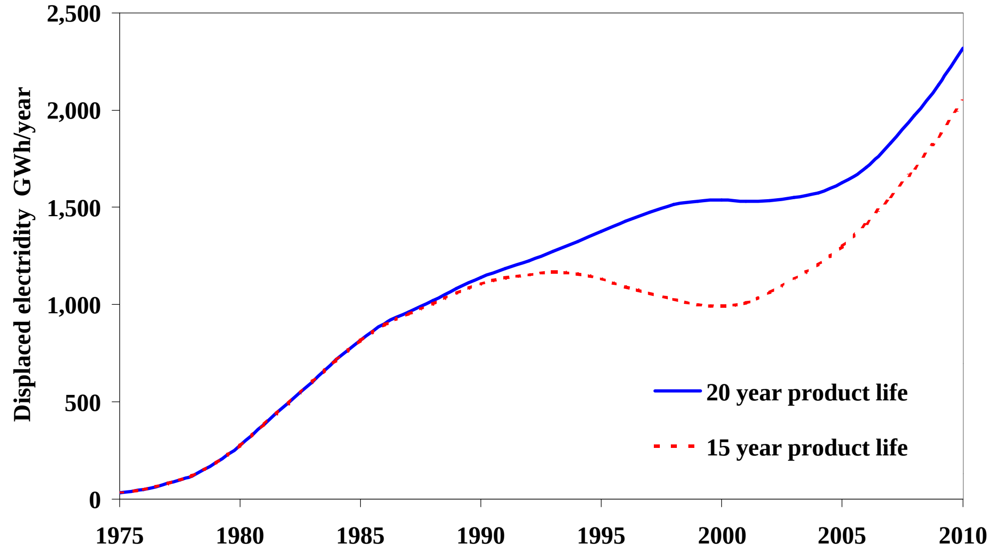


Fig 2. Annual electricity production displaced by solar water heaters for 10% annual production increase and 40% exports.

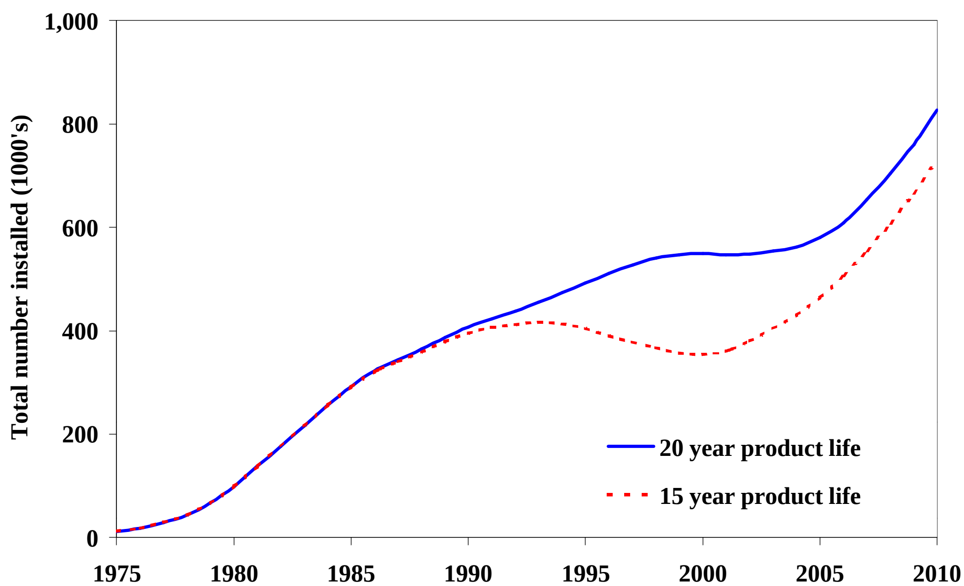


Fig 3. Number of installed solar water heaters for 10% annual production increase and 40% exports.

Even for this slow market development solar water heaters would displace an additional 2045 to 2300 GWh/annum of electricity by 2010. The annual production rate for local and export markets in 2010 would be 145,000/year.

Accelerated market expansion (20%/annum growth for 5 years)

The impact of an annual production increase of 20% over the period 2000 to 2004 due to market intervention by government or utilities is shown in figures 4 & 5. For this scenario the production is assumed to increase by 10%/annum to 1999, 20% from 2000 to 2004 and to drop back to 10% from 2005 to 2010. An export market of 40% of production is assumed to be maintained across the full period.

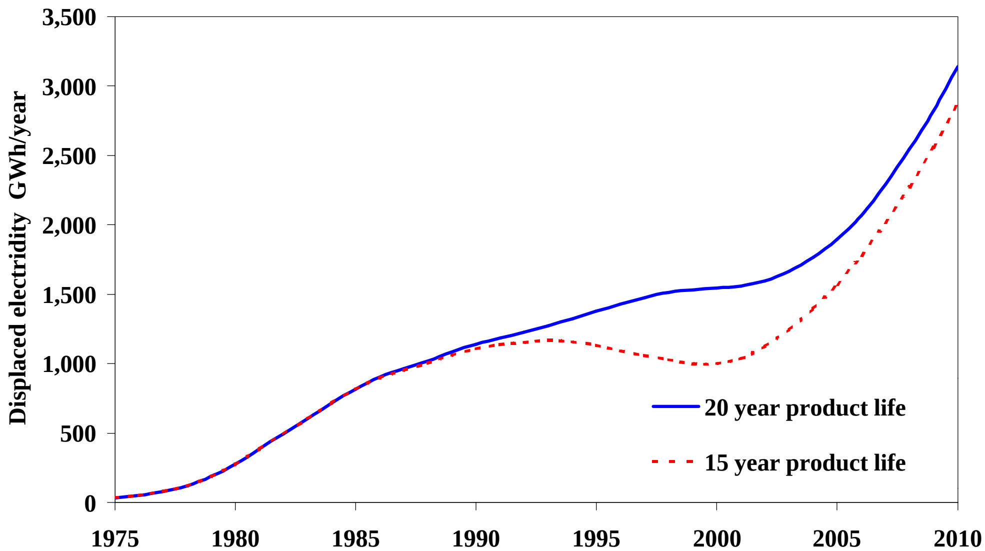


Fig 4. Annual electricity production displaced by solar water heaters for 20% annual production increase in years 2000 to 2004, 10% other years and 40% exports.

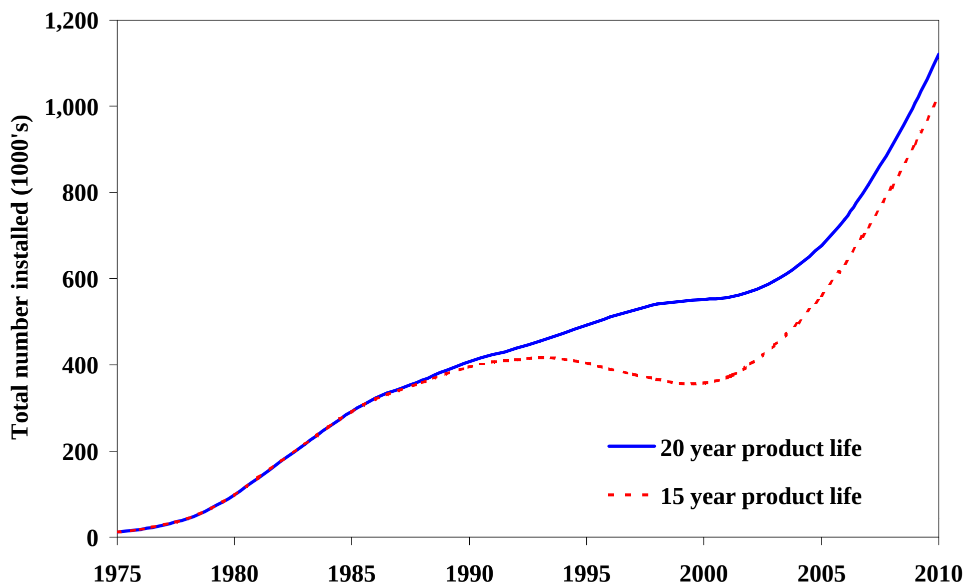
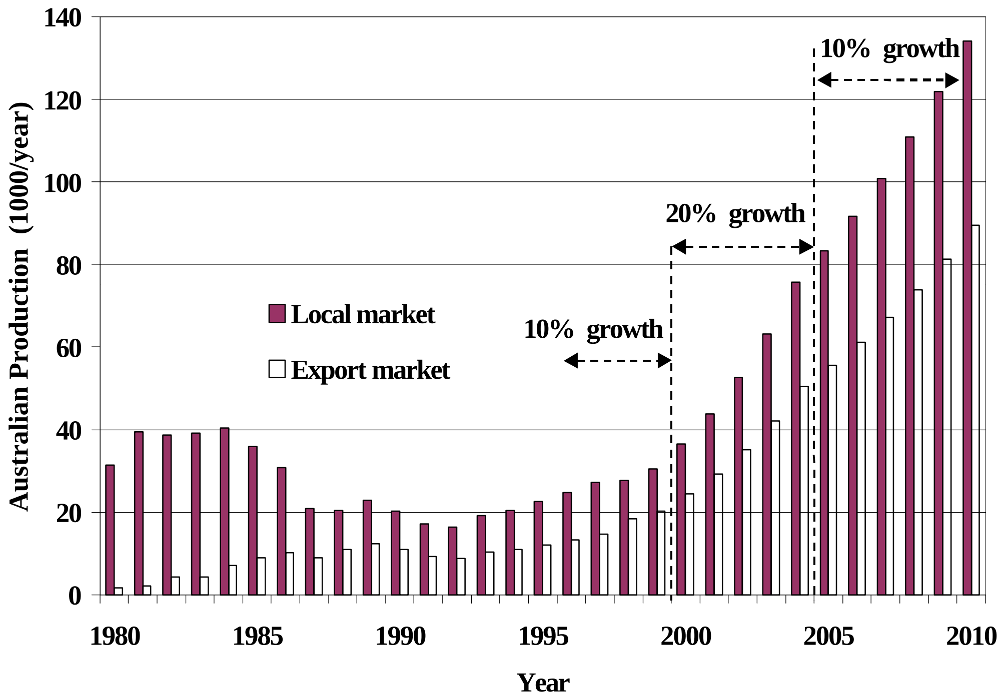


Fig 5. Number of installed solar water heaters for 20% annual production increase in years 2000 to 2004, 10% other years and 40% exports.

Analysis of the growth of installed products included allowance for the replacement of products more than 15 (or 20) years old. This analysis shows that if a 20% growth period were introduced for five years then the additional electricity displaced by solar water heaters in 2010 would grow to 2870 to 3140 GWh/annum. The increase over the current (1998) displacement of electricity would amount to 58% to 67% of the additional 2% of grid electricity required from renewable sources required in this program.

The model of 20% expansion over 5 years assumed that the export volumes were maintained at the existing level of 40%. This relatively limited expansion program for solar water heaters would satisfy up to 2/3rds of the 2% new renewable electricity production target and would also result in significant expansion of exports due to more cost effective high production rates required for the local market. Projected local and export volumes for this expanded program are shown in fig 6.

Fig 6. Annual production rates of local and export markets for



accelerated market development over 2000 to 2004.

ASSESSMENT OF IMPACT OF SOLAR WATER HEATERS

Large-scale implementation of solar water heaters would result in significant and quantifiable displacement of electricity and hence reduction of greenhouse gas emission. Past assessment of solar water heater performance has been directed at the value for individual consumers and little consideration has been given to the value of capacity displacement and pollution reduction on a utility scale. Australian standards[1] have been developed for quantifying energy savings and hence the economic value of domestic solar water heaters to the consumer. These standards have been widely used and have been adopted as international standards however, the simple energy savings performance factor that results from the application of these standards is not the relevant measure needed to quantify utility pollution displacement.

To quantify the contribution of large-scale adoption of solar water heaters to reduction of utility pollution emissions detailed information is required on the characteristics of the particular utility power generation plant and the pollution index for each piece of plant. To evaluate emission reduction it is necessary to assess the electricity demand pattern of the stock of water heaters on a continuous basis over each day and to compute pollution reduction on the basis of displacement of the marginal generating plant each hour across the day. Pollution reduction will be a function of the profile of the available generating plant and the pollution index of each piece of generating equipment, hence the impact of wide spread adoption of solar water heaters will be a function of the plant profile of each utility. To reliably evaluate pollution reduction it is necessary to have an evaluation tool that accounts for the number and type of solar water heaters installed and the generating plant management strategy for each utility.

A state by state assessment of pollution reduction due to solar water heaters would be required to ensure promotion effort was directed at markets that would achieve the greatest return. Although solar performance in the southern parts of Victoria is substantially lower than for northern NSW and Queensland the displaced pollution may be significant due to the high greenhouse gas impact of brown coal fired power stations used in that state.

[1] Australian Standard AS4234. Rating of solar and heat pump water heaters.

PARTICULAR QUESTIONS POSED IN THE PROGRAM OUTLINE

"How can parties liable to meet the measure be credited with specific installations of solar water and wood fuel heaters?"

"How should the amount of electricity displaced by solar water heaters be calculated? Should factors such as boosting technology or local climate be assessed?"

Evaluation of the impact of an expanded solar water heater program in a particularly utility market could be determined as follows.

- Survey of sales and product types in the utility distribution area, or in the case of a deregulated market in the appropriate customer base of the retailer.
- Evaluation of the electricity demand profile for the cohort of products revealed in the survey.
- Evaluation of the electricity demand profile that would have applied if conventional electricity products had been used.
- Evaluation of the pollution index of the electricity purchased by the electricity retailer.
- Evaluation of energy and pollution displacement produced by solar water heaters relative to conventional electric water heaters.
- Analysis of the pollution reduction due to off-loading marginal electricity generation plant in the case of a closed market retailer/generator area or by analysis of the pollution index of supplies available but not used in a deregulated electricity supply market.

Quantification of the impact of renewable energy products would need to be carried out on a short time step basis (at most on a half hourly basis) to quantify the savings produced due to displacement of marginal generating plant or power services available throughout the day.

A demonstration of the application of such an analysis tool has been reported by Trzesniewski[2] and Cragan[3] for an application in a single supplier market in Wisconsin USA. This analysis was directed at evaluation of the impact of displacement of marginal plant in a closed supplier system but could be readily adapted to a deregulated generation and distribution market.

Once the analysis tool was in place the only cost to quantify energy and pollution savings would be to collect reliable data on the number and type of products in the retailers supply area or customer base. This data would then be combined with pollution data for the power available from the open supply market throughout the day.

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[2] Trezesniewski J et al. Impact of solar domestic hot water demand-side management program on an electricity utility and its customers. American Solar Energy Society Annual Conference, 366-373, 1996

[3] Cragan K et al. The impact of an ensemble of solar domestic water heating systems on a utility. Advances in Solar Energy V10, chapter 2. ASES 1996

APPENDIX 1

RENEWABLE ENERGY WATER HEATING TECHNOLOGY

The world market for solar water heaters expanded significantly during the 1990's and as a result there has been a substantial increase in range and quality of products now available. Solar water heater production is now a significant industry in Australia, China, Greece, Israel and the USA. The "self-build" industry has also expanded significantly in Europe. The primary exporters of solar water heaters are Australia, Greece, Israel and the USA; most other countries only supply domestic demand. Solar water heater technology has recently expanded to include a range of vacuum insulated collectors in both flat plate and tubular form, solar boosted heat pumps and a range of concepts to reduce the cost and improve product performance of pumped circulation systems.

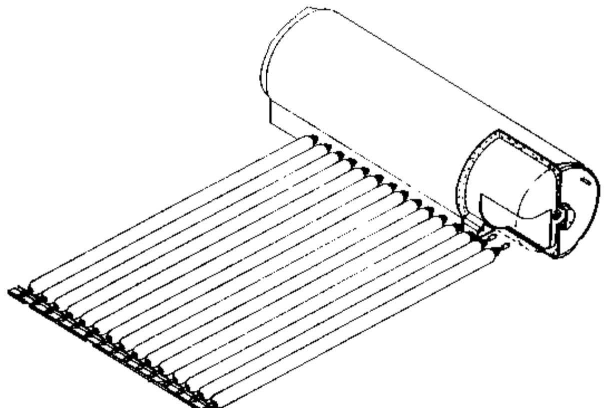
The most common forms of solar water heaters are integrated solar pre-heaters and thermosyphon systems with a mantle heat exchanger around a horizontal storage tank. In areas where freezing is not a problem solar water heaters are based on direct water circulation between the tank and collector, with protection against the occasional frost provided by drain valves or an electric heater in the collector. For markets requiring a temperature regulated hot water supply, auxiliary boosting of solar water heaters is generally integrated into the solar tank, two tank systems are not commonly used outside of Europe and North America. The principle types of solar water heaters are outlined in the following sections.

The majority of domestic solar water heaters use thermosyphon circulation of water between the solar collectors and the storage tank. This requires the storage tank to be mounted above the collector to produce thermally driven circulation between the collector and the tank. The advantage of these systems is that they do not require an electrical connection and have very low maintenance. The collector-tank configurations used include:

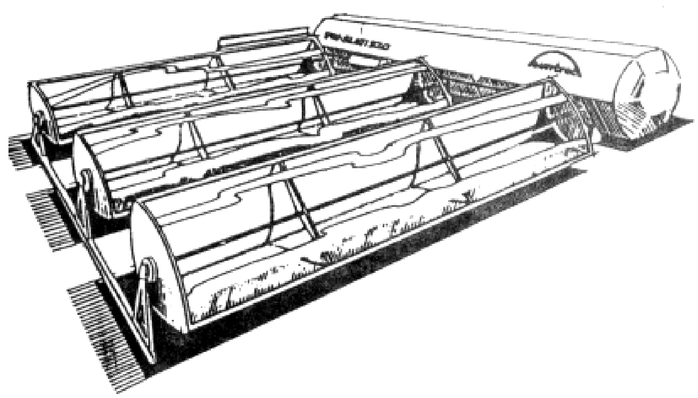
Thermosyphon solar water heaters

- 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.

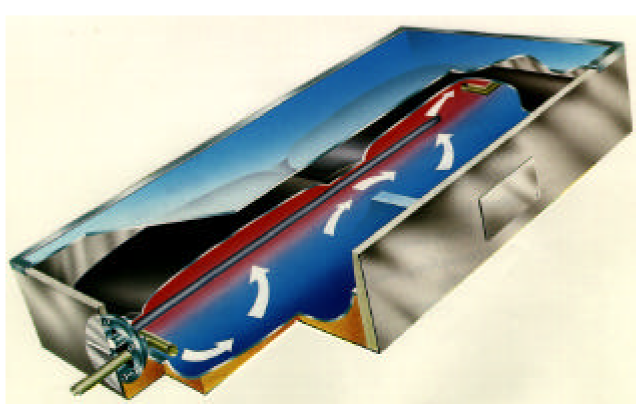


- Heat pipe energy transfer from parabolic trough concentrating collectors with the heat pipe condenser inserted directly into the base of a horizontal water tank.



Integral tank-collector systems

Integral systems combine the tank and collector into one unit. These systems are simple and effective however, due to high heat loss at night they only provide hot water during the day and early evening. The products range from simple glazed low-pressure plastic tanks to high quality steel tank systems with selective surface coatings to minimise heat loss. These systems make up the major portion of the large market in Japan. The main limitation with this system concept is that it is only a pre-heater and hence must be connected in series with a conventional water heater if a 24hr hot water supply is required.

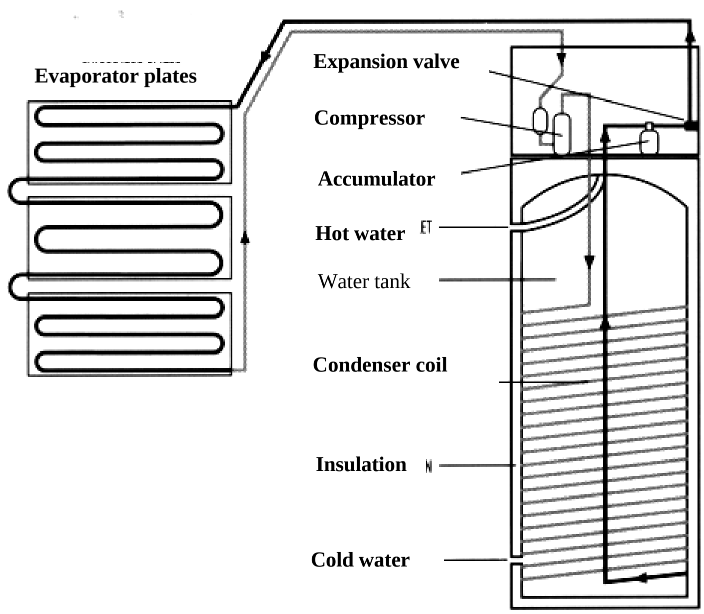


Pumped circulation systems

Pumped circulation solar collector arrays connected to conventional enamelled steel hot water tanks have been widely used for domestic solar water heating in North America and Europe. The development of this design concept was driven by the need to provide freeze protection in these climates. The market share of such systems dropped significantly during the 1990's due to the lower cost of externally mounted thermosyphon systems. However production of pumped systems has started to increase in recent years, due to an increasing number of consumers who are not willing to accept the visual impact of an external roof-mounted tank, even though such systems are cheaper and have better performance. New design concepts for pumped systems may result in increased use of this configuration however, it is primarily suited to larger commercial systems.

Solar boosted heat pumps -roof mounted evaporators.

The heat pump water heater concept has been extended to incorporate solar boosting of the heat pump evaporator performance. Solar boosted heat pumps are now manufactured in a number of countries. The original system concept proposed by Charters was for a system with direct evaporation of the heat pump working fluid in the solar collector. This was a significant simplification over earlier designs based on a solar pre-heater in series with a heat pump. To minimise system costs and parasitic energy requirements this system incorporates the heat pump condenser directly in the water storage tank. The integration of the condenser in to the tank eliminated the parasitic energy of the pump used to transport heat from the heat pump condenser to the water storage tank in more conventional solar heat pump configurations. Although this system has achieved significant acceptance it has the disadvantage that the heat pump refrigeration circuit must be evacuated and charged at the installation site.



Compact heat pump systems with partial solar boosting.

Compact solar boosted heat pump systems have also been developed to reduce installation costs due to the need for on-site refrigeration component installation of the remote evaporator systems. The compact system incorporates an evaporator mounted on the outside of the water tank with natural convection air circulation over the evaporator as shown below.

This system can be installed outdoors in order to gain solar boosting however, a significant part of its operation may be in the conventional air to water heat pump mode. This system is being extensively used in commercial plant rooms where there is a high ambient temperature due to heat generated by other equipment. It can also be installed near or inside air conditioner exhaust outlets to benefit from the warm humid exhaust air passing over the evaporator. The advantage of this system over a conventional air to water heat pump is that it does not have the parasitic energy of a conventional fan coil unit. The packaged system also has the advantage that all the components are assembled in the factory and the installation is simpler than a conventional electric water heater since the unit does not require a high current electrical connection, as the compressor motor power is typically only 500 W.

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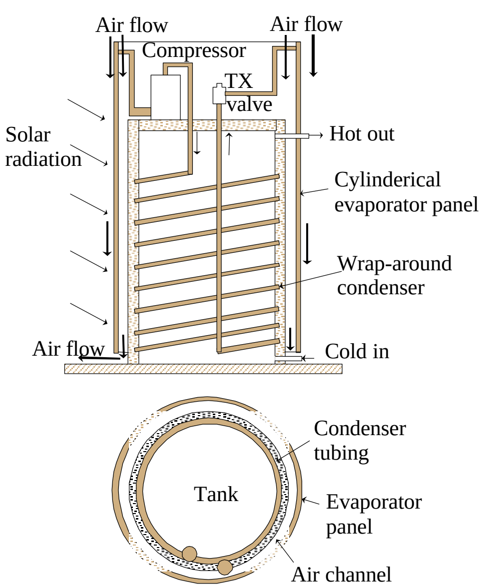
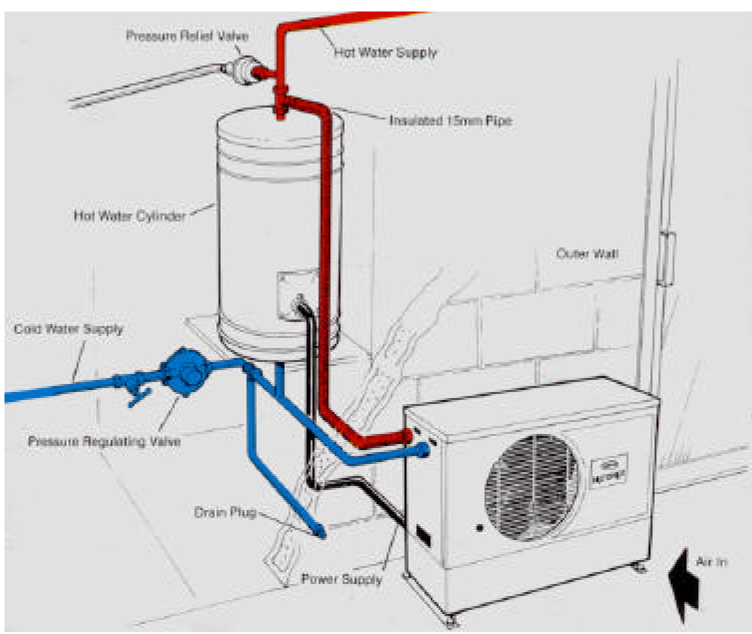


Air source heat pumps

A series of air source heat pump water heaters for domestic application have recently started to be manufactured in Australia. The majority of the energy output of an air source heat pump is drawn from air passing over the evaporator coil, hence these products are indirect solar water heating systems. These systems are also ideally suited for commercial applications and have achieved good penetration in hotels in Australia and overseas.

Integrated air-source heat pump water heater.



Separate heat-pump air-source water heater.

Evacuated tubular absorbers

Extensive development of evacuated tubular solar collectors in Australia and China has led to the development of a range of selective surfaces for use in all-glass evacuated tubes. The Australian designed tubes are manufactured under licence in Japan and have been adopted in China where they are now produced in very large quantities for wet tube domestic water heaters. The wet tube concept in which water is in contact with the glass tube can only be used for low-pressure water heating systems, as the tubes cannot withstand more than a few metres water pressure. Systems incorporating pressure tubing inside the evacuated tubes have been developed in Australia and are manufactured in Japan. Joint projects between Australian solar water heater manufacturers and Chinese suppliers of evacuated tubes are currently being developed.

Overheating of solar water heaters in summer is a problem in many parts of the world particularly with pressurised water tanks attached to evacuated tubular solar collectors, due to their high efficiency at temperatures above 100°C. Introduction of a high temperature switch in the heat loss from evacuated tubes by the use of temperature dependent gas desorption materials has been investigated however, these devices have not gained commercial acceptance.

An evacuated tube system using air in the tubes rather than water has been developed 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 a concentric air to water heat exchanger around a horizontal tank. Using air as the working fluid overcomes freezing problems in the collector and the fan controller can be used to avoid tank overheating. The tube outlet is mounted above the tank so that thermosyphoning is restricted between the collector and the tank when the fan is off. 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 and other evacuated tube configurations may be commercialised in the near future.

Prototype evacuated tubular collector solar water heater

Seasonally biased collectors

To minimise installation costs solar collectors are usually mounted flush on available roof surfaces. This results in poor winter performance and over heating in summer. Winter performance can be improved by mounting collector at a steeper angle however this requires an expensive and possibly unattractive sub-frame for the collector. The annual energy savings can be improved by using collector design that can be mounted on a standard 20° to 25° roof pitch and yet give a winter biased performance. Such a collector was originally developed for a solar cooking system and then adapted to solar water heating. The original prototype collector employed a series of low profile reflectors that give a winter bias to the system performance as shown below.

Prototype solar water incorporating stationary mirrors to give
winter biased peak performance.

A flat plate collector can also give a winter-biased performance by incorporating a fixed mirror booster above the collector as shown below as shown on the trail systems on a hospital near Newcastle. This water heater concept is currently being evaluated in field trials.

Mirror booster solar collectors on a low slope roof.

WORLD MARKET

The solar water heater market in many parts of the world was surveyed by IT Power for the CEC Directorate General for Energy, the IEA CADDET Renewable Energy review in 1994-1995 and the APEC Compendium of renewable energy programs in 1995. The findings of these studies are summarised in the following table.

Major solar water heater markets (1994)

Country	Total number of SDHW systems in use.	Number of SDHW systems produced.	Total glazed collector area installed m^2	Glazed solar collector area produced m^2
Australia	350,000[*]	30,000[*]	1,400,000[*]	140,000[*]
Austria			400,000[+]	100,000[^]
Canada	12,000[#]			
China			1,500,000[&]	500,000[#] (2 M vac tubes in 1997)
Cyprus			600,000[+]	30,000[+]
Denmark	14,000[*]	2,000[*]	74,000[&]	8,000[o] (20,000[&] in 1996)
France			260,000[&]	18,000[+]
Germany			685,000[&]	40,000[+] (150,000[&] in 1996)
Greece			2,000,000[&]	170,000[+]
Israel			2,800,000[+]	300,000[+]
Japan	3,800,000[*]	150,000[*]	7,000,000[*]	
Korea	8700[#]			50,000[+]
Netherlands	10,000[*]	3,000[*]	49,000[&]	9,000[&o]
New Zealand	10,000[*]	750[*]		3,000[*]
Norway	100[*]	20[*]	1,000[&]	200[o]
Portugal			200,000[&]	13,000[+]
Spain			118,000[&]	12,000[+]
Sweden		2,000[*]	71,000[&]	20,000[o]
Switzerland	9,300[*]	1,300[*]	131,000[&]	6,000[o]
Thailand		>740[#]		
Taiwan		25,000	200,000[#]	90,000[&]
UK	45,000[*]	1,821[*]	108,000[&]	7200[o]
USA	1,200,000[*]		4,000,000[*]	70,000[**]

[+] CEC survey[4], [*] CADDET survey[5], [#] APEC Compendium[6], [&] Sun in Action, CEC[7] 1996, DOE USA[8], [o] estimated, [^] primarily “self-build” products.

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[4] I.T Power Pty Ltd., (1993), “The development of renewable energy manufacturing facilities”. CEC Directorate General for Energy, contract No 4.104/91-44.

[5] CADDET, (1995), “Mini-review of Active Thermal Solar Energy”; International Energy Agency, CADDET Renewable Energy Technologies

[6] APEC (1995), “Compendium of Renewable Energy Programs and Projects in Asia Pacific Economic Cooperation (APEC) Member Economies”, APEC#95-RE-01.3.

[7] "Sun in Action. The solar thermal market. A strategy plan for action in Europe" European Solar Industry Federation, 1996.

[8] Renewable Energy Annual (1995), National Energy Information Centre, Department of Energy USA

Comparison of markets in different countries is difficult due to the wide range of designs used for different climates and different 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 a favourable climate and to regulations mandating installation of solar water heaters. The largest market is in China where there is widespread adoption of advanced evacuated tubular solar collectors developed through co-operation with Australian research groups.

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. France also exports a substantial number of systems to its overseas territories. The majority of US exports are to the Caribbean area, Australian companies export approximately 50% of production (mainly thermosyphon systems with external horizontal tanks) to most areas of the world that do not have hard freeze conditions.

Impact on Utilities

The adoption of solar water heating is not wide spread however, these renewable energy products make a significant contribution to the energy supply systems in Australia, China, Greece, Israel and the USA. The power output from 100,000 m^2 of flat plate solar collectors is of the order of 50 MW during the middle of the day (assuming 1000 W/m^2 incident radiation and 50% collector efficiency). Thus the peak power capacity of solar water heaters in a number of countries already exceeds 1000 MW. The wide scale adoption of solar water heaters can have benefits for electricity supply utilities as solar water heaters displace a significant part of the expensive peak electricity demand generated by domestic water heating.