PACKAGED SOLAR WATER HEATING TECHNOLOGY

TWENTY YEARS OF PROGRESS

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Abstract - The production of packaged solar water heaters has developed into a significant industry. In a number of countries production exceeds 100,000 m^2/year. The market for solar water heaters expanded significantly during the 1990's and as a result there has been a substantial increase in the range and quality of products now available. Solar water heater production is now a major industry in China, Australia, Germany, Greece, Israel and the USA. The "self-build" industry has also expanded significantly in many parts of Europe. The primary exporters of solar water heaters are Australia, Greece, Israel and the USA; most other countries only supply domestic demand. Commercially available packaged solar water heater technology has recently expanded to include a range of vacuum insulated collectors in both flat plate and tubular form, freeze resistant passive systems, solar boosted heat pumps and a range of low flow pumped circulation systems. A photovoltaic solar water has been demonstrated however it is only in concept stage at present. This paper reviews design concepts for small packaged solar water heaters and surveys the scale of the international markets for such products. New product developments for passive and active solar water heating including evacuated collectors, seasonally biased collectors and photovoltaic water heaters are outlined. Using market survey data from the United States, the concept of consumer market value for solar domestic water heaters is defined and discussed. A life-cycle-cost model is used to assess the energy and environmental impacts of packaged solar water heaters.

1. INTRODUCTION

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 major industry in China, Australia, Greece, Israel and the USA. The "self-build" industry has also expanded significantly in Europe. The market forces are quite different in each market area. They range from being required in Israel to free market competition in the USA. The primary exporters of solar water heaters are Australia, Greece, Israel and the USA; most other countries only supply domestic demand. Commercially available solar water heater technology has recently expanded to include a range of vacuum insulated collectors in both flat plate and tubular form, freeze resistant passive systems, solar boosted heat pumps and a range of low flow pumped circulation systems. A photovoltaic solar water has been demonstrated however it is only in concept stage at present.

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 potable 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.

A thermosyphon system relies on natural circulation of water between the collector and the tank or heat exchanger. To achieve circulation during the day and to limit reverse circulation at night, the tank must be above the collector. There are also techniques that allow the tank to be mounted level with the collector rather than above the collector. Thermosyphon systems can be designed with various levels of freeze protection, ranging from dump valves or heaters in the bottom collector header for mild freeze areas to inherent freeze resistance by using a natural circulation anti-freeze closed loop between the collector and the tank.

2. WORLD MARKET FOR SOLAR WATER HEATERS

Annual production statistics and cumulative installation data for some countries is shown in Table 1. (Renewable Energy Annual 1995, Sun in Action, 1996)

3. DESIGN CONCEPTS FOR PACKAGED SDWH'S

Many alternative concepts for packaged solar water heating systems have been proposed. (APEC 1995, CADDET 1995, CEC 1993, Fanney and Dougherty 1997) Common design concepts that are used in the large markets are shown in Fig 1.

3.1 Thermosyphon solar water heaters

Thermosyphon circulation systems are the commonest packaged SDHW product configuration in warm climates. The development of freeze tolerant thermosyphon solar water heaters is resulting in the expanded use of these low cost systems in markets such as Europe, China, Korea and

Taiwan, where hard freeze conditions must be managed. Thermosyphon systems can also be operated with the collector mounted level with the tank without excessive heat loss due to reverse circulation.

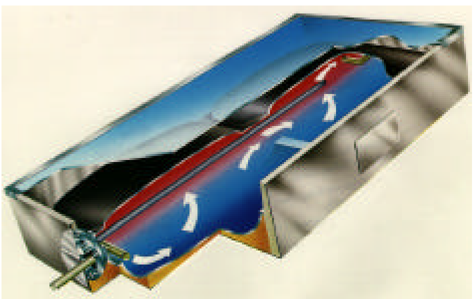
3.2 Evacuated insulation

Extensive development of evacuated tubes has led to the introduction of a range of evacuated tubular collectors and evacuated integral water heaters. Vacuum insulated collectors and tanks range from the widely adopted flooded Dewar-tube collector systems in China to the high performance vacuum insulated collector/storage systems in

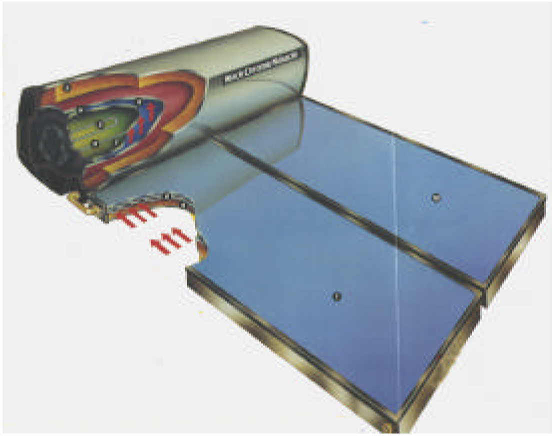
Table 1. Major global SDWH markets in 1994.

Country	Total SDWH in use (1,000)	Number SDWH produced annually (1,000)	Total glazed collector area installed (1,000 m^2)	Glazed collector area produced annually (1,000 m^2)
Australia	350[1]	30[1]	1,400[1]	140[1]
Austria			400[2]	125[6]
Canada	12[3]			
China			1,500[4]	500[3] (2M vac' tubes in 1997)
Cyprus			600[2]	30[2]
Denmark	14[1]	2[1]	74[4]	8[5]
France			260[4]	18[2]
Germany			685[4]	140[2]
Greece			2,000[4]	120[2]
Israel			2,800[2]	300[2]
Japan	3,800[1]	150[1]	7,000[1]	
Korea	8.7[3]			50[2]
Netherlands	10[1]	3[1]	49[4]	9[4, 5]
New Zealand	10[1]	0.75[1]		3[1]
Norway	0.1[1]	0.02[1]	1[4]	0.2[5]
Portugal			200[4]	13[2]
Spain			118[4]	12[2]
Sweden		2[1]	71[4]	20[5]
Switzerland	9.3[1]	1.3[1]	131[4]	6[5]
Thailand		>0.75[3]		
Taiwan		25[3]	200[3]	90[4]
UK	45[1]	1.8[1]	108[4]	7.2[5]
USA	1,200[1]		4,000[1]	70[1]

[1] CADDET Survey, [2] CEC Survey, [3] APEC Compendium,
[4] Sun in Action, CEC 1996, DOE USA, [5] Estimated,
[6] Primarily "self-build" products



(a)



(b)

(c)

Fig 1**.** Common solar water heater and heat pump water heater configurations, (a) integrated system, (b) close-coupled thermosyphon system, (c) air source heat pump.

Japan, Figs 2-4. Evacuated collector systems for air heating or with an air to water heat exchanger have also been demonstrated but have not achieved commercial development. The wet-tube concept, Fig 3d, 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 meters water pressure. Systems incorporating pressure tubing inside all-glass evacuated tubes are also in wide use.

Overheating of solar water heaters in summer is a problem in many parts of the world, particularly with pressurized 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 between the collector and the tank is restricted when the fan is off. The tubes can operate safely under stagnation conditions in the non-concentrating configuration adopted for this system, Fig 3a.

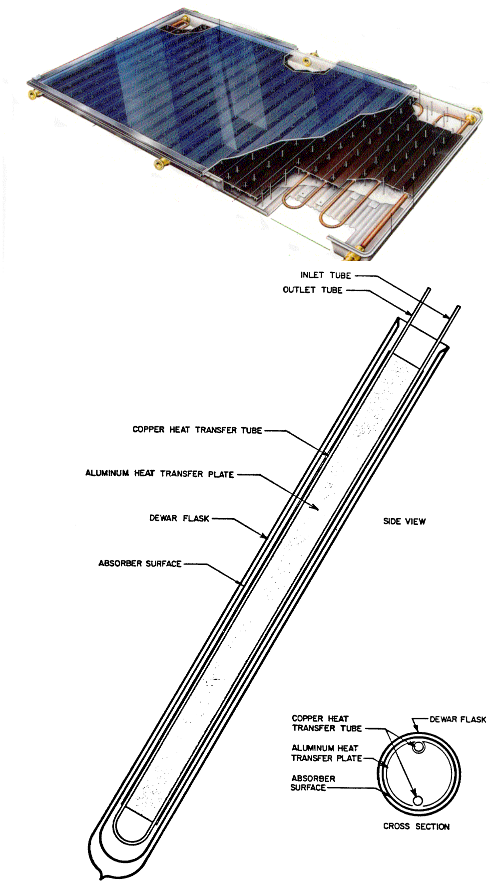
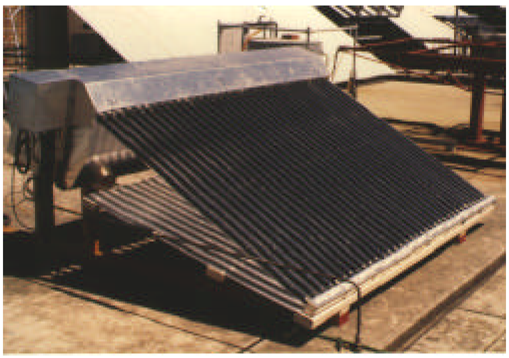


Fig 2. Evacuated collectors (a) flat plate, (b) single ended evacuated tube.



(a)

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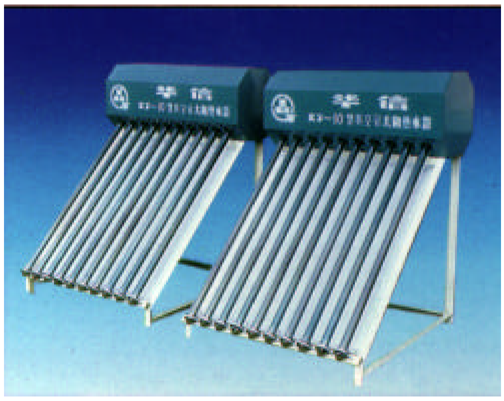

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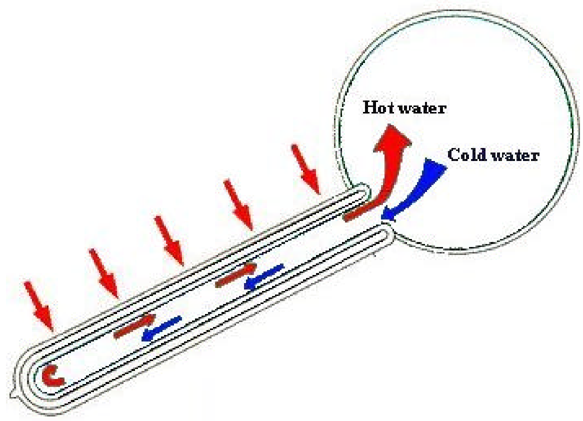

(d)

Fig 3 Solar water heaters incorporating all glass evacuated tubes, (a) air circulation in tubes, (b) seasonally biased reflector with evacuated tube absorber, (c) & (d) flooded tube water heater (China).

3.3 Seasonally biased collectors

As a result of the development of low cost micro-sheet glass, low cost reflectors are now being used to increase the aperture area of collectors and to introduce a winter bias to solar input to match the winter peak demand for hot water, Fig 5.

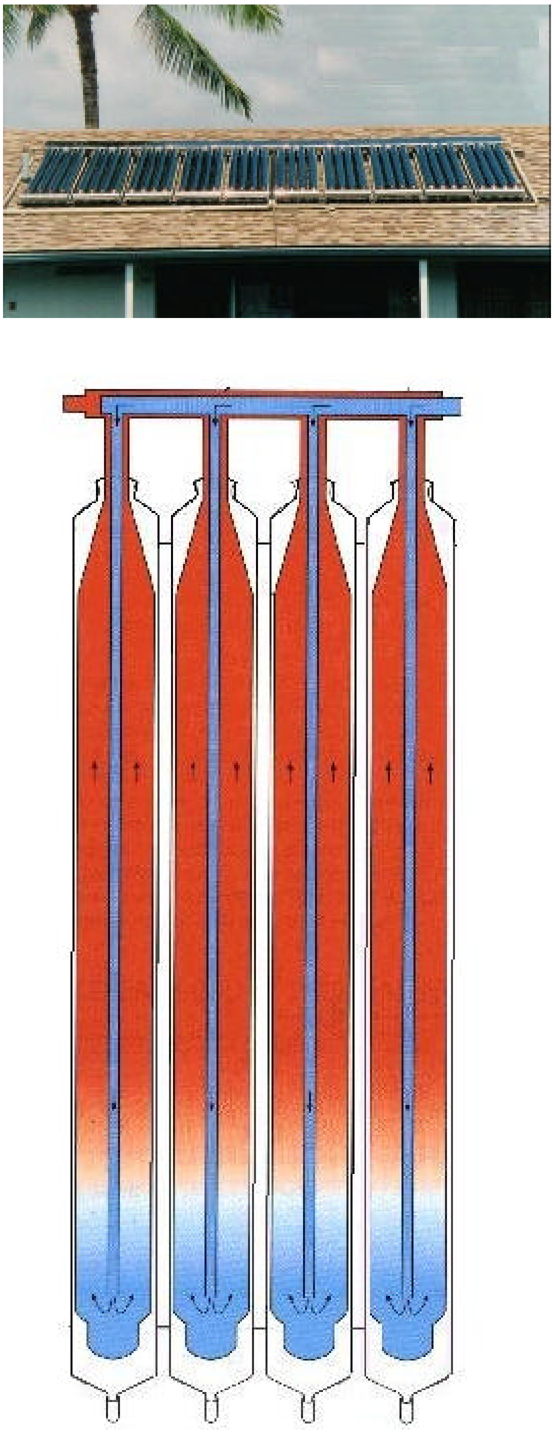

Fig 4 Evacuated collector with integral store.

3.4 Heat pump water heaters

A range of heat pump water heaters with direct solar heating of the heat pump evaporator have been developed. System configurations ranging from the direct solar input to conventional air source systems are being used, Figs 6 and 7.

(a)

(b)

Fig 5. Micro-sheet flexible glass as stationary booster for flat plate collectors, (a) integrated mirror booster in close-coupled thermosyphon system, (b) mirror booster for low inclination mounting of collectors.

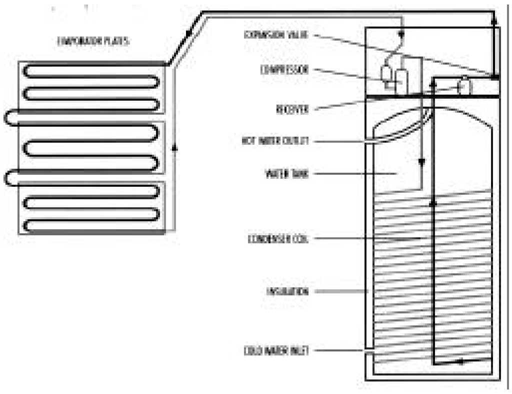

Fig 6. Solar boosted heat pump water heater.

Fig 7. Air source systems with enclosed fan and evaporator on top of the tank, (a) fan coil air source, (b) passive air source evaporator.

3.5 Photovoltaic water heaters

A demonstration program of direct photovoltaic water heating has been completed in the USA, Fig 8. Although the current cost of PV modules is extremely high, the concept of a PV-SDWH has been proposed and evaluated by Fanney and Dougherty (1997) and Williams et al. (1997). The advantage of a PV-SDWH is that it eliminates the piping and associated heat loss of the liquid collector loop and it does not require freeze protection. A controller is used to vary the water heater electric element resistive load to match with the peak power point of the PV array. However, unlike other residential PV systems a PV-SDWH does not require an inverter or a battery storage system. There are no roof penetrations and the installation is simple, although the collector area will be several times that required by a thermal collector. Superior system reliability would be expected

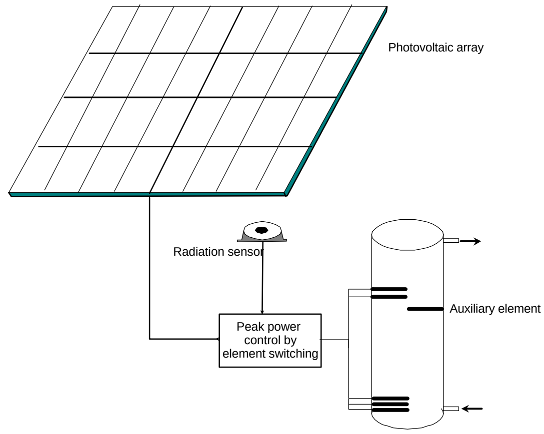

Fig 8. Direct heating photovoltaic solar water heater.

relative to a pumped SDWH with freeze protection however, a PV-SDWH would be more complex and perhaps not as reliable as a thermosyphon system in temperate locations where freeze protection was not an issue. For such a system to be competitive with a pumped SDWH, with freeze protection, the price of the PV modules is projected to have to fall below US$1.90.

4. UNDERSTANDING THE CONSUMER MARKET VALUE FOR SOLAR WATER HEATERS

4.1 United States Market Trends

In the late 70's to 1986, Federal and State tax credits were used to develop the United States Solar Domestic Water Heater (US SDWH) market. In 1986 both the Federal R&D funding and tax credits ended abruptly. Consequently, the market changed dramatically as shown in Table 2. (SEIA, 1986-1998) Presently the market has stabilized and is showing very slow growth. Seven collector manufactures produce over 90% of the collectors made in the United States. Third party system certification has helped to improve system quality. A voluntary national system certification has been put in place by the Solar Rating Certification Corporation. (SRCC, 1999) The Florida Solar Energy Center maintains a system certification program for systems installed in the State of Florida. (FESC, 1999)

Table 2. Market history for the United States

Year	No. of Manufac-turers	Pool Collectors Shipped (1000 m^2)	SDWH Collectors Shipped (1000 m^2)
1984	225	416	1,109
1986	98	348	103
1990	51	339	235
1994	41	634	75
1998	32*	623	79*

Estimated *

The US Department of Energy has estimated that in 1998 there were 1.2 Million SDWH's working that displaced 800 MWe electrical generating capacity, (DOE, 1999).

4.2 Consumer Market Value

Consumers make purchase decision based on what may be termed the *consumer market value* of the product. For example, why do some people buy a BMW that will transport them the same as in a VW that costs considerably less? Each vehicle has a different *consumer market value* that is based on a complex combination of a number of considerations.

The Consumer Market Value for SDWH's will include some combination of the following considerations.

- The amount of maintenance required,
- The type of warranty provided,
- The hot water delivery capacity of the system,
- Money saved on water heating bills,
- The price of the system fully installed,
- Increased value of the home,
- What will friends & neighbors think,
- Availability of state or federal tax benefits,
- The size and appearance of the system,
- Helping to clean the air,
- Ability to include the system in the mortgage,
- The brand name on the equipment,
- A builder recommendation.

FOCUS Marketing Services was hired by the US Department of Energy in 1997 to gain a better understanding of the marketplace from the perspective of homebuyers who will a buy new home within two years. (Lofland, January 1998). Five focus groups were conducted in three states. Orlando, FL; Phoenix, AZ; and Sacramento, CA . Each focus group consisted of 8-10 participants that included 18 solar users and 28 non-solar users. The solar user and non-solar user groups were conducted separately.

Non-user discussion areas included:

- Awareness and image of solar water heating systems,
- Purchase interest and reasons for interest,
- How home buyers would approach purchasing a solar water heating system,
- Feelings toward solar energy political issues and Million Solar Roofs Initiative,
- Reactions to different types of solar water heating systems.

Solar user discussion areas included:

- Purchase process for obtaining solar,
- Type of system installed,
- Solar usage and maintenance,
- Feelings toward their solar systems,
- Reactions to different types of solar water heating systems.

The major conclusions that came from these focus groups were:

1. The solar energy industry faces an enormous communications job of educating the Public and "damage control" among the large majority of non-users and among some current users as well. (The poor durability & reliability and exaggerated performance claims that were common during the tax credit era have not been overcome by the industry even after more than a decade later.)
2. Demonstrating both short and long-term money savings that are possible when using solar water heating in a straightforward and believable manner is the key to increasing sales of these systems.
3. In addition to money savings, the solar industry needs to clearly communicate the Facts that the new solar systems come with strong warranties and are relatively Maintenance free.
4. Both users and non-users of solar water heating systems agree that it is nice to do what you can to help the environment, but did not/would not base their purchase Decision upon environmental factors.
5. The building industry could clearly make a big impact in the use of solar water heating if it chose to do so, without hurting their home sales. However, builders will need to install solar systems as standard equipment, or at a minimum show the systems in their model homes alone with information about the long-term money savings.
6. The reputation of the installer and the length of time they have been in business is more important than the actual brand name or type of equipment offered in the solar energy industry. Both solar users and non-users agree that they are more interested in the reputation of the installer than they are in the actual equipment. Specifically, they want to know that the company has been around for a long time, and will be staying in business. They also want to know that the installer will stand behind his product and provide servicing when needed.
7. The newer versions of solar panels (flush mounted on the roof) are significantly more appealing to both users and non-users than the older rack mounted collectors. However, they do raise concerns regarding capacity and efficiency due to their much smaller size.
8. While the majority of the users who participated in these groups are extremely satisfied with their solar experiences, they may only represent one side of the solar user marketplace – those who continue to use their systems.

FOCUS Marketing Services also conducted three hundred telephone interviews; one hundred each in Florida, Arizona, and California. (Lofland, March 1998)

The screening criteria for all respondents were:

- Own the single family unit home they are currently living in,
- Owned this home for one year or less,
- Do not have solar water heating on this home,
- Telephone interviews lasting 15 minutes each,
- Interviews were conducted from February 12 - 17, 1998.

The outcome of these interviews is given in Tables 3-5. The percentage given is the percent of respondents that identified the item as important.

Table 3. Perceived Advantages of Solar Water Heating

Save money	76%
Better for the environment	32
Use less gas/electricity	21
More hot water capacity	2
Safer/less danger to people	2

It is interesting to note that saving money on utility bills was the dominant issue. Brand name, builder recommendations and financing the system on a mortgage are clearly less important to these respondents than are factors dealing with money savings, maintenance, and product performance. It was surprising that environmental benefits was ranked so low by these respondents.

Obviously there are other market forces that contribute to the sales of SDWH's. For example:

- In Australia, Germany, and USA, consumers voluntarily pay more for electricity that is generated from renewable resources,
- Solar is only choice for DHW in many parts of China. The utility infrastructure simply could not meet the demand if every home heated its water from its energy distribution system,
- Solar is a societal decision in Israel. Virtually all residences are required by law to use a SDWH,
- Solar has strong government encouragement in Greece.

Table 4. Perceived Disadvantages of Solar Water Heating

Too expensive to install	29%
Not enough sun for solar energy	21
Not as much hot water capacity	14
Appearance	14
Takes longer to get hot water	9
Too much maintenance	8
Not save any/enough money	3
One more thing to break down	1

Table 5. Relative Importance of Purchase Decision Factors

The amount of maintenance required	88%
The type of warranty provided	87
The hot water delivery capacity of the system	83
Money saved on water heating bills each month	83
The price of the system fully installed	82
Increased value of the home	75
Receiving tax benefits	73
The size and appearance of the system	70
Helping to clean the air	70
Ability to finance the system on your mortgage	51
The brand name on the equipment	33
A builder recommendation	32

4.3 Durability & Reliability

SDWH's that have electronic controls, pumps, freeze resistant heat transfer fluids, air vents, mixing valves, etc. require a certain amount of maintenance. To get a better feeling of how long systems last, opinions from 28 Service Contractors and Installers of SDWH's were obtained via a survey/interview process in 1997. (Ramirez-Vargas et al., 1998) The process included a comprehensive written survey and a follow up interview. The service areas selected were in Arizona, California, Nevada, and Oregon. The salient results are given below and in Table 6.

- The mean lifetime for pumps and plumbing fittings was almost half of that for the collectors, temperature sensors, tanks, pipe insulation and heat transfer fluid.
- The most reliable components were drain ball valve, horizontal shaft pump, glass cover and collector enclosure.
- The least reliable components were mixing/tempering valve and untreated pipe insulation.

It was very revealing that the service/installers themselves identified that improper installation was the largest factor contributing to the relatively high maintenance cost of the SDWH's.

4.4 Performance Assurance

Standardized performance tests have proven to be an essential tool for both marketing and system development. Desirable features of a SDWH Thermal performance test method include:

- Long term performance prediction,
- Ability to compare relative performances of systems,
- Use as a diagnostic tool to improve system performance,
- Predict performance variations for different solar/meteorological sites, hot water demand load and hot water load profiles.

Table 6. Mean Life Time of System Components

Mean Life Time (years)	
Air vents	6 ± 2
Collectors	19 ± 5
Storage tanks	11 ± 2
Check valves	7 ± 2
Controllers/Sensors	7 ± 2
Insulation	8 ± 1
Glycol Fluids	5 ± 1
Mixing/Tempering valves	6 ± 1
P/T relief valves	7 ± 2
Pumps	8 ± 1

Most Frequent Maintenance Problems

1.	Air Vent Valves
2.	Glycol degradation
3.	Freezing
4.	Controller/sensors
5.	Pump

Problem facing the SDWH Industry today?

High initial cost	75%
Bad experience with solar	60
Low cost of natural gas	30

Factors causing most maintenance problems with SDWH's?

Improper installation	57%
Bad water quality	52
Lack of regular maintenance	44

ISO (International Organization for Standardization) is the world's largest non-government body developing voluntary technical standards for business, industry and government users. It members are the national standards organizations of about 110 countries, one from each. Located in Geneva, Switzerland, ISO has developed 10,000 international standards since 1947. (ISO, 1999).

ISO TC 180 Solar Energy was established in 1979. Its Secretariat is the Standards Association of Australia. Presently, ISO TC 180 has 56 members. Its accomplishments resulting from its eleven working meetings are summarized in Tables 7-9. (ISO 9459).

The work is carried out in various subcommittees. The standards related to SDWH's are being developed in Sub-Committee 4. The American Society for Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) is the secretariat for SC 4. Its activities are summarized in Table 8.

Table 7. Work Items in ISO TC 180 SC4 Systems –Thermal Performance, Reliability and Durability

ISO 9459-1	Performance Rating Using Indoor Test Methods
ISO 9459-2	Performance Test for Solar-Only Systems
ISO 9459-3	Performance Test for Solar Plus Supplementary Systems
ISO/CD 9459-4	System Performance Characterization by Means of Component Tests and Computer Simulation
ISO/DIS 9459-5	System Performance Characterization by Means of Whole System Tests and Computer Simulation
ISO/DIS 1924	Test Methods to Determine Reliability and Safety
ISO/NP 12595	Commissioning Test for Solar Hot Water Systems
ISO/TR 12596	Swimming-Pool Heating Systems-Dimensions, Design and Installation Guidelines
ISO/WD 12598	Code of Practice for Installation for Health and Safety / Thermal Performance Test

International Standard ISO 9459 has been developed to help facilitate the international comparison of solar domestic water heating systems. Because a generalized performance model which is applicable to all systems has not yet been developed, it has not been possible to obtain an international consensus for one test method and one standard set of test conditions. Therefore, ISO 9459 is being developed with five parts.

Table 8. Work Items in ISO TC 180 SC5 Collectors and Other Components

ISO 9806-1	Test Methods for Solar Collectors – Thermal Performance of Glazed Liquid Heating Collectors Including Pressure Drop
ISO 9806-2	Test Methods for Solar Collectors – Qualification Test Procedures
ISO 9806-3	Test Methods for Solar Collectors – Thermal Performance of Unglazed Liquid Heating Collectors (Sensible Heat Transfer Only) including Pressure Drop

Actually, Parts 1-3 are complete and have been published as an ISO standard. Table 9 is a brief comparison of these standards. The five parts are:

1. Performance rating using indoor test methods,
2. Outdoor test methods for system performance characterization and yearly performance prediction of solar-only systems,
3. Performance test for solar plus supplementary systems,
4. System characterization by means of component testing and whole system simulation,
5. System performance by whole system testing and computer simulation.

The system rating used by the Solar Rating & Certification Corporation is very similar to the procedure in ISO 9459 Part 4. SRCC has adopted TRNSYS for Predicting SDWH Performance. In carefully controlled experiments at Colorado State University for a two-tank drain back system, TRNSYS predicted performance within 10% for a wide range of operating conditions. (SRCC, 1999).

4.5 Annual costs for heating residential water

Solar water heaters have two very positive impacts, namely, reduced urban pollution and a slowed rate of fossil fuel depletion. A life-cycle-cost model will be used to illustrate the total cost and benefits of ownership. (Wood and He, 1992) The mix of power generation technologies and fuel sources will be taken into account as well as the service life of individual components that comprise the system.

Table 9 Comparison of ISO 9459 Parts 1-5.

Part	System Types	Methodology	Outcome	Duration/Cost
1	All w/ flat plate collectors	Whole system w/ Solar Simulator for standard test day	Rating for one set standard conditions	3-4 days high
1	All w/pumped circulation	Whole system w/Thermal Simulator for standard test day	Rating for one set standard conditions	3-4 days medium
2	Solar preheat	Whole system outdoor test for daily heat gain w/o load	Annual monthly energy gain w/o load	6-10 days low
3	All	Whole system outdoor test for daily performance w/ daily load averaged over 5-10 days	Annual monthly solar fraction w/single load	6-10 wks low
4	All w/TRNSYS models	Component tests as needed w/ component models	Simulation of all aspects of performance	1-2 wks medium
5	All	Whole system outdoor transient test w/daily load	Generalized simulation model calibrated from test data	10-15 days medium

The typical US Water Heater is

- 200 liter electric EF≥0.86,
- 150 liter gas EF≥0.54,
- 240 liter/day with 43 C temperature rise,
- Load profiles: Morning, Evening, Distributed, or Balanced.

The Life-Cycle-Cost is simply all of the costs associated with the installation and operation of the SDWH during its service life. Using time value of money LCC can be expressed in terms of an equivalent annual cost. Table 11 lists the basic assumptions in a simplified LCC model.

Table 10 lists the primary environmental emissions produced in heating domestic water. The emissions for the electric water heater are based on electricity being generated by a mixture of fuels: Coal 55.5%, Natural Gas 9.4%, Nuclear 20.6%, Oil 4.2%, Hydro and other 10.3% This is the approximate distribution for the whole United States. Using a very conservative life-time of ten years the annual cost for heating water is given in Table 11.

Table 10. Environmental Emissions Produced in Heating Water

	Natural Gas ($kg/10^6$ kJ)	Electric ($kg/10^6$ kJ)
SOx	0.00026	2.38
NOx	0.043	0.44
COx	0.050	0.89

Table 11. Annual Costs for Heating Domestic Water

Annual cost for 10 year service life		
Electricity Costs	$0.06/kWh	$0.10/kWh
Solar Fraction = 0.60 Installed cost = $2,000		
EF = 0.88 EF = 0.97	$446 $429	$542 $515
Solar Fraction = 0.70 Installed cost = $3,000		
EF = 0.88 EF = 0.97	$527 $514	$599 $578

The Energy Factor, EF is defined as (useful energy delivered)/(energy consumption)

The California Energy Commission (1998) has developed a comprehensive economic model for solar water heaters in collaboration with the solar industry.

4.6 Installation Aesthetics

During the last decade there has been an increasing demand to make SDWH's aesthetically pleasing. In the beginning of the SDWH industry, maximum performance took precedence over appearance. The new home market has changed this. The vast majority of subdivisions throughout the US have restrictions as to what can be placed on the roof and street side of the house. Figure 9 is a picture giving a typical installation before 1990. Figure 10 illustrates the kind of installation that consumers prefer today. The collector is flush mounted or integrated into the roof. The appearance of a skylight is very acceptable.

5. A NEW BEGINNING IN THE USA

A number of new initiatives to increase the sales of packaged solar water heaters have recently been initiated within the US.

The federal government has issued Executive Order 13123 *Greening the Government Through Efficient Energy Management* Sec. 204. Renewable Energy of that order states that *Each agency shall strive to expand the use of renewable energy within its facilities and in its activities by implementing renewable energy projects and by purchasing electricity from renewable energy sources. In support of the Million Solar Roofs initiative, the Federal Government shall strive to install 2,000 solar energy systems at Federal facilities by the end of 2000 and 20,000 solar energy systems at Federal facilities by 2010.* (DOE, 1999)

The Million Solar Roof Initiative (1999) was officially announced June 1997. The goal is to install one million solar energy systems on U.S. rooftops by 2010. The primary purposes for this initiative are:

Fig. 9. Typical installation method in USA before 1990.

Fig. 10. Flush mounted installation is now preferred in USA.

- Slowing greenhouse gas emissions,
- Expanding our energy options,
- Creating high-technology jobs,
- Building on existing momentum,
- Keeping U.S. companies competitive,
- Relying on market forces and consumer choice,
- Marshaling existing federal resources,

Solar Technologies that qualify for the MSRI are: photovoltaic (PV) systems, solar water heating, and solar

space heating systems that provide energy to homes or buildings. To date, the federal government has supplied very little money in MSRI but it has generated lots of interests. As of July 1, 1999 MSRI Partnerships have registered 284 solar systems that have been installed under the MSRI.

Pulte Homes, the USA Largest Home Builder sells 18,000 homes annually. Its Las Vegas, Nevada division builds 1,100 homes annually. This Division has developed some innovative strategies for integrating energy conservation into new home construction and has shown that in the Las Vegas Market energy efficient homes have Consumer Market Value to the extent that its homes are very competitive in the market. Beginning in July 1999 Pulte – Las Vegas will offer SDHW as a standard option. Pulte Homes is part of the Nevada MSRI.

6. SUMMARY & CONCLUSIONS

The authors have attempted to give a brief overview of:

- World SDWH Market
- SDWH Technology Development
  - Products types
  - New Products
- Understanding SDWH Consumer Market Value
  - Consumer market study
  - Quality Assurance through Standards
  - Various Market Forces

What can we expect in product development?

- Innovative Concepts and ideas to support the industry,
- Utilization of new materials to improve cost/performance ratio of equipment.

What can we expect in market development?

- Only a few Production Builders understand that energy efficiency sells homes. This is rapidly changing.
- Outside investors will begin to invest in SDWH's development and marketing within the next 5-10 years.

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