Solar Water Heating Systems
A review of global experiences

reeep renewable energy & energy efficiency partnership

Ministry of New and Renewable Energy
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STFI SOLAR THERMAL FEDERATION OF INDIA





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Introduction

A Solar Water Heating System (SWHS) is a device that makes available the thermal energy of the incident solar radiation for use in various applications by heating the water. The SWHS consists of solar thermal collectors, water tanks, interconnecting pipelines, and the water, which gets circulated in the system. Figure 1 illustrates the simplified form of working of a SWHS. Solar radiation incident on the collector heats up the tubes, thereby transferring the heat energy to water flowing through it. The performance of the SWHS largely depends on the collector's efficiency at capturing the incident solar radiation and transferring it to the water. With today's SWHS, water can be heated up to temperatures of 60 °C to 80 °C. Heated water is collected in a tank insulated to prevent heat loss. Circulation of water from the tank through the collectors and back to the tank continues automatically due to the thermosiphon principle[1] . The hot water generated finds many end-use applications in domestic, commercial, and industrial sectors.

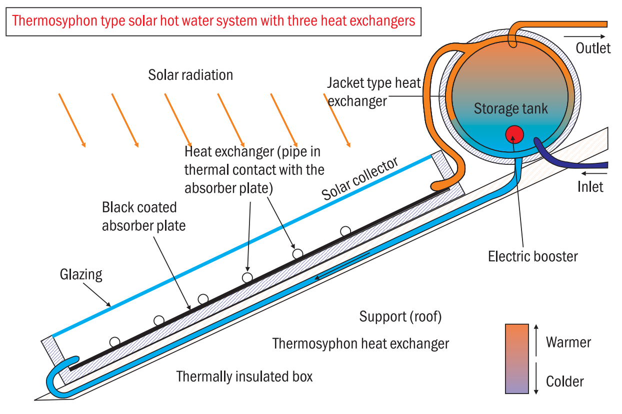

Figure 1 Diagrammatic representation of working of solar water heater [2]

Need for SWHS

Most of the hot water demand in various applications is met by heating water through conventional energy, that is, electric geysers running on largely fossil power or natural gas based heating systems. Apart from being highly polluting, conventional electric heaters consume only a percentage of the actual electricity that is dispatched from the power plants across long transmission distances, which have large transmission losses. A good reason to use SWHS instead of conventional energy based systems, is that it offsets those greenhouse gases that would have been generated had the water been heated by electric power or natural gas.

Most of the times, water heating (especially in the domestic sector) coincides with the peak load timings of the grid. This results in higher peak loads if most of

[1] Solar water heater: A device operating on renewable energy

[2] Details available on <http://www.q-s olar.com/img/products/jacket_thermosyphon.gif>, last accessed on 13 October 2010

Figure 2 Flat plate solar water heaters on residential rooftops[3]

Figure 3 Flat plate solar collector panels installed in residential rooftops in Hawaii

the hot water demand is being met from conventional electric heaters. From the point of view of demand side management, it becomes indispensable to adopt non-conventional energy-based and energy efficient technologies, which can generate hot water with minimal requirements and dependence on fossil fuels, thereby contributing to shaving off the peak load. On the industrial front, a major portion of thermal energy requirements in the sector lies in the temperature range of 50 °C–250 °C, which corresponds to the low/medium temperature range of solar thermal systems. These include dairy, food processing, textiles, hotels, edible oil, chemical, marine chemicals, bulk drug, breweries, and distilleries. Many of these industries also use hot water in the range of 70 oC–90 oC .These requirements are presently met primarily by combustion of fossil fuels like coal, lignite, and fuel oil.

Solar energy, being abundant and widespread in its availability, makes it one of the most attractive sources of energies. Tapping this energy will not only help in bridging the gap between demand and supply of electricity but shall also save money in the long run. According to the Ministry of New and Renewable Energy (MNRE), Government of India, a 100 litre capacity SWHS can replace an electric geyser for residential use and may save approximately 1500 units of electricity, annually, under Indian conditions. Thus, a typical family can save 70%–80% on electricity or fuel bills by replacing its conventional water heater with a solar water heating system. It has also been estimated that a 100 litres per day (lpd)[4] system (2 m^2 of collector area) installed in an industry can save close to 140 litres of diesel in a year. So also, usage of solar water heater to supply pre-heated boiler feedwater can help saving 70%–80% of fuel bills.

Reduction of pollution and preservation of environmental health are some of the co-benefits of this technology. This is probably why the use of solar energy for water heating has become one of the largest applications of solar thermal systems[5] today. Based on the above-mentioned equivalence (100 lpd system saves 1500 units of electricity), it is estimated that in generating the same amount of electricity from a coal-based power plant, 1.5 tonnes of CO_2 is released into atmosphere annually. One million SWHSs installed in homes will, therefore, result in reduction of 1.5 million tonnes of CO_2 emission into the atmosphere . Clearly, SWHS is one of the most cost-effective, viable, and sustainable options available for hot water generation today.

Status and trends: global and Indian experiences

The demand of SWHSs has been increasing significantly in the few past decades and studies[6] have shown that

[3] <http://www.targetbuildinginspections.com/home-inspection-blog/2010/4/6/inspecting-solar-water-heaters.html>

[4] Lpd= Litres per day

[5] Muthu S. 2003. *Solar water heater – challenges and prospects. In Avinashilingam Institute for Home Science and Higher Education for Women, Domestic Use of Energy Conference*. Cape Town, South Africa.

[6] Solar Water Heating System (Potential and Savings)

SWHS installations are increasing throughout the world. As a result, the global solar market achieved a growth rate of 15% in 2007.

Solar thermal energy for domestic heating purposes is common all over the world with significant market penetration in Australia, China, Europe, Israel, Turkey, and Brazil [7]. The existing capacity of solar water heaters across the globe has increased from 125 Gigawatt-thermal (GWth) to 180 GWth in a span of two years (2007–2009) as shown in Figure 4. China and Germany are the world leaders in terms of the number of SWHS installations. They are followed by Turkey, Brazil, and India in that order. In terms of existing capacity, China is still the leader, followed by Turkey, Germany, Japan, and Greece. Globally, China and the European Union are the two largest markets for solar water heaters. At the end of 2008, the solar thermal capacity worldwide, in operation, was 171 GWth, of which almost 59% (101 GWth) took place in China. Provisional numbers suggest that 2008 witnessed further 42% growth in the Chinese market (IEA 2009) (See Figures 5 and 6).

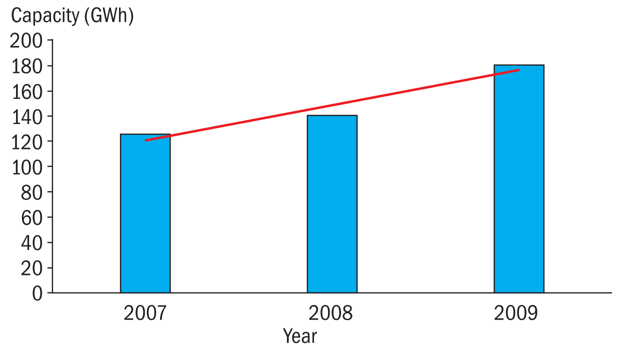

Figure 4 Trend in capacity addition of solar water heating systems (2007–2009)[8]

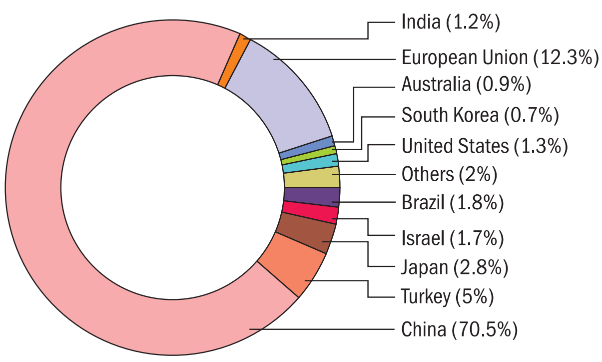

Figure 5 Global picture of SWHS in 2008[9]

An interesting example of successful replacement of existing heating systems with SWHS is that of South Africa's as it has a number of learnings worthy of emulation. Although it does not figure among the top 5 achievers of the world in SWHS installations, South Africa has abundant sunshine and the average daily solar radiation is between 4.5 kWh/m^2 and 6.5 kWh/m^2. It is relatively predictable and well distributed throughout the country, with some regional variations. The country has an established manufacturing infrastructure for SWHSs. The South African experience with SWHS can be chronologically phased as below.

Phase 1 (1978–1983) This phase was marked by the widespread acceptance and installation of SWHs. The government supported the promotion of SWHs with the Centre for Scientific and Industrial Research (CSIR), which developed effective communication strategies and projects by motivating home-owners to install them. Home owners would pay, either with a home improvement loan, or through cash. The SWH market grew mostly among the middle-to high-income customers. In 1983, about 27 000 m^2 of solar collectors were produced. In that year, the SWH communication project of the CSIR came to an end and the market collapsed and has not yet recovered (Figure 7).

Phase 2 (1984–2003) The collapse of the SWH market happened during this period. SWH installations dropped and annual glazed collector installations were about half of what they had been in the previous phase.

Phase 3 (post–2003) The White Paper on the Renewable Energy Policy of the Republic of South Africa, prepared by the Department of Minerals and Energy, Pretoria in 2003 gave a new perspective and created renewed interest in the field. The city of Cape Town has taken the initiative to supporting RE and ensuring that 10% of the households have SWH systems by 2010. For this, it has initiated a number of activities to promote the technology such as drafting a bylaw to promote SWHS, to retrofit low-income homes with SWHS, and so on.

The SWHS industry in the country is currently experiencing a revival. The media have begun covering the industry extensively. SESSA50[10] is another project, which installed subsidized SWH and collected data for a detailed

[7] Renewable Energy Essentials: heating and cooling, IEA Report (2009)
[8,9] REN 21 Global Status Report (2010)
[10] The Sustainable Energy Society of Southern Africa (SESSA)

assessment of the technology. At the SWH workshop held at the International Conference on the Domestic Use of Energy in Cape Town in April 2007, Eskom[11] presented its new approach to solar water heating and its inclusion into Eskom's Demand Side Management Programme. In June 2007, the Eskom Board approved the investment of R 2 billion [12] to be made over five years. This is expected to have a positive impact on the SWH industry in South Africa.

China, on the other hand, continues to dominate the global solar hot water industry. Chinese companies manufactured 28 million m^2 of systems in 2009, representing 80% of global solar hot water heating output, the dominant manufacturer being Himin Solar Energy. Although the European solar hot water heating industry has been marked by acquisitions and mergers among leading players in that market, it has managed to show a healthy growth of more than 12% annually during 2001–07, and a shift toward increased use of systems for space heating in addition to hot water. World-over, the residential sector has the largest market share in the solar water heater market. Majority of the SWHSs are installed in urban areas. An estimated 70 million households worldwide now employ solar hot water heating by sector[15].

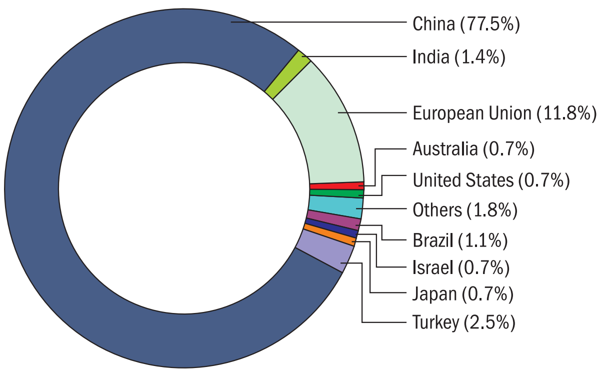

Figure 6 Global capacity additions in 2008[13]

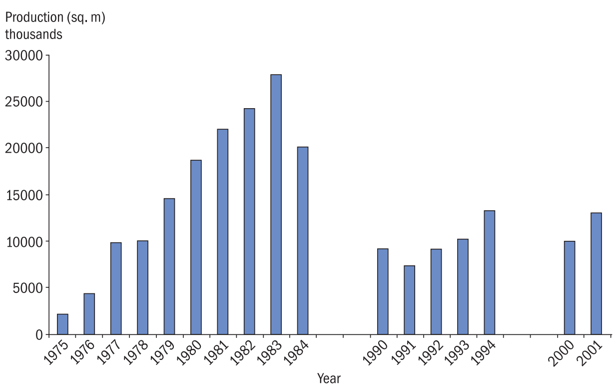

Figure 7 Solar collector production in South Africa (1975–2001)[14]

Experience of UNDP–GEF with SWHS projects

The Global Solar Water Heating Market Transformations and Strengthening Initiative, a programme by the United Nations Environment Programme (UNEP)[17], being implemented in India by the United Nations Development Programme (UNDP)[18] , aims to accelerate the commercialization of solar water heating on a global

Figure 8 Solar Systems installed at Infosys, Bengaluru[16]

[11] Eskom – South Africa's electricity generation and supply company
[12] 1 R (South African Rand) = 0.146 US$
[13] REN 21 Global status report 2010
[14] Case 19 – Solar Water Heaters, Cultural Influences on Renewable Energy Acceptance and Tools for the development of communication strategies to promotE ACCEPTANCE among key actor groups, study co-funded by European Commission; G Prasad; July 2007
[15] Global Trends in Green Energy 2009: New Power Capacity from Renewable Sources Tops Fossil Fuels Again in US, Europe
[16] Ministry of New and Renewable Energy
[17] United Nations Environment Programme
[18] United Nations Development Programme

scale, thereby transforming the market and reducing the use of electricity and fossil fuels for heating water. The initiative's first phase includes two components—developing a global knowledge base, and establishing specific programmes in six countries. The knowledge management (KM) component (being carried out by UNEP) comprises the creation of a vast online knowledge base that will include comprehensive information on financial incentives, policy, standards, and other SWH subjects, as well as the latest industry news and technology trends. The country programmes are to be launched in Albania, Algeria, Chile, India, Lebanon, and Mexico during the initiatives' first phase, and will focus on overcoming the barriers and supporting the activities needed at a national level to stimulate sustainable SWH market development.

The UNDP–Global Environment Programme (GEF) programme in China has been quite successful. As of March 2007, the programme achieved two major targeted outcomes, that is, the creation of a favourable environment for the commercial adoption of renewable energy and the widespread adoption of renewable energy technologies (RET), including SWHSs. To achieve these outcomes, the programme undertook the several activities that helped in the upliftment of SWHS in the Chinese market. These activities include the following.

- Organizing several events (workshops, international study tours, training events, domestic and international conferences, and press conferences) to build national and local capacity
- Development of the National SWH Testing and Certification Programme, in cooperation with the Government of China (includes the development of new standards, support for the establishment of three SWH National Test Centres, and the development and promotion of the certification programme for SWH products)
- Support for the legislative process required for developing China's Renewable Energy Law, which was put into effect on 1 January 2006. Technical assistance was also provided to the strategic planning process of the central government to develop roadmaps and national action plans for renewable energy development.
- Apart from SWHS, activities were also undertaken to bolster the wind resource assessment in China, its rural electrification programme, and biogas programme.

Figure 9 One family shows off its new SWH system

In South Africa, the Central Energy Fund—a government-supported company managing the future energy needs of the country—subsidized 500 SWHs with funding from GEF and UNDP , which were installed in the first half of 2007. In each of the three major cities—Johannesburg, Durban, and Cape Town—165 systems were installed. The project was advertised in the newspapers and it had a positive demonstration effect and renewed customer interest in SWH and encouraged the SWH industry.

Elsewhere, the Lebanese Centre of Energy Conservation Project [19] was founded in 2002 by the GEF and is managed by the UNDP. Its instructions are directly executed by the Lebanese Ministry of Energy and Water and it assists the Lebanese government in promoting solar water heater systems in the Lebanese market. It also lends a helping hand when it comes to marketing, awareness raising, policies, and regulations. It provides free, practical advice for business and public sector organizations, with the goal to decrease the use of energy.

Experience of REEEP with SWHS projects

The Renewable Energy and Energy Efficiency Partnership (REEEP), a global public-private partnership and an international NGO, focuses on reducing barriers that are limiting the uptake of renewable energy technologies in several developing countries. By providing opportunities for concerted collaboration among its partners, REEEP aims to accelerate the marketplace for renewable energy and energy efficiency. Table 1 summarizes some of these projects.

[19] *Source* Global Solar Thermal Energy Council website - http://www.solarthermalworld.org/node/948,, accessed on 17.10.2010

Table 1 Summary of REEEP projects on promoting solar water heaters[20]

S. No.	Country(s)	Project name	(Expected) impacts
1	South Africa	Commercialization of large-scale SWHSs	The project was E and Co.'s first-ever investment in a SWH, end-user financing company. The project raised awareness of local banks and other stakeholders of the potential of the SWH sector. Shortly after the project, ABSA Bank, one of the banks engaged by E and Co. during the project, released a home loan option.
2	Brazil and the Caribbean region	Innovative financing to accelerate solar water heating	This project has contributed to the broadening of activities and sources of financial support for renewable energy and energy efficiency systems (REES), by directly contributing to the engagement of local investors in Brazil who established CBE Solar. This company now has three solar fee-for-service projects in operation. This project contributed to the development of market-based innovative sources of finance. The solar fee-for-service business model is similar to those used for the provision of other services at the domestic level, for example, cable television and satellite television. Hence, the solar fee for service business model can be classified as an adaptation of an "orthodox" financial mechanism and business structure to the solar market.
3	South Africa	Developing a vehicle for SWH mass implementation in SA, and extending the existing REEEP manual	Set the process in place for the establishment of vehicles for, and implementation of, SWHs on a mass scale in three cities, leading to similar rollout in other cities. Improved energy security for cities due to peak load reduction, as well as financial benefits due to reduced peak power needs.
4	Uganda*	Promotion of SWHs (agreed by REEEP with Government of Uganda)	Create awareness about the benefits of solar water heaters among city planning authorities, Ministry of Housing, professional bodies of architects and engineering professionals, and the general public Establish appropriate financing mechanisms for manufacturers, vendor companies and consumers Establish standards and guidelines for integrating solar water heaters in buildings
5	Brazil (Latin America and the Caribbean)	Brazil solar water heating and energy efficiency development	Organize an international seminar for information exchange with state-of-the-art specialists and technology providers Investigate the technology, finance, policy, environment, and social barriers for SWH development in Brazil Definition of technical standards for low income household SWH systems Support government to set up SWH finance mechanism for low income population Provide M&V for a SWH pilot project that would support the scale up plans
6	South Africa (Southern Africa)	Combined legislative and financial mechanisms for solar water heater mass rollout	Support for city of Cape Town leading to implementation of SWH bylaw—estimated additional 10 000 SWH units pa 6.25 MWpa, 20 000 T CO_2 pa Support Ekurhuleni to move forward in SWH bylaw process—may not be implemented by project end Capacity building and support in rolling out the legislation to other municipalities through the Department of Provincial and Local Government—the national government structure whose mandate is to link the different spheres of government. Continued work with government to support the development of SWH mass implementation business in the country.

*Refer to Box 1 (**Source** "Uganda Government turns to Solar Water Heaters", 28-09-2010,www.greenbaba.com;

[20] www.reeep.org

Current status in India

In India, the first serious attempts to deploy the technology were made with the formation of the Department of Non-Conventional Energy Sources (DNES) [21] in 1982, though the history of research and pilot-demonstration go back to the 1960s. The continuing increases in electricity tariffs as well as problems associated with the electricity supply such as outages and voltage fluctuations have forced users to look for alternate means of which solar hot water system is one of the options. Most parts of India receive high amount of solar radiation, which makes solar water heating an attractive and viable option. Today, India ranks fifth in terms of the number of SWHSs installation, accounting for 1.4% of the total heating capacity through solar water heaters around the world [22] (REN21 Global Status Report 2010). Table 2 lists down the Indian solar water heating scenario as per UNDP–GEF Global Solar Water Heating Project.

It can be seen from Figure 6 that the total installed collector area increased from 119 000 m^2 in 1989 to 525 000 m^2 in 2001 to 2 650 000 m^2 in 2008. And, going by this trend, the number is going to rise. Up until 31 October 2009, 3.12 million m^2 of solar water heating collector area was achieved.

Box 1 Promotion of solar water heaters: a REEEP funded project with Government of Uganda

In Uganda in 2008, the energy ministry launched a two-year pilot project aimed at encouraging the use of solar water heaters. In two years, they have installed 500 solar water heaters in Kampala and Entebbe and over a period of six years, they plan to install 65 000 solar water heaters. The REEEP Uganda project focused on electricity during peak hours by switching water heating in households and institutions from electricity to solar water heating. The project succeeded in establishing appropriate financing mechanism for manufactures, vendor companies, and consumers, helped the government develop policies to promote the technology in the country, establish standards and guidelines for integrating SWH in buildings, and prepare an investment plan to finance replication and scale up of SWH use. Through this project, the government manages to save 1 MW of electricity during peak hours.

Table 2 Indian scenario of solar water heating [23]

Techno-economic potential	40 million m^2
National Solar Mission goal	20 million m^2 by 2022 7 million m^2 by 2013
Demand projection	5.4 million m^2 by 2013 18.7 million m^2 by 2022
Cumulative achievement	3.52 million m^2 up to 31.03.10
Pre-project baseline	2.55 million m^2 as on 30.09.08

Figure 10 illustrates the SWHS installation scenario in India. Residential sector is the largest sector, both in terms of installations as well as sales. As per industry estimates, currently, almost 70%–80% of the SWHS sales occur in the residential sector (Figure 11). In the year 2001, almost 80% of the SWH installations in India were in the commercial and industrial sectors. Since then, the residential sector has overtaken commercial and industrial sectors and has become the main driver of growth of SWHS in India. Almost 60% of these households are located in two states—Karnataka and Maharashtra. More than 95% of these households are located in the urban areas. Diffusion of SWHSs in industrial sector is limited and scattered.

Policies that influence SWHS

To meet the increasing demand, some countries have mandated the use of solar water heaters in certain

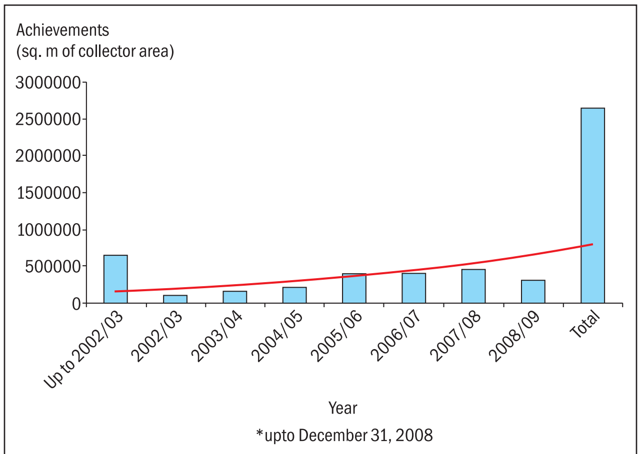

Figure 10 Total SWHS installations in India[24]

[21] Now Ministry of New and Renewable Energy
[22] REN21 Global Status Report, 2010
[23] UNDP/GEF Global Solar Water Heating Project
[24] Ministry of New and Renewable Energy (Last visited in September 7, 2010)

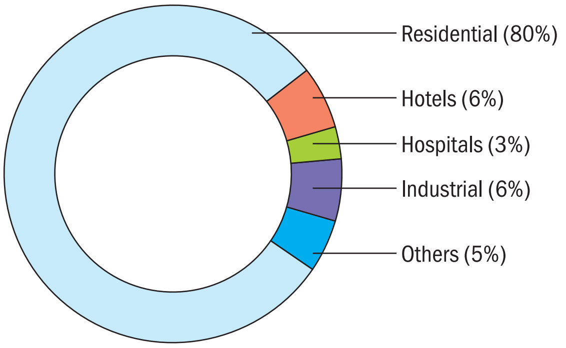

Figure 11 SWHS installation in India in different sectors[25]

Figure 12 SWHS installed in residential rooftop in Bengaluru, India

sections of the society. Various policy measures have been taken by the governments of different countries to promote large-scale use of solar water heaters in various sectors. These measures include several mandates and targets, mainly in the building sector. For promotion of solar water heaters, some financial incentives have also been offered by the governments of various countries. At least 20 countries (several more are expected to follow suit) provide capital grants, rebates, VAT exemptions, or investment tax credits for investments in solar hot water heating. Table 3 summarizes some of these policy measures taken in different countries.

ESCO-based model for SWH promotion

The initial Energy Service Company (ESCO) started in Europe more than 100 years ago. Over the last ten years,

Table 3 Summary of some policy measures across various countries in the world [26]

Country	Policy
China	Target for solar hot water: 150 million m^2 by 2010 and 300 m^2 by 2020 50% of buildings with solar hot water by 2010 in Denzhou and Kunming Requires solar hot water in all new residential buildings up to 12 stories, and in new construction and renovation of hotels and commercial buildings in Lianyungang
Morocco	Solar hot water: 400 000 m^2 by 2012 and 1.7 million m^2 by 2020
Singapore	Solar hot water: 50 000 m^2 by 2012
Tunisia	Solar hot water: 740 000 m^2 by 2011
Uganda	30 000 solar water heaters
Spain	100 000 m^2 of solar hot water by 2010 in Barcelona
UK	1000 buildings with solar hot water by 2010 10% of homes in Oxford by 2010
South Africa	10% of homes with solar hot water by 2010 in Cape Town
Spain*	Mandates 60% of hot water heating energy from solar in all new buildings and major renovations in Barcelona
Brazil	Requires all public buildings to use solar hot water for 40% of heating energy in Rio de Janeiro Grants for solar hot water in buildings in Porto Alegre
Japan	Requires property developers to assess and consider possibilities for solar hot water and other renewables and to report assessments to owners in Tokyo
Germany	Subsidies for solar hot water (30%) on apartment buildings in Berlin
Italy	Subsidies for solar hot water (up to 30%) in Rome

* Refer to Text box 2

there has been an increased interest within Europe for the provision of energy services. An ESCO is defined as a company that would install, own, and operate RE systems, which in this case would be the SWHS, and provide energy services to consumers. Such companies are characterized by the following features.

- It guarantees the energy savings and/or provision of the same level of energy services at lower cost.

[26] REN21 Global Status Report, 2010

Box 2 Solar Water Heater installation success in Spain, Barcelona Model

In July 1999, the Barcelona Solar Thermal Ordinance (municipal legislation) was approved and it came into effect in August 2000. Subsequently, it was updated in 2006. The legislation permitted combination of technologies to achieve the ambitious target set by the city council and various Catalan local governments, thus, widening the market penetration. The existing building code "Código Técnico de la Edificación" (CTE) entered into force in 2006. Among the basic quality requirements for buildings, the CTE contains the DB•HE chapter, which aims, among others, at the efficiency of thermal installations (HE2 = RITE [25]) and the application of solar thermal systems for hot water preparation for domestic purposes and indoor swimming pools (HE4) in buildings. Besides financial assistance, the adoption of ESCOs for selling solar heat in order to facilitate the market introduction of these technologies or business models is considered to be the key success factor. The "Barcelona model" was adopted by other cities as Madrid or Seville. In February 2006, the Catalan Government adopted the so called Decree on Eco•efficiency, obliging all new buildings to install solar thermal energy systems. The Spanish transposition of the European Building Performance Directive (2002/91/EC), in force since September 2006, also includes the compulsory installation of solar thermal energy systems in new buildings.

- Its remuneration is directly tied to the energy savings achieved.
- It can either finance, or assist in arranging financing for the installation of an energy project they implement by providing a savings guarantee.

For setting-up large SWH installations in commercial buildings, industries, and large residential developments, the ESCO approach has the potential to become the most preferred implementation arrangement.

India's policies for SWHS and the Jawaharlal Nehru National Solar Mission

The central government, through Ministry of New and Renewable Energy (MNRE) provides soft loans/ capital subsidy for installation of solar water heating systems. These loans are being provided through 34 banks/ financial institutions at an interest rate of 2%–5% to various categories of users. However, soft loans are available to domestic users of solar water heating systems at 0% interest rate in states falling under special category. Rebates and accelerated depreciation are also being provided to residential and industrial/commercial customers, respectively [27].

In a separate initiative, a model regulation/building bylaw for mandatory installation of SWHS in new buildings was circulated by the Ministry of Urban Development to all states and Union territories with a request for onward circulation to all local bodies for incorporation in their building bylaws. Necessary orders have been issued in 21 states and 98 municipal corporations/municipalities have so far amended their building bylaws. A few municipal corporations such as Thane, Amravati, Nagpur, and Durgapur are providing 6%–10% rebate in the property tax for users of solar water heaters. Many of the utilities are providing rebate in electricity bills to the users as well.

The Jawaharlal Nehru National Solar Mission, also known as the National Solar Mission (NSM), is a major initiative of the Government of India in the field of climate change and energy security to promote ecologically sustainable growth, while addressing India's energy security challenge through harnessing of solar energy. Solar water heaters are also an integral part of the NSM. It has ambitious targets to achieve—20 million m^2 of collector area of SWHSs by the year 2022. The target set for solar water heaters is as per Table 4. The key strategies of the NSM will be to make necessary policy changes to meet this objectives, ensure the introduction of effective mechanisms for certification and rating of manufacturers of solar thermal applications, facilitate measurement and promotion of these individual devices through local agencies and power utilities, and supporting the upgradation of technologies and manufacturing capacities through soft loans, to achieve higher efficiencies and further cost reduction.

Table 4 Target set for SWHS as per JNNSM[28]

	Cumulative target (Million m^2)	Addition during the phase (Million m^2)
Phase I (2010–13)	7	3.45
Phase II (2013–17)	15	8
Phase III (2017–22)	20	5

[27] Solar water heaters in India: Market assessment studies and surveys for different sectors and demand segments
[28] JNNSM, MNRE

The financial incentives have recently been modified under the JNNSM. As per this scheme, 30% of the system cost or Rs 3300/- per square metre of collector area installed under flat plate collector based system and Rs 3000/- for evacuated tube collectors (ETC) based system is available as capital subsidy. In addition, soft loans at 5% on 50% of the cost of the system is available through various banks/financial institutions. However, the capital subsidy for the users in special category states such as Himachal Pradesh, Jammu and Kashmir, Uttarakhand, north eastern states, and islands is Rs 6600/- and Rs 6000/- per square metre of collector area installed for the FPC and ETC based systems, respectively.

The scheme could be implemented through various channel partners like renewable energy service providing companies, financial institutions/aggregators, system integrators, NGOs, and various central/state government departments/agencies. These channel partners, other than the central/state departments, need to get accredited for participating in the scheme to get direct financial support from the Ministry. Details of the scheme are available on the Ministry's website.

UNDP–GEF project on solar water heating in India

MNRE is implementing a UNDP–UNEP–GEF project on "Global Solar Water Heating Market Transformation and Strengthening Initiative" under UNDP's India country programme. The objectives of the project are: (i) accelerating and sustaining the growth of the solar water heating market in India and using the experiences and lessons learned in promoting similar growth in other countries participating in the global project; (ii) establishing a supportive policy and regulatory environment; (iii) building up the market demand; and (iv) strengthening the supply chain. The project will contribute partially to the Eleventh Plan target of 5 million m^2 through installation of 2 million m^2 of solar SWHS. As a result, nearly 25 million tonnes of GHG emission reduction will be achieved.

The gross potential for solar water heating systems in India has been estimated at 140 million m^2 of collector area. Of this, 40 million m^2 has been estimated as the realizable techno-economic potential at this stage. A total of 3.53 million m^2 of collector area has been installed so far in the country for solar water heating. A target of 7 million m^2 has been set by the JNNSM by the end of the first phase of the Mission (2010–13) and a goal of 20 million m^2 by the end of the third phase of the Mission (2017–22). Projections under a realistic scenario has found that the demand will increase in years to come and the national mission target would be almost achievable through this project by the end of 2022, that is, upto 18.7 million m^2 of area could be covered with SWHS installations as against the national target of 20 million m^2 (See Figure 13 and 14). Figure 14 shows the increase in the number of installation area across the country. Projected realistic scenario suggests that Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, and Gujarat would lead in SWH deployment by contributing about 67% of the country wide total [29].

In India, for setting-up large SWH installations in commercial buildings, industries, and large residential developments, the ESCO approach has the potential to become the most preferred implementation arrangement. The potential areas identified for the above demand segments are Gurgaon; Coimbatore; Leh, Ladakh; and, Haridwar/Rishikesh, Uttarakhand.

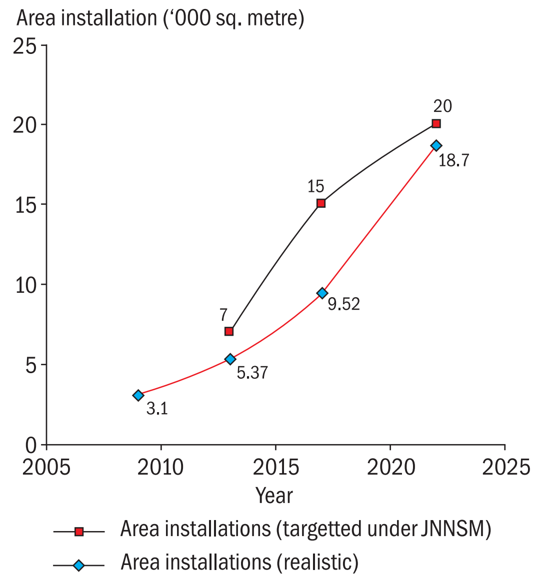

Figure 13 Projected scenario vs the JNNSM targets by 2022[30]

[29] Solar Water Heater (SWH) Market Assessment Studies and Surveys for Different Sectors and Demand Segments, study under

[30] Solar Water Heater (SWH) Market Assessment Studies and Surveys for Different Sectors and Demand Segments, A study for UNDP/GEF Global Solar Water Heating Project

Barriers in widespread adoption of SWHS

Despite being in the market for a number of decades, SWHS still finds limited application in getting integrated in the energy sector. The reasons for this could be variegated with respect to the context and the sector it falls in, but they all have a common essence that is made up of one or more of the following issues—lack of awareness among potential users, delivery/supply/service chains (including ESCOs), availability of SWHS products and components, capital cost, space availability to install the collectors (especially in industries and commercial establishments), and efficacy of regulatory interventions. Some of the significant barriers are discussed below with respect to markets and technology.

Market barriers

One of the major reasons behind its slow adoption is in the high capital cost of the system. This is the most common drawback in all the sectors where SWHS can find potential utility. Studies[31,32] suggest that this is the most common factor among the residential customers for whom economy of the technology is the prime concern (See box 3). They also find the maintenance cost higher and more cumbersome (in terms of getting qualified technicians) than that of electric heaters.

It is also suggested that in developing countries like India, the weakness in supply chains is a significant barrier in increasing the penetration of SWH. This is the reason why it is found more commonly in the commercial sector than the residential sector as in the case of India.[33]

Some other drawbacks are in the rural areas because of size and dispersion of the market and difficulty in installing conventional SWH systems on sloping roofs made of metal sheets, thatch, and so on. Lack of information, certification authenticity, or stringent specifications/standardization allows for many unqualified players to enter the market and supply low-quality systems that under-perform and cause discontent among users.

The above market barriers vary in the degree from region to region and from one sector to another. Although there is no single major barrier that deserves concerted

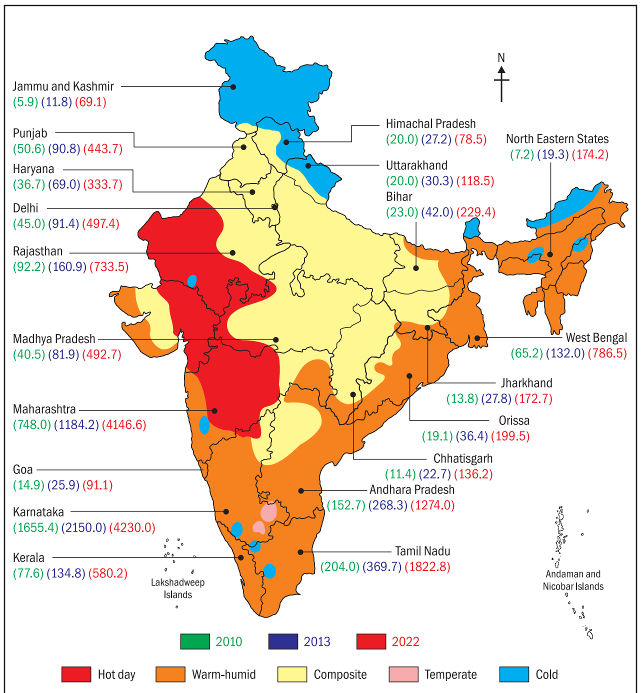

Figure 14 Estimated distribution of SWHS in India by 2022 [34]

attention, the issue of high capital cost remains a cause for concern leading to slow adoption of SWHS. Therefore, the lack of knowledge and information about SWH technology at the municipality and household levels calls for serious large-scale marketing and branding exercises in the residential and commercial sectors.

There remains a unanimous perception amongst the consumers that solar water heaters are more suited for independent houses compared to apartment buildings, hence, resulting in a lack of demand in large housing complexes, which would ideally have more roof space that is essential for an economically attractive SWHS installation. This disparity in perception needs to be addressed by suppliers wherein they tailor their solutions to specifically meet a certain type of demand, rather than promising to supply continuous hot water for many users through a single system.

For developing countries like India and China, the SWHS technology shows great potential to reduce the import of fossil fuels and shaving of peak loads, and this

[31] Painuly R and Reddy S.2004. Diffusion of Renewable Energy Technologies-barriers and stakeholders perspectives, *Renewable Energy*. **29**(9). pp. 1431–1447

[32] Sidiras D K and Koukios E G.2004Solar Systems Diffusion in Local Markets, *Energy Policy*. **32**(18). Pp. 2007-2018

[33] Painuly, R. & Reddy, S., 2004. Diffusion of Renewable Energy Technologies-barriers and stakeholders perspectives, *Renewable Energy*. **29**(9). pp. 1431-1447

[34] Market assessment of SWH in India, study under UNDP-GEF SWH project

Box 3 Design and implementation of new financing mechanisms and instruments for promotion of solar water heating systems in India

As part of UNDP–GEF project on solar water heating underthe UNDP's India country programme

The study was structured into the following four segments.

1 Segmentation of market for SWHS into domestic and non-domestic users
2 Assessment of financing needs of various user segments
3 Identification of financing instruments suitable for various user segments
4 Identification of channels through which financial assistance can be provided

The variables influencing the "affordability" and "financial viability" of SWHS were identified. Some of the key variables include capital cost, maintenance cost of SWHS, hot water consumption pattern, and geographical location of user. The cost-benefit analysis over the useful life of SWHS formed the basis for estimation of financial viability of SWHS from the user's perspective. A computational model was developed to estimate the difference between the net present value of the life cycle cost for SWHS and that for the existing water heating method of a user. It showed that financial assistance is required to enhance the affordability of the SWHS to the buyer. This financial assistance may be provided through the capital and/or interest subsidy scheme.

could lead to economic growth and jobs through adoption of the technology at a local level. Simpler business and financial models can be developed and local supply chains could be ameliorated with the assistance of local grassroots organizations like NGOs, social development institutions, educational institutions, and self-help groups.

Some form of incentive would still be needed for the adoption of SWHS, but there are ways to make the technology economically viable as has been the experience with some of the REEEP funded projects and studies in Brazil and the Caribbean region[35] . China, India, and Brazil may house some of the major solar PV cells and module manufactures focusing on the European market for distribution, but for SWH they have a sizeable market base within their own boundaries. China has great experience with solar thermal technologies and is one of the largest players in the use of the technology and the potential penetration of the SWH is very high. Other countries can gain a lot of experience and insight from the Chinese experience.

Technical barriers

Clearly, the need for improved quality components for the solar collector systems in India cannot be ignored. By using high quality low-iron glass, it is possible to increase the solar energy gain by 2%–6%. The primary barriers include lack of public awareness of the benefits of SWHS, lack of properly trained engineering and installation technicians, and the need for more research and development of improved designs of SWHS. The greatest technical challenge for efficient performance of solar hot water systems lies in their planning and installation.

There is a lack of technical capacity in designing properly sized solar systems and in integrating them with the existing systems, especially in large industrial and commercial systems. Moreover, solar water heating systems do not function well if they are not installed correctly. The dearth of trained and competent planning engineers and installation technicians creates a significant hurdle to the growth of the SWHS market.

Now, solar supply is greatest in summer, when there is no demand for heating, and lowest in winter, when the demand is highest. This resource-side barrier affects the performance of the system since for domestic hot water, even if the water temperature demand remains constant, more energy is needed in the winter to generate the same amount of heat as in the summer. Trade-offs between the surplus summer heat and smaller amount of heat in the winter must be considered to determine the size of the solar thermal system. Balancing this trade-off differs depending on the goals—economic optimization or highest possible coverage of heating load from solar energy.

Another important obstacle to the widespread adoption of SWHSs is the cost, which is significantly greater than the cost of conventional electric/gas water heating system. Solar thermal systems require high upfront costs. Payback time is often used as a criterion for decision-making; however, payback time does not account for the entire lifetime of the system and excludes long-term savings. Additionally, discount rates vary widely

[35] Solar thermal for hot water for domestic and industrial use, 28-09-10, http://climatetechwiki.org/technology/solar-thermal-hot-water

among customers and energy suppliers. So, technological innovations to bring down costs, is an area for intensive R&D.

Conclusions

The technology of solar water heaters is not very complex, but it has certainly advanced from simple design to more efficient systems. Technical innovation has also helped improve performance, life expectancy, and ease of use of these systems. Innovations have been made broadly in areas such as type of collector (flat plate, evacuated tube, concentrating); location of the collector (roof mount, ground mount, wall mount); and location of the storage tank in relation to the collector, as well as in the method of heat transfer (that is, open-loop or closed-loop with heat exchanger).

Some systems are relatively easy to install, while others require more technical expertise. This calls for enhancing the knowledge status for technical capacity in designing properly sized solar systems and in integrating them with the existing systems/processes. The Table 5 compares various features of different types of SWHS. With increasing potential for SWHS being realized across the world, there is a likelihood that the demand for these systems will increase, thus, bringing down costs.

Though SWHSs have high initial costs, they payback the cost relatively quickly. In the Indian context, the payback period for a SWHS is less than four years. Typically, for an Indian-make system with single BIS[37] -approved flat plate collector of 2 m^2 area (required for an average household), the current market costs are reported to be in the range of 15 000–20 000 (roughly $340–450). If SWHSs are assumed to cover 75%–85% of annual hot water demand, then accordingly the cost of hot water decreases in similar ratio[38]. Based on the price of electricity in India, the savings per year for a typical Indian household, through the use of solar water, is in the range of 4000–7000 (approximately $90–160). Since SWHSs last 15–20 years, it implies that beyond the breakeven period of four years, you get hot water at no cost at all [39].

Given all these facts, there is still a lot that needs to be learnt from across the world. Several countries have experimented with different ways of promoting SWHS. High cost being one of the most important barriers

Table 5 Comparison of various features of different SWHS[36]

Characteristic	Batch	Thermo-siphon	Open-loop direct	Gly-col	Drain-back
Low-profile, unobtrusive in appearance	No	No	Yes	Yes	Yes
Light-weight	No	No	Yes	Yes	Yes
Freeze-tolerant	No	No		Yes	Yes
Easy installation and infrequent service	Yes	Yes	Yes	No	No
Passive operation–no pumps or control	Yes	Yes	No	No	No
Space saving–storage tank unnecessary	Yes	Yes	No	No	No

Figure 15 SWHS installed in Union Hospital in Gauteng, South Africa

[35] Solar thermal for hot water for domestic and industrial use, 28-09-10, http://climatetechwiki.org/technology/solar-thermal-hot-water
[36] *Source* Solar Hot water basics by John Patterson; Homepower Magazine; weblink - http://homepower.com/basics/hotwater/, accessed on 10.10.2010
[37] BIS – Bureau of Indian Standards
[38] *Source* SWHS in Georgia – cost-benefit analysis; April 2008; Winrock International report prepared for USAID
[39] *Source* Energy Alternatives India, http://eai.in/blog/2009/12/india-solar-water-heaters-domestic-and.html, accessed on 10.10.2010

Box 4 Survey/audit and assessment of potential of SWH and Rooftop SPV systems in the Gurgaon-Manesar area of Haryana

The Gurgaon-Manesar Urban Complex has emerged as one of the fastest growing urban areas in India. The main objective of the survey was to quantify the present and future requirement of hot water and backup power in institutions, establishments, complexes, and industrial units; and estimate the potential of SWH and Rooftop Solar PV. The present (2010) total daily hot water requirement is estimated as 30 million lpd and is likely to increase to 46.92 million lpd by 2014. The annual hot water requirement is estimated at 5866 million litres, out of which residential sector accounts for 56%, industries for 30%, and the remaining 14% are accounted for by commercial establishments and institutions. The total installed capacity of solar water heaters (2010) is estimated at 0.33 million lpd, which is about 1 % of the total daily requirement of hot water. The demand for solar water heaters was estimated under three different scenarios. All the scenarios indicate that with a focused effort it is possible to increase the installed SWH base by 20 to 30 times of the present value, by the year 2021/22. For instance, it is projected that SWH installations in 2021/22 will reach the 115 294 m^2 mark. Among commercial establishments, guest houses have been identified as one of the large, untapped potential segment. Among industries, the automobile sector was identified as a promising sector.

for adoption of SWHS among residential sectors, the barrier can be mitigated by designing appropriate financial mechanisms. Since the poor cannot afford this technology, it has to be made affordable by innovative finance instruments, like in the South African case. The other option is to increase awareness levels about the system and make it readily available to those who can afford it.

Many rural areas still remain the unexploited market for SWHS, especially in the developing world. The need for capacity building in rural areas is a must, and this must be carried forward to the policy-makers so that backward linkages may be established among the users and policy-makers.

It is necessary to (a) build flexible programmes that can adapt to changing markets and accommodate changing perceptions of the users (for instance, building sector policies that mandate SWHS installations for certain types of buildings depending on their footprint and energy consumption may have to be looked afresh) and (b) improve the legal and regulatory environment for encouraging the installation of SWH systems. In doing all this, it is very important to create awareness about the SWHS and gauge the users' perception. It is equally important to develop capacity of local manufacturers, distributors, installers, and the financing sector to offer products, delivery models, installation, after-sale, maintenance, and financial services that are conducive to the overall market transformation goals.

Another view of Magarpatta city, Pune
Source MNRE

System integrated with building in a Hotel
Source MNRE