Solar Heating and Cooling
application factsheet

Domestic hot water for single family houses

GLOBAL SOLAR WATER HEATING PROJECT

Project partners: gef, ESTIF European Solar Thermal Industry Federation, UNDP, International Copper Association, Copper Alliance

APPLICATION:
Solar thermal collectors for the production of domestic hot water in the residential sector

DESCRIPTION OF USE

Domestic hot water refers to the heated water used for domestic purposes. Energy consumption for domestic hot water depends on various factors, i.e. consumption patterns: how much hot water is used and the increase in water temperature required (difference between the inlet and outlet temperature). We can consider that, on average, the annual domestic hot water consumption in developed countries is around 1000 kWh per person[1].

Domestic hot water demand is rather constant all year round. Solar thermal collectors are therefore particularly suited to meet this demand. In higher latitudes, where the radiation in winter is significantly lower than in summer, such systems can cover between **60 and 80% of the annual domestic hot water demand**. This means that a supplementary or backup heater is required. In low latitudes, solar thermal can cover 100% of the domestic hot water demand and no backup heater is required.

PRINCIPLES AND BASIC OPERATION

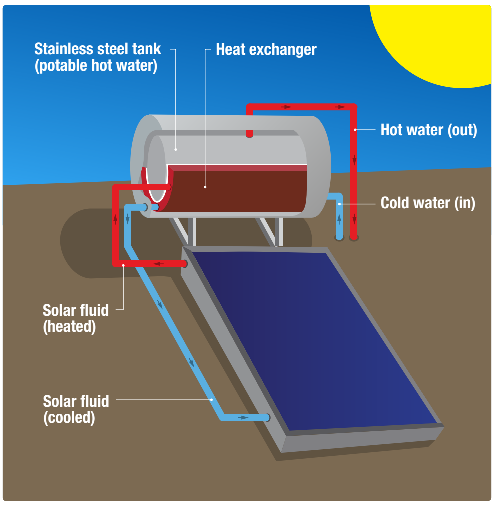
The operating principle is rather simple. The sun heats a fluid in a solar collector, which is then used to heat domestic hot water that will be stored in a tank, ready to be used.

The system consists of solar thermal collectors, pipes and a hot water store. A thermosiphon system, the simplest, may use only these components. Forced circulation systems are more complex and require, besides the basic components mentioned above, pumps, controller, heat exchanger, valves and backup heater.

The **solar thermal collector** is the main component of the system. Within the collector, the solar irradiation is captured by an **absorber** and converted into heat. To increase efficiency, the absorber is often selectively-coated, which means that the absorption of the irradiation is maximised, but the emission of heat is minimized. The absorber heats a fluid circulating in contact with it. This fluid can be just water, a mix of water and glycol (to avoid freezing during the winter in colder climates) or another **heat transfer fluid**.

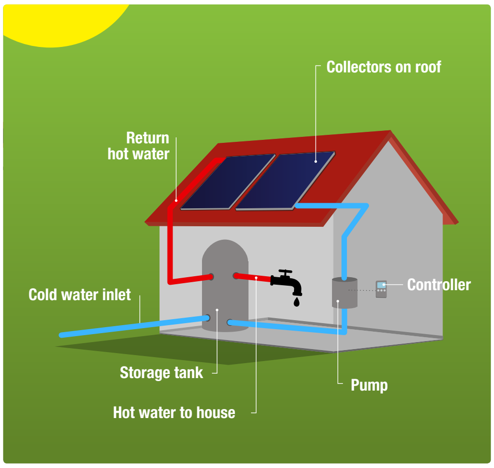
Solar thermal collectors can heat directly the water that will be used: these are called direct systems. In such systems the water for domestic use circulates inside the solar thermal collector. In contrast to such system, **indirect systems** use two circulation loops. A first closed-loop system allows the circulation of the heat transfer fluid between the collector and the heat exchanger. A secondary loop is then used for the circulation of the water for domestic consumption between the heat exchanger and the hot water storage.

The figure below shows an example of an indirect system. The heat transfer between the solar fluid and the water is done by means of a heat exchanger. The figure portrays a common **thermosiphon system**. It takes the name from a physical effect that uses natural convection generated by the expansion of a warm liquid, becoming less dense than colder liquid. The warmer liquid hence moves upwards while the colder liquid moves downwards.



There the thermosiphon systems operate without a pump, using **natural convection** to carry the hot water to a **storage tank located above the solar collector**. Because the storage tank is located on the roof, gravity is used to bring the water from the tank to the house.

The other configuration is **forced circulation systems**, as shown on the figure below. In this case, the **hot water storage tank is located inside the house**. This is a common solution in colder climates, to avoid heat losses in the tank during the winter. In these systems the water is pumped between the collector and the hot water storage tank. Additional backup heating systems, such as gas boilers, usually also feed into the storage tank to cover the eventual shortcomings of the solar thermal system, especially in winter.



SYSTEM REQUIREMENTS

Temperature

40°C to 60°C
This is the usual temperature range required for the most common uses, even if the user lowers the temperature by mixing with cold water.

Simple Metering | **Simple Control** | Remote Monitoring

These systems require simple metering and control. It is possible to have more advanced metering and control, and even remote monitoring, but the costs are relatively high when considering the overall investment in such systems.

Operation & Maintenance

Low
The operating and maintenance requirements are rather simple, requiring usually one routine visit per year.

SECTORS COVERED

Residential
- [x] Single-family house
- [ ] Multi-family house

Tertiary
- [ ] Commercial (offices, hotels, shopping centers, …)
- [ ] Institutional (schools, nursing homes, hospitals, …)

Industrial
- [ ] Low temperature processes (washing, dyeing, pasteurization, …)

EXAMPLES OF APPLICATIONS

Solar thermal collectors for domestic hot water is a common application worldwide, and represents the largest share of the solar thermal technology market.

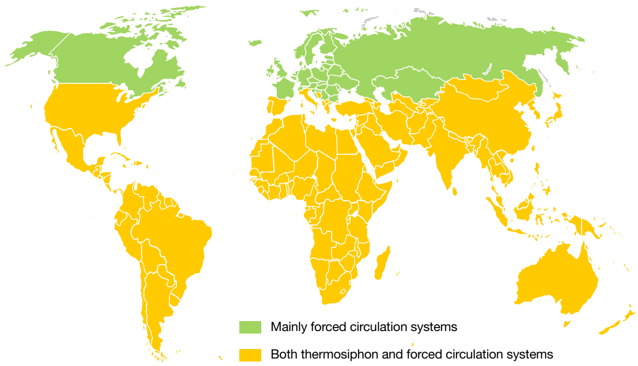
There are two main systems used for this type of application: thermosiphon and forced circulation. **Thermosiphon systems** are simple and compact, using a thermodynamic principle for operation. As such, thermosiphon are especially effective in warmer climates. **Forced circulation systems** use a pump to circulate water through the collector and system. This is a solution common in colder climates.

WORLDWIDE APPLICABILITY

Solar thermal systems for the production of domestic hot water in single family houses have the potential to be deployed in all geographical areas. Different systems may, however, be more appropriate in different locations. **Thermosiphon systems** are a **simple, efficient and cheap choice**, in places where the storage tank can be easily installed on the roof. They are mostly used in **high solar irradiation areas** (above 5kWh/m²/day, as a reference).

Forced circulation systems are better suited for medium solar irradiation areas, where a larger collector area is needed and the storage tank is usually installed inside the building to protect from colder temperatures (prevent freezing or heat losses). Evacuated tubes can improve performance in low solar irradiation areas.

From an economic and energy system point of view, the applicability of solar thermal collectors for domestic hot water in single family houses is particularly indicated for countries with high energy dependency on fossil fuels imports, in particular gas for heating; as well as countries with an unbalanced power grid system relying on electricity for some of their heating needs.



Solar thermal systems use worldwide

BENEFITS

The benefits of solar thermal collectors cover several aspects: environmental, political and economic.

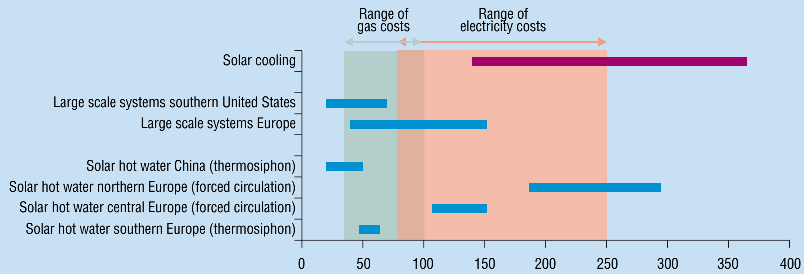
Environmental benefits stem from the capacity to reduce harmful emissions. The reduction of CO_2 emissions depends on the quantity of fossil fuels replaced directly or indirectly, i.e. when the system replaces the use of carbon-based electricity used for water heating. Depending on the location, a **2.8 kW_{th} (4 m²)** system could generate the equivalent of **2.2 MWh_{th} /year**, a saving of around **350 Kg of CO_2**.

Political and economic benefits are associated with the potential savings in energy costs and the possibility of improving energy security by **reducing energy imports**, while **creating local jobs** related to the manufacturing, commercialization, installation and maintenance of solar thermal systems.

Regarding energy costs and potential savings, there are three main aspects to consider that have a bigger impact on the comparable costs of the energy produced by a solar thermal system. These are the initial cost of the system, the lifetime of the system and the system performance.

These factors depend on the location (affecting climate, insulation, taxes, cost of living, etc.) and quality of the system (affecting performance, lifetime and cost). This can vary significantly from country to country.

Therefore, average investment costs for solar thermal systems can vary greatly from country to country and between different systems. In China, direct thermosiphon systems for single family houses with average **4 m² (2.8 kW_{th})** collector size can cost from **100 to 250 USD/kW_{th}** (90 to 225 EUR/kW_{th}) and have an energy cost ranging from **2 to 5 USD cents/kWh_{th}** (1.8 to 4.5 EUR cents/kWh_{th}). In the Mediterranean region, the average cost for a open-loop, pressure-less thermosiphon systems (180 lt hot water, 70 lt feeding tank) is around **920 USD** (830 EUR). Pumped indirect systems investment costs can go from **850 to 1900 USD/kW_{th}** (765 and 1710 EUR/kW_{th}) in central Europe, while in northern Europe they can go up to between **1600 and 2400 USD/kW_{th}** (1440 to 2160 EUR/kW_{th}). In terms of energy costs, the former can range from **10.5 and 15 USD cents/kWh_{th}** (9.5 to 13.5 EUR cents/kWh_{th}) while the latter may range between **18.5 to 29.5 USD cents/kWh_{th}** (16.7 to 26.55 EUR cents/kWh_{th}). The most competitive systems in Europe are the thermosiphon systems in Southern Europe, with costs as low as **4.5 to 6.5 USD cents/kWh_{th}** (4 to 5.9 EUR cents/kWh_{th}).



Costs of solar heating and cooling (USD/MWh_{th}), Source: IEA 2012

Key data

Average systems size: **2.8 kW_{th} (4 m²)**

Such a system could generate the equivalent of **2.2 MWh_{th} /year**

Estimated **350 Kg of CO_2 emission savings**

REFERENCES

(1) Value is an approximation. Energy consumption depends on:
a. How many litres of hot water at a given temperature are used per day (e.g. 40 litres at 50 °C)
b. how much energy is needed to heat up this amount of water (eg. 1.6 kWh per day if the water is heated from 15 to 50 °C)
c. Which type and quantity of fuel is used (or replaced)
Some studies estimate the consumption of hot water on the basis of house area, as this is the pattern for estimating overall energy consumption. For domestic hot water the number of inhabitants is more relevant than the area. Consumption averages can vary being usually above 4 000 kWh while the average of inhabitants per house is between 3 and 4.
(2) According to IEA-SHC, the average size of a solar thermal systems for domestic hot water heating in single-family houses by end of 2013 is 4 m².
(3) According to IEA-SHC, the average specific solar yield for solar thermal systems for domestic hot water heating in single-family houses by end of 2013 is 615 kWh per square meter of solar collector per year. Value was rounded to 600 kWh for simplification. Installed capacity is converted according to IEA-SHC default: 1 m² -> 0.7 kW_{th}. Estimations of CO_2 savings based in calculations from IEA, namely in the Solar Heating and Cooling Technology Roadmap (1 kWh -> .0.16 Kg CO_2).

Solar Heat Worldwide, IEA-SHC 2015, www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2015.pdf
Technology Roadmap: Solar Heating and Cooling, IEA 2012, www.iea.org/publications/freepublications/publication/technology-roadmap-solar-heating-and-cooling.html
Domestic Solar Water Heater for Developing Countries, Professor Ashok Gadgil et al., 2007 http://energy.lbl.gov/staff/gadgil/docs/2007/solar-water-heater-rpt.pdf
Solar Heating and Cooling for Residential Applications - Technology Brief, IEA-ETSAP and IRENA 2015, www.solarthermalworld.org/sites/gstec/files/news/file/2015-02-27/irena-solar-heating-and-cooling-2015.pdf
Solar thermal in the Mediterranean Region: Market Assessment Report, OME 2012
www.solarthermalworld.org/sites/gstec/files/news/file/2013-04-26/regional_market_assessment_report_ome-mediterranean.pdf
Exchange rates calculated at 1 USD = 0.9 EUR, a rounding of the approximate exchange rate in September 2015.