Solar Heating and Cooling
application factsheet

Domestic water heaters for multi-family houses

UNEP GLOBAL SOLAR WATER HEATING PROJECT

Project partners: 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 different factors, namely consumption patterns: how much hot water is used and the increase in water temperature required (difference between the inlet and the outlet temperature). We can consider that, on average, the annual energy consumption for preparing domestic hot water in developed countries is around 1 000 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.

EXAMPLES OF APPLICATIONS

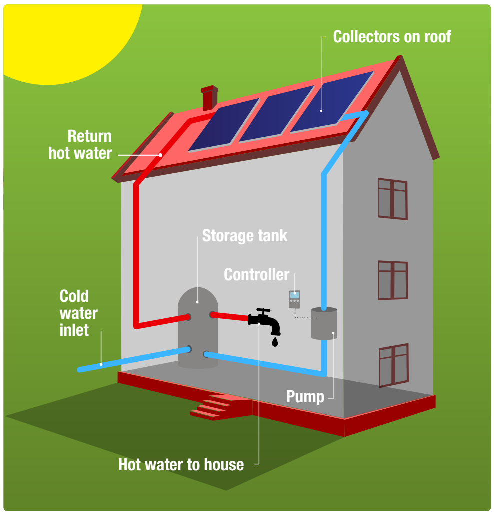
These applications mainly use forced circulation systems, but in warmer climates it is also possible to use thermosiphon systems in multi-family houses, in particular using individual systems serving each dwelling. **Forced circulation systems** use a **pump** to circulate water through the collector and system. **Sensors** and a **controller** activate the pump. In these systems, the **hot water store** is located inside the building. The configuration of these systems may vary, as it is possible to have central or individual backup heaters and common or separate hot water stores.

The solar thermal collectors' area in systems providing domestic hot water in multi-family houses vary greatly in terms of size, depending on requirements. It is usually between **10 and 50m² (7 to 35 kW$_{th}$)**, although much larger installations exist.

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.

Larger systems are usually forced circulation systems (example in the figure), consisting of solar thermal collectors, pipes, hot water store, pumps, controller, heat exchanger, valves and backup heater.



The **collector** captures **solar irradiation** using a selectively-coated metal sheet (**absorber**). The heat is absorbed by a fluid circulating in contact with the absorber. The heat from this fluid is then transferred to domestic hot water by a **heat exchanger**. The domestic hot water is stored in a tank, ready for use. Additional water heating systems, such as gas boilers, usually also feed into the storage tank.

SYSTEM REQUIREMENTS

Temperature

40°C to **60°C**
This is the usual temperature range required for the most common uses, such as showering, 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. Although it is possible and even desirable, for larger and/or commercial systems, to have advanced metering and control, with remote monitoring.

Operation & Maintenance

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

SECTORS COVERED

Residential
- ☐ Single-family house
- ☑ Multi-family house

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

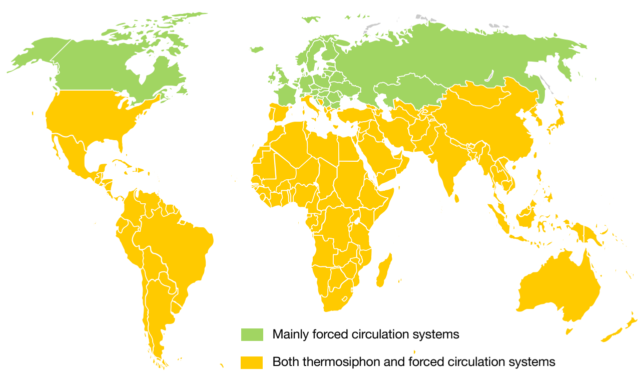
Industrial
- ☐ Low temperature processes (washing, dyeing, pasteurization, …)

WORLDWIDE APPLICABILITY

Solar thermal systems for the production of domestic hot water in multi-family houses have the potential to be deployed in **all geographical areas**. As mentioned above, forced circulation systems are well suited for multi-family houses but also thermosiphon systems can be considered. Both flat plate and evacuated tubes collectors can be used.

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

These systems are also commonly used when building regulations require minimum levels of in-situ energy generation. In some cases, they can be counted as a positive contribution towards meeting energy efficiency requirements for buildings.



Map of 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, for instance, when the system replaces the use of carbon-based electricity used for water heating. Depending on the location, a system of **14 kW_{th} (20 m²)**, could generate the equivalent of **11 MWh_{th} /year**, a saving of around **1.75 Mt CO_2** (2).

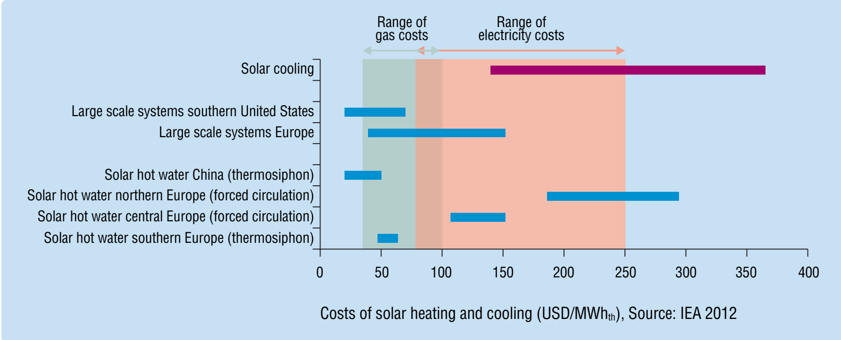
Political and economic benefits are associated with the potential savings in energy costs and the possibility of improving energy security by reducing energy imports, while creating local jobs related to the manufacturing, commercialization, installation and maintenance of solar thermal systems.

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. Thermosiphon systems, the cheapest, are more appropriate for single family houses (or individual supply).

For multi-family houses pumped indirect systems are appropriate. For these, investment costs can go from **850 to 1900 USD/kW_{th} in central Europe** (765 to 1710 EUR/kW_{th}), 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 **18.5 to 29.5 USD cents/kWh_{th}** (16.7 to 26.6 EUR cents/kWh_{th}) while the latter may range between **10.5 and 15 USD cents/kWh_{th}** (9.5 to 23.9 EUR cents/kWh_{th}).



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

EXAMPLES

SOUTH AMERICA

Low Income Multi-family Houses in Rio de Janeiro, Brazil

In 2009 these newly built **multi-family houses for low-income families** were equipped with solar thermal systems. Such systems were the first of a kind in Rio de Janeiro and developed as a showcase for this solution, consisting of solar water heaters using gas (not electricity, as is common in Brazil) as an auxiliary heating source. The 496 flats were equipped with **thermosiphon systems** composed of two flat plate collectors and one storage tank of 200 l, dimensioned to supply the needs of a **family of five**.

Reference:
www.solarthermalworld.org/content/brazil-low-income-multi-family-house-individual-solar-water-heaters-and-gas-back

Key data

496 flats

Thermosiphon systems

Multi-family houses for low-income families

ASIA

Multi-family house with façade integrated systems

The "Utopia Garden" project, in the city of Dezhou in China, combines a central system with individual systems integrated in the balconies. The central systems, with a gross collector area of about 756 m² (529 kW_{th}) using pressurised heat-pipe vacuum tubes, provide heating and cooling. The hot water is supplied by individual systems installed through all 20 floors of the building. These consist of vacuum tube collectors installed in the façade and a 300 litre tank installed on the balcony, equipped with an auxiliary electric heater.

Reference:
http://www.renewableenergyworld.com/articles/print/volume-15/issue-3/solar-energy/solar-thermal-scales-new-heights-in-china.html

Key data

Façade integrated collectors

20 floors

Individual hot water systems

EUROPE

Multi-family house in Vilanova i la Geltrú, Spain

In 2000, this residential building was developed to demonstrate the technical, economic and environmental feasibility of a building using a low energy concept. The **132 m² (92.4 kW_{th}) flat plate solar thermal collector** area provides hot water for **240 users living in 80 dwellings, on 5 floors**. The hot water system is **semi de-centralised**, using primarily solar thermal energy with a natural gas backup heater. The estimated solar energy generation amounts to 65 MWh_{th}/a.

Reference:
http://www.solarge.org/uploads/media/SO-LARGE_goodpractice_es_elllimonet.pdf

Key data

65 MWh energy annually

240 users

80 dwellings

5 floors

19.3 tonnes of CO_2 emissions avoided

REFERENCES

(1) Value is an approximation. Energy consumption depends on:
- How many litres of hot water at a given temperature are used per day (e.g. 40 litres at 50 °C)
- How much energy is needed to heat up this amount of water (e.g. 1.6 kWh per day if the water is heated from 15 to 50 °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 specific solar yield for solar thermal systems for domestic hot water heating in multi-family houses by end of 2013 is 569 kWh per square meter of solar collector per year. Value was rounded to 550 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 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.