International Energy Agency

Renewable Energy Essentials: Solar Heating and Cooling

- Solar heating and cooling technologies use the sunlight to produce directly usable heat for water and space heating or industrial processes, or to run air-conditioning systems.
- Global solar heating and cooling (SHC) potential continues to grow. The solar thermal collector capacity in operation worldwide equalled 171 gigawatts thermal (GW_{th}) corresponding to 244 million square meters at the end of 2008.
- China alone accounted for more than half global capacity, with 101 GW_{th}. Other countries with a large number of collectors in operation are the United States (unglazed collectors), Germany and Turkey. With respect to the capacity installed per 1 000 inhabitants, the leading countries are Cyprus (651 kW_{th}), Israel (499 kW_{th}) and Austria (273 kW_{th}).
- Solar thermal energy for domestic hot water preparation is common all over the world with significant market penetration in Australia, China, Europe, Israel, Turkey and Brazil.
- So-called solar "combi-systems" for combined hot water preparation and space heating show a rapidly growing market in European countries. In Germany and Austria, the predominant share of the annual installed collector area is already for combi-systems.
- Large-scale (producing 1MW or more) solar systems for district heating show considerable growth rates in the Scandinavian countries, Germany and Austria.
- New applications for low temperature process heat, air-conditioning and cooling, as well as desalination, are now entering the market.
- Low temperature solar collectors for water and space heating are very efficient. High temperature solar collectors for refrigeration, industrial process heat and electricity generation, require improvements. Heat storage (both seasonal and compact) represents a key technological challenge.

Market status

Recent trends

The global solar thermal market enjoyed a growth rate of about 15% in 2007 (down from 20% in 2006), thanks to a sustained growth of 22% in the largest world market, China (see Figure 1.) Provisional numbers for 2008 suggest that 2008 witnessed further 42% growth in the Chinese market, with 21 GW installed.

The disappointing results of 2007 in Europe (minus 9%), due to a 30% decrease in the largest European market, Germany, were more than compensated in 2008 by a staggering rebound in growth of 45-50%. The US market, mostly of unglazed collectors, also showed a decrease in 2007. Industrial process heat has taken off in recent years with a couple of large projects in China and Europe.

Figure 1: Annual newly installed capacity of glazed tube collectors by economic region

Source: IEA SHC 2009

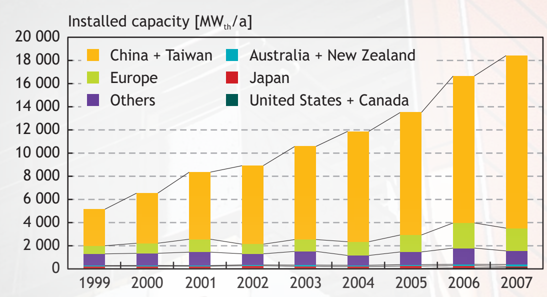
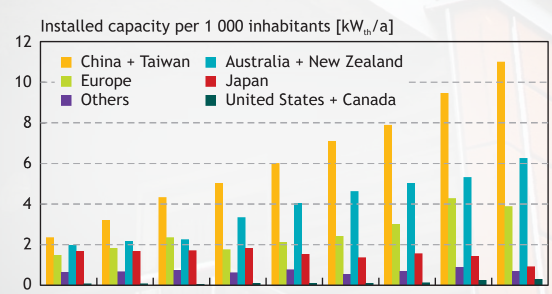


Figure 2: Annual per capita installations by regions

Source: IEA SHC 2009



The dominance of China is driven by its large population and the dynamic growth of its solar heating sector. Australia and New Zealand form the second largest regional market (Figure 2).

Cumulative installed capacity

At the end of 2008, the solar thermal collector capacity in operation worldwide equalled 171 GW_{th}, of which 101 GW_{th} in China alone. Figure 3 shows its distribution by country at the end of 2007.

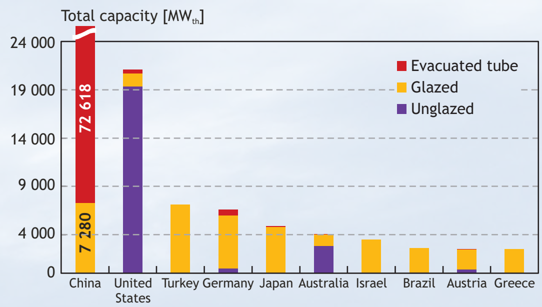
Top ten

With respect to cumulative installed capacity, China ranks first (101 GW_{th}), followed by the United States (22 GW_{th}). With approximately 8 GW_{th} each, Turkey and Germany rank third, followed by Japan (~5 GW_{th}), Australia (4 GW_{th}), Israel, Brazil, Austria and Greece.

China represented 77% of the global market in 2007. The United States ranked second with unglazed collectors and Germany third, but its growth may have outpaced the United States in 2008.

Figure 3: Total capacity in operation of water collectors at the end of 2007

Source: IEA SHC 2009



Top ten per capita

On a per capita basis, taking into account both unglazed and glazed collectors (flat plate and evacuated tubes), leading countries are Cyprus and Israel, followed by Austria, Granada and Greece, the Barbados, Australia, Jordan, Turkey and Germany. The United States and China have been added for reference in Figure 4.

Energy produced

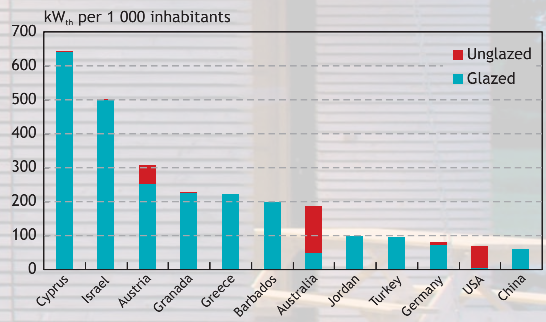
The energy produced in 2007 was about 89 TWh or 319 PJ, or 7.6 million tonnes oil equivalent (Mtoe). Amongst the "new" renewable energy sources (excluding biomass and hydropower), solar thermal energy production comes second only to wind. Still, it represents less than 1% of the global primary energy demand, However, passive solar inputs are not accounted for in the statistics.

The solar resource and the demand for heat

The solar resource is virtually unlimited – the earth receives from the sun each hour as much energy as humankind currently consumes in a year. Heat demand is probably close to half the total demand for energy services. However, the solar resource is dispersed and does not always correspond in time and place to the demand for heat; the opposite is more often true, notably for space heating.

Figure 4: Solar thermal capacity in kW_{th} per 1 000 inhabitants at the end of 2007

Source: IEA SHC 2009



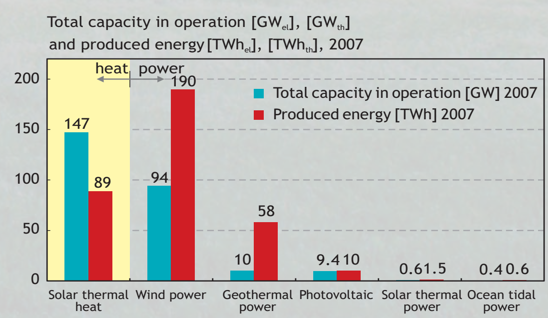
In the absence of affordable ways to store large amounts of heat from one season to another, the contribution of solar heat to space heating needs is currently limited. Installed capacities vary considerably among countries with similar climatic conditions and solar resources. This suggests that considerable development still lies ahead. Many countries with large water-heating loads, high energy costs and huge solar resources still make little use of this considerable potential. Domestic hot water and process heat are less sensitive to climatic conditions and thus more favourable for solar heat. To date, only solar water heating has entered into use on a significant scale.

Manufacturing and employment

The solar heating and cooling sector employs more than 200 000 people worldwide, according to the IEA Solar Heating and Cooling programme. Some other estimates give higher figures.

Figure 5: Total capacity in operation (GW) in 2007 and energy generated (TWh) in 2007

Source: IEA SHC 2009



Economics

Costs vary greatly according to climate conditions, requiring more or less complex installations, and other factors such as labour costs. A SHW thermo-siphon system for one family unit consisting of a 2.4 m^2 collector and 150 litre tank costs EUR 700 in Greece, EUR 200 in China. In central Europe, a pumped system of 4–6 m^2 and 300-litre tank, fully protected against freeze, costs around EUR 4 500.

Systems of this size might be used only for water heating, or also contribute to space heating (as in the Netherlands). Combi-systems covering a larger fraction of heating loads may require collectors from 15 to 30 m^2 in Europe.

Solar domestic hot water systems cost in Europe EUR 50-160 per MWh of heat, which is usually more expensive than heat from natural gas in urban areas, but often prove competitive with retail electricity prices. For solar combi-systems the cost is about EUR 160-500 per MWh. These costs are expected to decline by 2030 to EUR 50-80 per MWh for solar hot water systems, 100-240 EUR per MWh for combi-systems, and EUR 30-50 per MWh for large-scale applications (>1 MW_{th}). Recent experience suggests that costs are reduced by 20% when the cumulative capacity doubles at country level. The profitability of solar space heating systems depend son solar resource and on the heat demand. In France, for example, space heating systems offer better economic performance in the east or the north while solar water heaters are more profitable in the south.

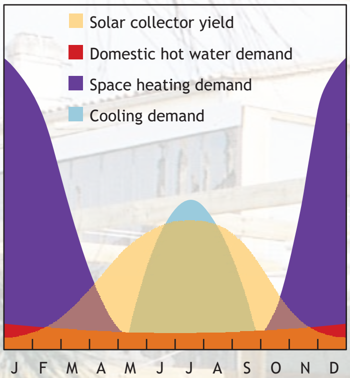


Figure 6: Solar energy, domestic hot water heating, space heating and space cooling needs in Central Europe

Source: ESTIF, 2007

Solar cooling requires more expensive investments, but costs are reduced if a solar thermal collector is designed to be used for both summer cooling and winter heating. Solar cooling benefits from a better time-match between supply and demand (See Figure 6).

Letting the sun heat buildings in winter and letting daylight enter them to displace electric lighting, is the least-cost form of solar energy. In many cases, for small additional investment costs, passive solar design can help cut up to 50% of heating and cooling loads in new buildings.

Outlook

Growth drivers

Markets can be naturally growing or incentive-driven. In China, Cyprus and Turkey, low-cost solar water heaters are already an economic alternative for households to produce hot water. In incentive-driven markets like Germany and Austria, there are grants for households and companies.

A third category of market is driven by legal frameworks such as solar ordinances. Israel passed an ordinance 30 years ago that applies to all new residential buildings, hotels, homes for the elderly and boarding schools. Spain followed two years ago with a national solar ordinance (regions had initiated the trend).

In Australia and some US States, solar water heaters can count toward utilities' renewable energy portfolio standards. Forthcoming stringent regulations of specific net energy consumption in new buildings, such as in most European countries, are likely to benefit solar heat markets.

Barriers

Barriers to the installation of SHC can be technical, economical, institutional, legal or behavioural. *Technical issues* at component level have been fixed by most manufacturers, but many countries have a shortage of skilled personnel able to properly conceive and install solar systems.

Economic barriers: High up-front expenses deter many potential investors looking for short "pay-back time" while the investment offers long-term benefits. The volatility of fuel prices, the lack of internalisation of environmental costs of various alternatives and, in some countries, the high-level of subsidies to fossil fuels can also twist decisions against solar heating. The slow rotation of building stock is also a barrier, as solar space heating technologies are usually possible in new construction or extensive retrofits only.

Institutional barriers: Property developers and building owners renting their properties have little incentive to invest in solar thermal devices for the benefit of the current occupants. "Split incentives" also exist in large companies or public services, when resources for investment and operating costs are separated. Other institutional barriers arise in multi-dweller buildings.

Legal barriers vary greatly from country to country, as well as at more local levels. Permitting is often an issue. Behavioural issues include lack of awareness of the current status of the technology, reluctance to manage a slightly more complex system and the (mis)perception that variability may lead to a lower comfort.

Long-term scenarios

The IEA *World Energy Outlook 2008* foresees a contribution from solar thermal of 45 Mtoe to final energy demand by 2030 if policies do not change. Extending the same trend to 2050 would lead to a contribution of 180 Mtoe, or about 18% of the total forecasted heat demand at that time.

The European Solar Thermal Industry Association forecasts an installed capacity of 1019 GW_{th} by 2030 in the European Union, supplying about 15% of the low temperature heat demand, by 2030. By 2050, the capacity could reach 2 716 GW_{th} to supply about 129 Mtoe of solar heat – 47% of the overall heat demand in EU-27, or roughly 20% of the region's overall energy demand.[1]

System-related aspects

Solar thermal technologies can have significant effects on electric systems or regional fuel markets. For example, in South Africa, electric water heating accounts for a third of the power consumption of the average household. The government has identified the massive deployment of solar water heaters as one effective option to avoid electric shortages.

Environmental impacts

External costs

Solar thermal requires no fossil fuel and produces little environmental pollution during its manufacture, operation and decommissioning. CO_2 emissions from solar thermal energy are small. If the external costs of energy technologies were systematically taken in account, solar thermal energy could possibly be already competitive with most heating technologies.

Local impacts

Solar thermal systems generally do not have a big visual impact. Recent systems are placed on the roof of buildings, and more and more integrated into roof systems and building envelopes (see Figure 7).

Technology status and developments

Systems for domestic hot water and space heating are now mature in various climatic environments but inexperienced installers might still make mistakes.

Solar thermally-driven air conditioning and cooling systems are still under development, in particular for individual houses.

Figure 7: Integration of solar thermal in the building envelop

R&D priorities

Material research

Effective optical coatings on surfaces and low-cost, anti-reflective, self-cleaning glazing materials need to be developed. To prolong service intervals and lifetime, the ability of new materials like polymeric materials and carbon nano tubes and components to withstand high temperatures must be improved.

Advanced components

Multifunctional facade and roof systems with integrated solar thermal collectors are needed for large-scale applications, especially in combi-systems. New process heat collectors for medium temperature levels (up to 250°C) would help develop solar heat for industry and cooling systems. Photovoltaic-thermal combined collectors would deliver warm water and electricity.

Compact storages with high energy density

Advanced and more compact storage could allow a cost-effective increase in the solar share of heating loads. Phase-change materials or thermo-chemical processes are being explored for these purposes, with the aim of increasing the energy density of heat storages by the factor of 8. Increased R&D efforts are necessary to provide these new storage technologies by 2030.

System development

Many improvements are expected in the area of solar air conditioning and cooling, especially for small systems and Combi+ systems providing domestic hot water, space heating and cooling, as well as combinations of solar thermal and heat pumps.

1. Weiss, W. and P. Biermayr: *Potential of Solar Thermal in Europe*, ESTIF, 2009.