Solar Heating and Cooling application factsheet

Solar thermal cooling

UNEP GLOBAL SOLAR WATER HEATING PROJECT

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

APPLICATION:
Thermally driven cooling using solar thermal collectors (small-scale and large-scale)

DESCRIPTION OF USE

The demand for cooling may be driven by different aspects, comfort and refrigeration being the most common uses. In fact, the cooling demand is growing worldwide, even in colder climates, as comfort demand rises. This results in an increase in air conditioning mainly for tertiary buildings but also for residential applications. Refrigeration is increasing as well with a wider variety of use, mainly within the food industry.

Air conditioning is the main process used for comfort cooling. It involves changing air properties, such as lowering temperature and humidity levels. **Refrigeration** implies bringing temperature to low levels, even below freezing point.

Cooling is basically achieved by retrieving heat from a fluid or gas and transferring it to the environment, which is usually called **heat rejection**. This transfer can be done mechanically or chemically.

One of the technologies used for cooling purposes are **thermally driven chillers**. These use thermal energy to cool down gases or fluids. This thermal energy can be provided by different technologies, including solar thermal energy.

EXAMPLES OF APPLICATIONS

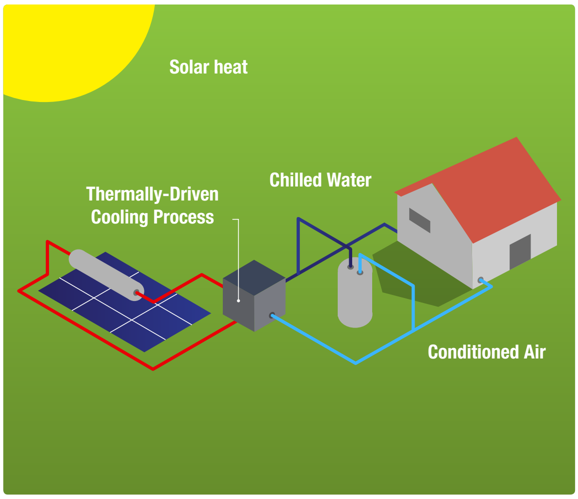
Solar cooling is suitable for **residential, commercial, institutional and industrial use**. The solar cooling supply is equal to the demand: when the sun is at its hottest solar irradiation is high, the maximum energy is available and the demand is also high. **A typical solar cooling system also provides space heating and hot water, besides cooling**. One of the main requirements of such systems is to have an effective **heat rejection system**. This means that applications requiring both heating and cooling are rather well suited for this technology (for instance, dairy farms, hotels or residential houses with heated swimming pool).

PRINCIPLES AND BASIC OPERATION

The main feature of a solar cooling system, beyond the solar collector field, is the thermally driven chiller. On the thermal supply side, the solar thermal system is rather conventional, consisting of high quality solar collectors, a storage tank, a control unit and pipes.

For the **cooling process**, the main element is the thermally driven cooling machine but the process of heat rejection is also important. This means that **cooling towers** or other heat rejection solutions are required.

The most common technological solution is an **absorption cycle**: the heat is used to chemically "compress" the refrigerant by desorbing (separating) it from a sorbent, cooling is produced as the "compressed" liquid is expanded in the evaporator to turn into gas.



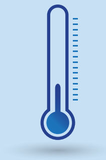
More generally, there are two main commercially available solar cooling processes:

- **Closed cycles**, where thermally driven absorption or adsorption chillers produce chilled water for use in space conditioning equipment.
- **Open cycles**, which typically use water as the refrigerant and a desiccant as the sorbent for direct treatment of air in a ventilation system.

Generally, solar cooling systems are not installed without **backup** for cooling and heating. Therefore the majority of the financial savings are on the avoided energy use, rather than on the avoided traditional cooling device cost.

SYSTEM REQUIREMENTS

Temperature



6°C to 20°C (cooling)
Average cooling temperature range. The temperature required from the solar thermal plant changes according to needs and desired performance. It can start at 80 °C but some systems operate well above 150 °C.

Advanced Metering | **Remote Monitoring** | **Advanced Controls**

Solar cooling systems are complex systems that require advanced metering and advanced controls. Remote monitoring is a great advantage in such systems.

Operation & Maintenance

High
Solar cooling systems require high operation & maintenance compared with a regular solar thermal system providing domestic hot water. Expert support is required, with pre-planned maintenance visits.

SECTORS COVERED

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

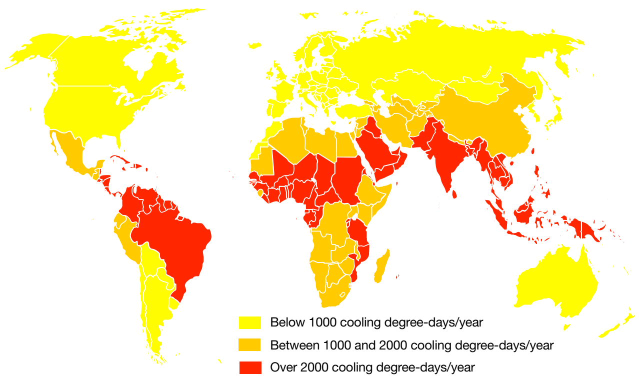
Tertiary
- ☑ Commercial (offices, hotels, shopping centers, …)
- ☑ Institutional (schools, nursing homes, hospitals, …)

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

WORLDWIDE APPLICABILITY

This technology is particularly suited for **sunny and dry climates**. Nevertheless, it can be applied in other climates, as solar thermal energy can be used for air conditioning in the summer, having a perfect correlation between the increase in comfort cooling demand in summer and the availability of the solar resource. As an example, in 2014, out of the 1200 systems of all technology types and sizes accounted for worldwide (mostly between 10 and 35 kW cooling capacity), more than **75% were installed in Europe**.

From an energy system point of view, it should be taken into account that solar cooling can **significantly reduce the electricity demand**. This is particularly relevant in countries with a warmer climate and/or having problems managing peak loads in summer due to **rising cooling demand** as well as high fossil fuel and electricity energy costs.



Map of Worldwide Cooling Needs

BENEFITS

The benefits of solar cooling systems 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, when the system replaces the use of carbon-based electricity used for water heating. The **savings** will be greater if the system provides both cooling and heating, when not operating for cooling or eventually using the residual heat from the heat rejection.

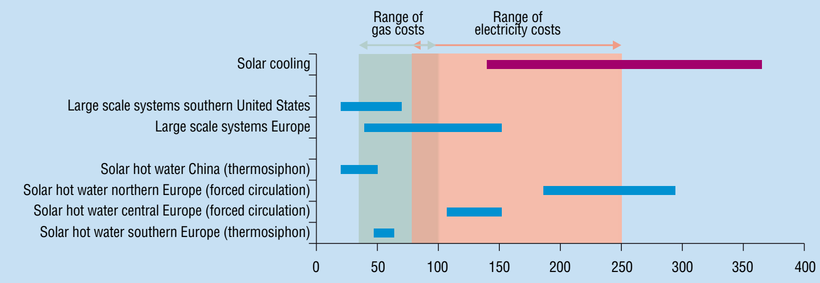
Political and economic benefits are associated with the potential **savings in energy costs** and the possibility of improving **energy security**, by reducing energy imports, while creating **local jobs** related to the manufacturing, commercialization, installation and maintenance of solar cooling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

Regarding the 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 cooling systems can vary greatly from country to country and between different systems. According to the IEA, the investment costs of solar cooling can range from **1600 to 3200 USD/kW$_{th}$** (1440 to EUR/2880 kW$_{th}$).

In terms of energy costs, solar cooling can range from **140 to 365 USD/MWh$_{th}$** (126 to 328.5 EUR/MWh$_{th}$) [1]. Prices, excluding installation cost and distribution system to the building for the package solutions, dropped from about **6000 EUR/kW** (6666 USD/kW) in 2007 to about **4500 EUR/kW** (in 5000 USD/kW) 2013 [2].



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

EXAMPLES

AFRICA

Telecommunications company in Johannesburg, South Africa

In 2014, a concentrating solar cooling system was installed in Johannesburg, South Africa, comprising **242 sun-tracking solar mirrors covering 484 m²**. The mirrors move into a self-cleaning position when it rains, and turn down into a protective stow position on cloudy days. This system is used by a telecommunications company to cool the IT equipment. The collector field provides a two-stage absorption refrigerator with pressurized water at a temperature of **180 °C**, providing an annual **gross heat production of 391 MWh**. The system has a **peak cooling capacity of 330 kilowatts**.

Reference:
www.htxt.co.za/2014/07/09/using-solar-energy-to-power-mtns-air-conditioning/

Key data

peak cooling capacity of **330 kilowatts**

242 sun-tracking solar mirrors covering **484m²**

pressurized hot water at **180 °C**

gross heat production of **391 MWh**

AMERICA

North High School in Arizona, USA

This is a warm environment with temperatures often soaring above 40 °C that has important cooling requirements. Therefore, it is not surprising that the **1.75 MW$_{th}$ solar cooling system** installed in the Desert Mountain High School in Arizona, USA, is one of the most powerful solar cooling systems in operation worldwide. The system is served by a solar thermal plant with a capacity of **3.4 MW$_{th}$ (4 865 m²)** and was installed in 2014. This system provides solar thermal air conditioning for the school. It covers 30% of the annual cooling demand and 100% during the summer when the school is seldom used.

Reference:
www.solid.at/images/pdf/ref_e_DMHS.pdf

Key data

1.75MW$_{th}$ solar cooling system

30% of the annual cooling demand

3.4 MW$_{th}$ (4865m²) solar plant

EUROPE

Office Building in Kordin, Malta

In 2008, this office building in Kordin, Malta was equipped with a solar cooling system made up from **30.5 m² of flat plate collectors** and **7 m² of vacuum tube collectors.** With a capacity over 26kW$_{th}$, the system generates **10 kW$_{th}$** of cold in a chiller consisting ammonia and water. The **cold water is stored in a 200 l tank**, while the hot water storage tank is 400 l. The distribution is done by fan coils and floor cooling.

Reference:
www.solarnext.eu/eng/ref/coolingkitprojects.shtml

Key data

Cooling performance **10kW**

Solar collector capacity **26kW$_{th}$**

Using both flat plate and vacuum tube collectors

REFERENCES

(1) Values based on the Technology Roadmap: Solar Heating and Cooling, IEA 2012.
(2) Values based on Task 48: Solar Cooling Position Paper (page 7)
Task 48: Solar Cooling Position Paper, 2015, http://task48.iea-shc.org/
Solar Cooling: Overview and recommendations, http://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/solco_solar_cooling_conclusions_and_recommendations_en.pdf
Technology Roadmap: Solar Heating and Cooling, IEA 2012, https://www.iea.org/publications/freepublications/publication/technology-roadmap-solar-heating-and-cooling.html
Cooling Degree Days, Climate Analysis Indicators Tool (CAIT): World Resources Institute, http://chartsbin.com/view/1030
Exchange rates calculated at 1 USD = 0.9 EUR, a rounding of the approximate exchange rate in September 2015.