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Keeping cool with the sun

Worldwide, the energy consumption required for cold and air conditioning is rising rapidly. Usual electrically driven compressor chillers (split units) have maximum energy consumption in peak-load periods during the summer. In the last few years in Southern Europe this has regularly led to grids working to maximum capacity and blackouts. In recent years, the sales figures of split units with a cooling capacity range of up to 5KW have risen rapidly.

The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) have estimated worldwide sales of 94.5 million units in 2011[1]. Conventional split-units have a high-energy consumption using non-environmentally friendly refrigerants. The refrigerants that are currently used in the split-units no longer have an Ozone Depletion Potential (ODP), but they have a considerable global warming potential (GWP). Solar cooling and especially sorption chillers use environmentally friendly refrigerants (water or ammonia) and have only very low electricity demand. Therefore the operating costs of these chillers are very low and the CO_2 balance compared to compressor chillers is considerably better. In case of solar cooling, the main advantage is the link between solar irradiation and cooling demand, which complements the sunny and hot climates all over the world.

A definition

Before presenting the solar cooling technology status, it is important to define the technology currently on the market and under development[2]. Solar energy can be converted into cooling using two main principles (see **Figure 1**):

- Electricity generated with photovoltaic modules can be converted into cooling using common technologies that are mainly based on vapour compression cycles (PV Cooling).
- Heat generated with solar thermal collectors can be converted into cooling using thermally driven refrigeration or air-conditioning technologies (Solar thermal Cooling). Most of these systems employ the physical phenomena of sorption in either an open or closed thermodynamic cycle. Other technologies, such as steam jet cycles or other cycles use a conversion of heat to mechanical energy. Mechanical energy to cooling is less significant.

The first principle – solar electricity driven cooling (PV Cooling) – is not commercially widespread and mainly used now for solar driven refrigerators for cooling medicine in remote, sunny regions. The second principle – solar thermally driven cooling – is mainly applied for comfort cooling and air-conditioning in buildings and first pilot installations that have been realised for large capacity refrigeration applications. The first principle installed in buildings is normally not considered a 'solar cooling system' today, since most photovoltaic plants are connected to the electric grid and are operated completely independent from the HVAC installations used in buildings, or the refrigeration machines used in industrial applications. This may change in the future, for instance, when the price of electricity produced with photovoltaic systems will be lower than the price that has to be paid for electricity from the grid. Nevertheless, this article focuses on the dominating technology using the second principle; heat driven air-conditioning and

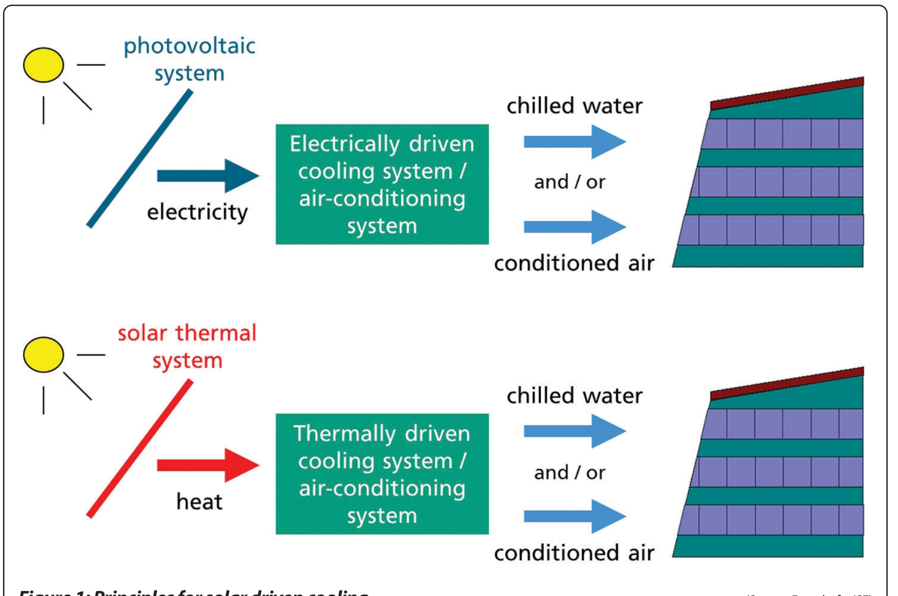

Figure 1: Principles for solar driven cooling

(Source: Fraunhofer ISE)

refrigeration systems using solar thermal energy as the main driving energy.

Market development and economy

Overall in 2011, around 750 solar cooling systems were installed[3], meaning the market has grown in the last seven years between 40 and 70 per cent per year (see **Figure 2**). This total number of installations indicates that the solar cooling market is still a niche one under development.

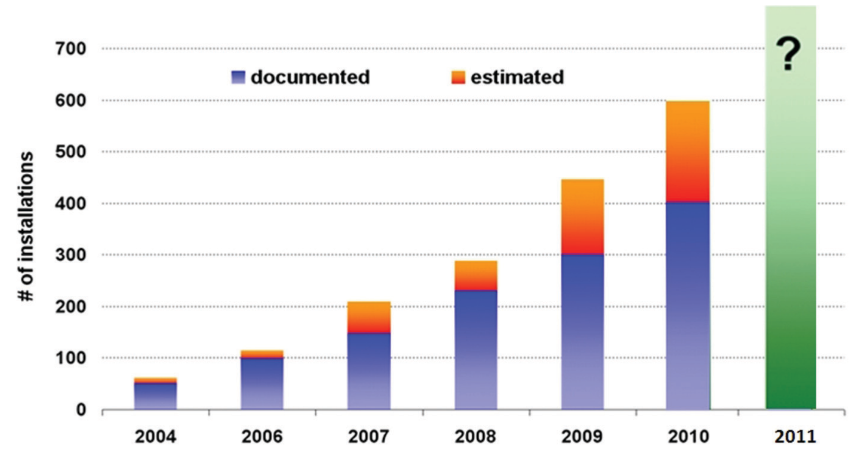

Figure 2: Market development of small to large-scale solar cooling systems worldwide and in Europe

(Source: Solem Consulting / Climasol, Fraunhofer ISE, Rococo, Tecsol)

Today, solar cooling systems are often not yet economically viable. The solar thermal system is usually the largest cost factor, the operating and maintenance costs of the sorption chillers are lower than conventional systems and the investment costs due to the small numbers even higher. Long running hours of the sorption chiller are crucial for the efficiency of solar cooling. Within the residential sector of Central Europe there are only about 50 to 200 cooling hours, in the southern Mediterranean around 1000 cooling hours and in South East Asia 2500 cooling hours. The specific investment costs of solar cooling in the power range of 8 KW to 105 KW cooling capacity (no installation cost and cold distribution included) is currently between 4500 EUR/KW for small-scale kits and 2250 EUR/KW for medium-scale kits[4], as shown in **Figure 3**. Since 2007, a cost reduction of 40 to 50 per cent was achieved within the last five years, because of the further standardisation of the solar cooling kits[5].

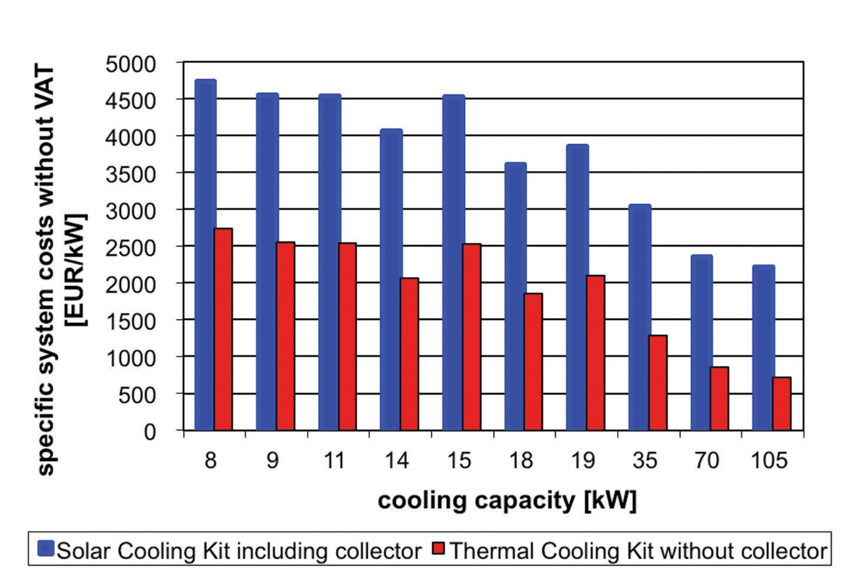

Figure 3: Specific total costs of solar cooling kits

(Source: Solem Consulting / SolarNext)

Technical developments

To face this market deployment challenge and the difficulties to reduce costs while improving system quality and reliability, different technical and R&D developments have been achieved and are currently ongoing.

Solar collectors and solar collector systems are common and have achieved a good status of technical maturity. For solar cooling systems that operate with temperatures below approximately 110°C there exists a good supply of robust, cost effective solar collectors. In the last few years some new concepts of solar collectors have been developed that have led to an increased safety and enhanced efficiency of the solar collection for solar cooling. Solar collectors operated with water that have a drain back system[6] are one such example. Solar collector systems for higher temperatures, as needed for solar cooling that requires higher driving temperatures are still scarce, but an increasing number of manufacturers are entering into this specific area of the market.

Large, thermally driven chillers and open sorption cycles have existed for many decades. Their main operation today is with waste heat (heat from a co-generation system or industrial waste heat) or directly gas-fired. Typically, they are designed for operation to provide base load cooling and not specially adjusted for operation with solar energy.

The very latest developments are triple-effect absorption chillers with COPs of above 1.8. In the last decade, the main progress has been made in the field of small capacity thermally driven chillers and solar cooling has significantly contributed to stimulate this development. Today, numerous systems from various manufacturers are offered within the market and have reached a considerable technical maturity[7].

The main technical challenge for solar cooling today lies in the system level. Many systems have difficulties in achieving the planned energy savings because of shortcomings in proper design, and energy management of systems that result in a high overall electricity consumption of auxiliary components. This concerns the heat rejection sub-system and the fact that many systems are far too complex and as a result created non-optimal control and large maintenance efforts. Special fields of investigation within R&D to solve these technical barriers are;

- Low electricity and water consumption with control capacity for part load[6].

Hybrid systems (dry/wet) seem to be a promising solution.

- High efficient auxiliary components like pumps, careful hydraulic design and advanced control systems. This is particularly important as solar cooling systems need more hydraulic loops than standard solutions.
- Integration of all components into a complete system. Packaging efforts for small as well as for large solar cooling systems[6].

Standardisation and quality procedure

As mentioned previously, there is a significant potential for further improvement of solar cooling energy and cost performance, particularly at the system level. Solar cooling technology is a complex technology and requires much more standardisation for the coupling of key components and the development of robust, standardised solutions in the future. Therefore, R&D on system optimisation and accompanying measures (development of tools for planners) has been recently addressed by decision makers in energy R&D. Also the industry and installation sector is starting to contribute here to provide turn-key solar cooling installations with guarantee on the performance. Besides work on the system level, R&D on the component level will enhance overall performance in terms of energy and cost. These topics are beginning to be covered in national (such as in France[8] and in Germany) and international R&D programmes.

A particular focus is starting to be put into quality procedures for designing, commissioning, monitoring, operating and maintaining solar heating and cooling systems. This is an extremely important step2 for overcoming most of the barriers that stand against the development of a mature market in the sector. Such a quality procedure has to fix the steps towards uniform and consistent planning, providing information, recommendations, and minimum requirements for each of its steps. This, in consequence, will contribute to an increase in awareness and acceptance of the technology and positively impact the number of applications since it would strengthen the stakeholders' trust and thus enhance the market potential of solar heating and cooling systems. Moreover, the introduction of concepts, such as a guarantee of solar results or minimum energy consumption, will stimulate the interest of investors and create the boundary conditions of a correct financial risk assessment, crucial for contracting energy service activities. This quality procedure will also work as a support tool for the policy implementation of the national renewable energy targets and begin the base for subsidy mechanisms.

New IEA SHC Task 48: Quality assurance and support measures for solar cooling

So as to deal with this important need of quality procedures and support measures, the IEA Solar Heating and Cooling (SHC) programme experts on solar cooling have initiated a new Task in early 2011. Called Task 48[9] started in October 2011 for a 3.5 year duration that will strongly address these topics. It is divided into four subtasks (quality procedure on component level, quality procedure on system level, market support measures and dissemination and policy advice). More than 30 international experts (from Australia, Austria, Canada, Belgium, France, Germany, Italy, Singapore, South Africa, Spain and USA) from the industry and R&D side are putting together their experience to work on these topics. First results are expected at the end of 2012.

> *"Solar cooling technology is at a critical stage but facing a very exciting challenge"*

Conclusion

Solar cooling technology is at a critical stage but facing a very exciting challenge. Mature components are available and many installations have been realised worldwide. The technology has shown that significant energy savings are possible, and it has reached a level of early market deployment. However, the financial risk for parties involved in solar cooling business is still not clear. This is because:

- There is no complete assurance on the quality of the system the user cannot be sure about the level of energy savings and related cost savings.
- Most planners and installers have little experience with solar cooling technology and thus the effort and related cost to install those systems is higher than standard systems.
- There are unstable and small markets, manufacturers cannot be sure about sale rates and thus cannot bear the risk to significantly increase their production scale.

Therefore, technical developments are ongoing but strong measures to support a sustainable market development are necessary as well. Establishment of quality procedures planned by R&D collaborative IEA SHC Task 48 is going in the right direction. This will cover all phases of a project and will satisfy the expectations of all involved stakeholders. Overall renewable energies will play an increasingly important role in future energy systems due to the strong need to limit CO_2 emissions originating from conventional energy sources. Solar cooling technology is one of the important solutions applicable to reducing these figures.

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BIOGRAPHY

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BIOGRAPHY

Dr Uli Jakob is the General Manager of Solem Consulting in Europe and an internationally renowned solar cooling expert. He has over 10 years of professional experience with solar thermal and solar cooling systems, especially with the product development and commercialisation of solar/thermal cooling kits.