Part of

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2 HISTORY

The world first solar cooling system was running in Paris, France (Figure 1) during the world exhibition 1878 (Mouchot 1987). This system has consisted of an ammonia/water absorption chiller and a parabolic reflector to produce ice.

The first commercial solar cooling systems for air-conditioning were developed in Europe and the USA one hundred years later in the 1970s, e.g. by the companies Dornier-Prinz Solartechnik, Germany, Arkla Industries (today Robur, Italy) and Carrier, both from USA. These systems have been realized in several demonstration projects. Due to the lack of demand on the market for solar cooling during this time, the production of these solar cooling systems was stopped in the late 1980s (Grossman 2002). In the 1990s companies like Yazaki, Japan and Thermolux, Germany have realized only a few costume-made solar cooling systems. After the year 2000 the first solar cooling system suppliers have started again the solar cooling business like CitrinSolar, Conergy, SolarNext all from Germany and SOLID, Sol-ution both from Austria. Some of these companies have already stopped again their activities.

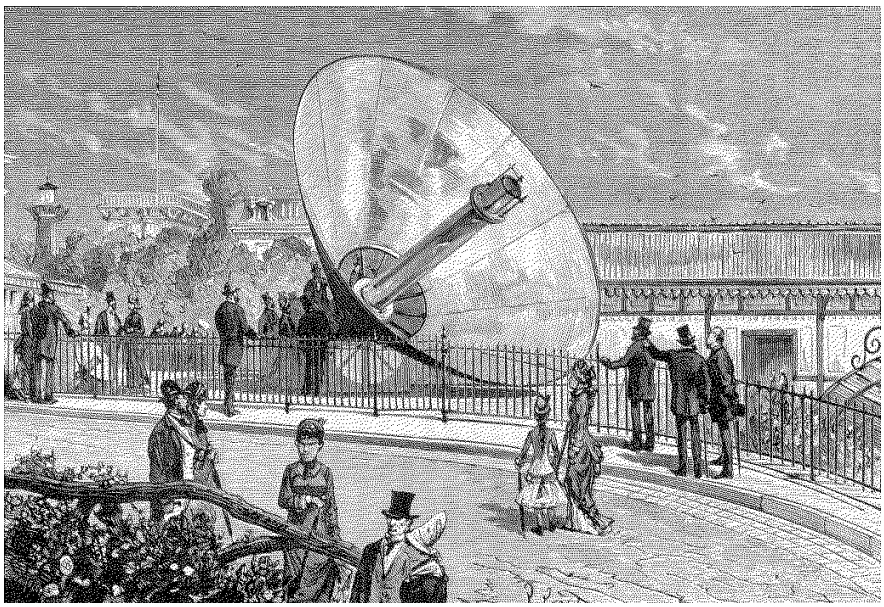

Figure 1: World exhibition 1878, Paris: Augustin Mouchot produced the first ice block through solar energy (Source: Olynthus Verlag)

3 MARKET READY SOLAR COOLING KITS

Medium and large-scale sorption chillers with cooling capacities above 35 kW are available since several years. Today these chillers are mainly manufactured in China, India, Japan and South Korea and used for costume-made solar cooling systems.

In contrast new small and medium-scale sorption chillers were developed in the last 5 to 10 years, which are used for standardized solar cooling kits. These absorption chillers have cooling capacities from 10 kW to 500 kW (working pair water/lithium bromide or ammonia/ water) produced by companies like EAW, Jiangsu Huineng, Sakura, Thermax, Yazaki, AGO, Pink and Tranter Solarice. The market available adsorption chillers have capacities from 8 kW to 370 kW (working pair water/silica gel or water/zeolite) produced by companies like SorTech, Shuangliang, InvenSor, Mayekawa and Mitsubishi Plastics. According to the latest figures from the year 2009, the market shares of various solar cooling technologies are as follows: approximately 71% absorption chillers, adsorption chillers 13%, 14% and 2% DEC systems and liquid sorption systems (Mugnier 2010), as shown in Figure 2.

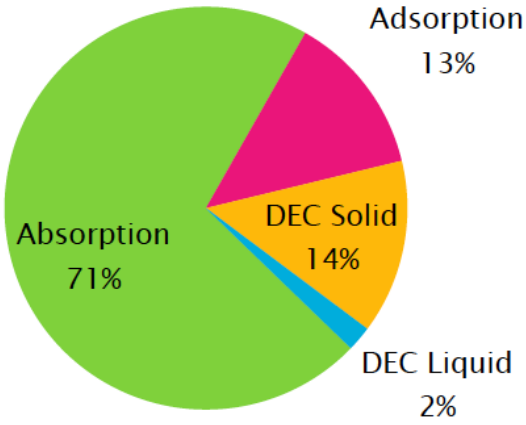

Figure 2: Market shares of solar driven sorption technologies in 2009 (Source: Tecsol)

For the simplification of the installation of solar cooling systems companies like Jiangsu Huineng from China offer an integrated absorption system, which is a combination of water/lithium bromide absorption chiller, wet cooling tower and pumps in one enclosure. InvenSor from Germany has developed a water/zeolite adsorption chiller with an integrated chilling station, which makes the installation essentially comes down to the pipework systems, as the necessary pumps, mixers and valves are already integrated into the machine (Figure 3).

Figure 3: 10 kW water/zeolite adsorption chiller with integrated chilling station and integrated absorption system with 23 kW water/lithium bromide absorption chiller and wet cooling tower (Sources: InvenSor [left], Jiangsu Huineng [right])

During the last few years, a few companies in the solar business have positioned themselves on the market as complete system providers for solar cooling. In the small and medium-scale capacity range up to 200 kW, the companies SolarNext (8-175 kW), Schüco (15 and 30 kW), Kloben (17.5-105 kW), Sol-ution (8-54 kW) and Jiangsu Huineng New Energy Technology (11-175 kW) are active. Their solar cooling systems basically contain solar thermal collectors and support structure, hot water storage tank, pump-sets, a sorption chiller, a heat rejection unit, sometimes cold water storage and a system controller. Figure 4 shows two examples of such solar cooling kits, which can be supplemented by cold storage package, cold distribution package, etc.

New system suppliers are also large companies such as Thermax (India) and Hitachi (Japan), both using in-house developed concentrating collectors, which are offered together with absorption chillers as solar cooling kit (Malaviya and Epp 2011; Augsten and Epp 2011).

Figure 4: Solar cooling kits (Sources: SolarNext [left], Schüco [right])

For solar cooling kits, the average value of specific collector surface of all market available kits is 4.2 m^2/kW cooling capacity (Epp 2009). SolarNext recommends collector areas with 4.5 m^2/kW and Schüco recommends the smallest areas with 3.2 m^2/kW. The average value of all installed small to large-scale solar cooling systems in Europe until the year 2006 was 3.0 m^2/kW (Henning 2007).

An all-season use of renewable energy sources for domestic hot water, space heating and solar cooling is advantageous. As a rule of thumb, the solar fraction for the solar cooling kit should be greater than 70%.

4 SOLAR COOLING MARKET

Today about 1,000 solar cooling systems were installed (Jakob 2012), where the market has grown in the last 8 years between 40 and 70% per year (Figure 5). The total number of installations shows that the solar cooling market is still a niche market, which is under development.

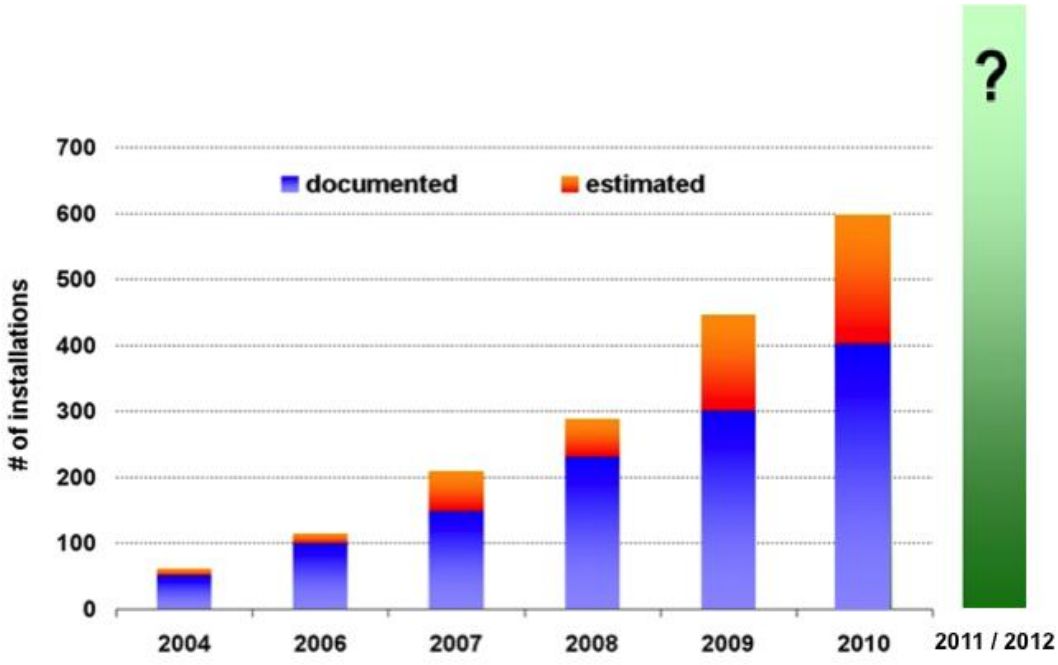

Figure 5: Market development of small to large-scale solar cooling systems worldwide (Source: Tecsol, Solem Consulting)

So far, according to a survey from the year 2009, most solar cooling systems are installed today in Spain (42%), Germany (17%) and Italy (10%) (Sparber and Napolitano 2010). Until 2004, the top three solar cooling markets were Germany (39%), Spain (28%) and Greece (9%) (Henning 2007). The picture has changed, because of many new small-scale installations in Spain during the last few years.

5 SYSTEM COSTS AND ECONOMICS

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, the investment costs due to the small numbers even higher. Is actively cooled, then long running hours of the sorption chiller are crucial for the efficiency of solar cooling. While in the residential sector in Central Europe only about 50 to 200 cooling hours occur, in the southern Mediterranean around 1,000 full load hours are required.

The specific investment costs of solar cooling in the power range of 8 to 175 kW cooling capacity (no installation cost and cold distribution included) are currently between 4,500 EUR/kW for small-scale kits and 2,250 EUR/kW for medium-/ large-scale kits (SolarNext 2012). Today, the cost share for the solar thermal collectors is about 45% to 65% of the total investment costs for the small-scale and medium-/ large-scale capacity range, respectively. Since 2007, a cost reduction of about 50% was realized within the last six years, because of the further standardization of the solar cooling kits (Jakob 2012), as shown in Figure 6.

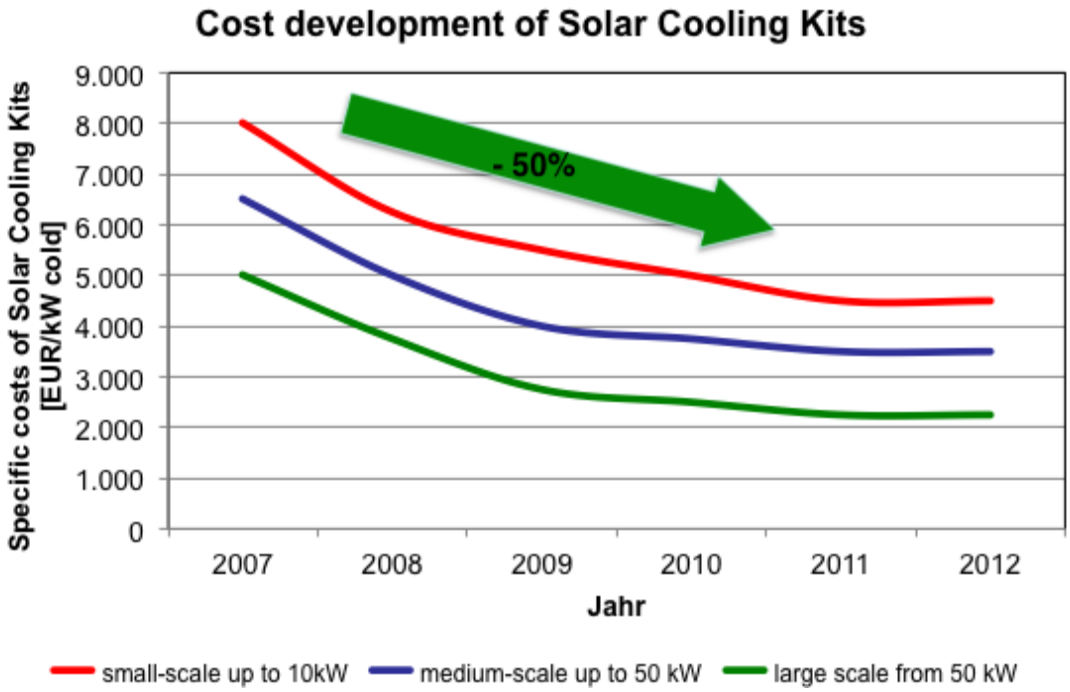

Figure 6: Specific total costs of solar cooling kits (Source: Solem Consulting / SolarNext)

Basically, in Europe at large solar cooling systems, e.g. possible today for administrative buildings, a ROI (Return on Investment) of about 10-15 years, in some cases with high electricity costs or long operating times even under 10 years is possible. For solar cooling kits for residential buildings or small offices, the ROI is depending on the boundary conditions between 12 and 18 years. The analysis of a solar cooling kit implemented in a single family house in Germany with 7.5 kW cooling capacity shows that the specific net cost including cold distribution are about 6,900 EUR/kW (Jakob 2009).

6 GREEN CHILLER

The increased interest in the technology also becomes apparent that more and more system suppliers to position themselves with solar cooling kits on the market and these are not just companies in the solar industry. That the industry is trying to organize could be shown that in March 2009, the Green Chiller - Association for Sorption Cooling e.V. was founded in Berlin. The objective of the association is the promotion and development of solar cooling and the thermal cooling market in Europe (Figure 7). The association brings together about 60% of all European manufacturers of sorption chillers in the small and medium cooling capacity range.

Figure 7: Website of Green Chiller Association (Source: Green Chiller)

During 2006 and 2012, the Green Chiller members have produced and commissioned together about 630 absorption and adsorption chillers with an accumulated cooling capacity of 18.8 MW. About 34% of these chillers are used for solar cooling systems and 44% for CHPC systems. The rest is installed in district heating networks (8%) or is using waste heat e.g. from industrial processes (14%).

7 CONCLUSION

Active air-conditioning of buildings is necessary, if high internal and external loads cannot be removed by efficient night ventilation. Therefore, thermally driven sorption chillers can often provide an environmentally sound alternative to electricity driven technologies. This is because sorption chillers use environmentally friendly refrigerants (water or ammonia) and they have a very low electricity demand for the chiller itself.

In the small and medium-scale cooling capacity range up to 500 kW several novel single-effect water/lithium bromide and ammonia/water absorption chillers as well as water/zeolite and water/silica gel adsorption chillers are now available on the market. The market potential for solar cooling is very large, so that different companies have developed complete solar cooling kits (sorption chiller, heat rejection, etc.) for the product business. Solar cooling is especially interesting if the solar thermal system is also used for other applications such as

heating, hot water, etc. Thus, maximum operation time and low-cost driving heat for sorption chillers are the key for economic efficiency of solar cooling systems. Other heat sources like district heat is particularly of interest if cheap excess heat in summertime is used for decentralized sorption cooling systems. Furthermore, if waste heat from a cogeneration unit (CHP unit) is used for sorption cooling, then this leads to longer operating times and increased electricity production of the cogeneration unit itself.

The Green Chiller – Association for Sorption Cooling e.V. is helping to develop and promote the solar cooling and thermal cooling markets in Europe to get solar cooling out of its niche existence.

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