DEVELOPMENT OF SOLAR THERMAL TECHNOLOGIES

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ABSTRACT

Solar Thermal market is mostly recognised as solar collector technology market and is represented by three main solar collectors types flat-plate, evacuated tube, unglazed plastic. Solar thermal market is mostly represented worldwide by Domestic Hot Water (DHW) systems for single family houses, then by Domestic Hot Water (DHW) systems for multi-family houses and public buildings, next are district heating systems that have been also installed mainly in Europe. New promising applications of solar thermal technology are solar combi-systems for domestic hot water and space heating, with their modern extension to solar-combi plus systems for domestic hot water, space heating and cooling. Solar thermal is also connected with solar passive technologies focused on avoiding heating loads in winter and cooling needs in summer. It is expected that solar thermal technologies will be very soon one of the major renewable energy technologies for the low and medium temperature heat supply (depending on the climate) in buildings. To improve implementation of solar thermal it is necessary to offer any building to a client by construction companies and developers as fully ready energy efficient technology product with solar technologies included. Solar cooling has huge potential in the future because of the natural synergy between solar energy availability and cooling needs.

INTRODUCTION

Nowadays solar thermal market is represented by many different technologies. It includes systems for hot water preparation (mainly domestic hot water), systems for space heating of single and multifamily houses and public buildings, and large scale systems (plants) for district heating. These systems are based mainly on flat plate and evacuated tube solar collectors (different types). In some regions of the world unglazed plastic collectors are widely used as swimming pool absorbers. Solar thermal technologies are recognized as mature technologies. Depending on the region, climate and energy resources of a given country, solar thermal technologies are more or less cost competitive to conventional heating systems. They have already reached a high level of deployment in some countries. There is a growing market for new innovative solar technologies as solar air conditioning, cooling and industrial applications. Apart from active systems there is a need to develop solar passive technologies for building application. The potential of these technologies to reduce energy demand is still underestimated.

SOLAR THERMAL MARKET

Solar Thermal market is mostly recognised as solar collector technology market. There are four main types of solar collectors: flat-plate, evacuated tube, unglazed plastic and air collectors. Solar Thermal market has been developing very fast since 90-thies. Nowadays, the total capacity of solar thermal collectors installed worldwide is about 180 GW_{th}. There are flat-plate and evacuated tube collectors (nearly 90%), unglazed plastic collectors (swimming pool absorbers, about 10%) and air solar collectors (about 1%). Of course depending on the region different types of solar collectors are used. In China there are mainly vacuum tube solar collectors, in Europe and Japan mainly flat-plate, then evacuated tube, in the USA, Canada, Australia and New Zealand plastic unglazed swimming pool collectors.

The top leading country in installed capacity in solar collectors is China (evacuated tube ones). The other top leading countries in application of flat-plate and evacuated tube solar collectors are: Turkey, Germany, Japan, Israel, Brazil, Greece, Cyprus, Austria, and India. The USA and Australia are leading in unglazed plastic collectors (Weiss, Bergmann, Stelzer, 2010).

Apart from the total installed capacity in different countries it is interested to analyze the solar thermal use from the point of view of the installed capacity per number of inhabitants. In this case the world top countries in application of glazed flat plate and evacuated tube solar collectors are: Cyprus, Israel and Greece. Of course it is because of very good insolation conditions. However, it must be also mentioned that the high latitude countries like Austria, Germany and Denmark are also at the top of this ranking. This situation is caused by strong supporting renewable energy policies that take place in these countries. It is also noticeable that China, the country with its highest population in the world takes the 9^{th} place. In this case reasons are more complex and complicated, and of course solar thermal market is driven by very fast growing economy where renewable energy sector plays important role.

Nowadays, solar thermal market is mostly represented worldwide by Domestic Hot Water (DHW) systems for single family houses, then by Domestic Hot Water (DHW) systems for multi-family houses and public buildings. Recently district heating systems have been also installed mainly in Europe. Nowadays, the district heating systems is represented by about 150 large-scale plants (collectors arrays ≥ 500 m²; what corresponds to 350 kW_{th}) (Dalenback, 2010). There are more than 40 plants with a nominal power of 1 MW_{th}. The biggest plant is in Denmark with capacity of 13 MW_{th} (18300 m² in Marstal, constructed in 1996) and 7,5 MW_{th} (10700 m² in Broager, constructed in 2009) and in Sweden with capacity of 7 MW_{th} (10000 m² in Kunglav, constructed in 2000). In Poland the biggest solar heating system has been installed recently with capacity of 5 MW_{th} (7000 m² in Łódź, constructed in 2010). The large solar heating plants, in a form of ground mounted solar collector arrays, and/or roof-integrated and roof mounted solar collectors, are used by district heating and housing companies. There are also some other large scale solar systems for industrial application mainly in the Netherlands and Greece.

The large scale solar heating systems are installed not only in Europe. The United Arab Emirates have become recently a centre of innovative civil engineering projects, including utilization of solar energy. At the Palm Jumeirah Island in Dubai Fourteen buildings with luxury tourist apartments constructed along the bank of the ”palm trunk” have been equipped with 3000 m^2 of solar collectors to supply heat for heating about 280000 liters of water per day. The biggest large scale solar heating systems have been installed in the United Arabic Emirates with 30 000 m^2 of the flat plate solar collectors. It should be mentioned that the working fluid in the solar collectors loop is antyfreezing mixture, because of risk of having one night in a year with temperature about 0^0C.

New promising applications of solar thermal technology are solar combi-systems for domestic hot water and space heating. These systems have been installed mainly in Europe (Austria, Germany, Switzerland, The Netherlands, France) and in Japan. They need a back-up of conventional fuel (e.g. gas, oil) or electricity or renewable source (e.g. biomass) or to be coupled with a heat pump to provide heating energy during periods of low insolation. Solar combi-systems require bigger area of solar collectors per one person than standard DHW systems.

There are also some examples of very innovative solar technology, so called solar-combi plus systems for domestic hot water, space heating and cooling. Solar cooling systems have reached the near-market stage of development recently. The operation of these systems is based on thermally driven processes including thermo-chemical sorption processes. Closed systems contain sorption chillers and can be used for smaller decentralized conditioning or bigger central one. The large solar cooling systems for air conditioning and refrigeration have been introduced recently. The first big solar cooling plant was installed in Athens in 1998. It consists of 2700 m^2 of flat plate solar collectors supplying heat to two adsorption chillers, each of 350 kW of installed capacity. Nowadays, there are some others in Italy, Spain, Portugal and Germany, they represent different solar collectors technology (flat-plate, vacuumed tube, concentrating) coupled with sorption technology: absorption or adsorption ones.

Concentrating solar collectors used in solar combi plus systems are mainly applied for medium scale industrial application and food production. The most popular are parabolic troughs in long arrays that concentrate the solar radiation on the absorber pipe located in the focal line of devices. Such systems require high irradiation of beam solar radiation and can be effectively use in low latitude countries.

Solar thermal is also connected with solar passive technologies. Such technologies utilize solar radiation in natural way and do not require any mechanical devices to force the flow of fluid gaining solar energy. Solar passive system collects solar energy and converts it into useful heat that is distributed and accumulated in the elements of building structures. Heat and mass transfer phenomena that takes part during these processes are well known from physics of building. Solar passive technologies are focused on avoiding heating loads in winter and cooling needs in summer.

PROSPECTS OF SOLAR THERMAL TECHNOLOGIES

It is expected that solar thermal technologies will be very soon one of the major renewable energy technologies for the low and medium temperature heat supply (depending on the climate) in buildings. If domestic hot water and space heating is plan to be used the low temperature heat supply systems are good solution. If apart from heating demand the cooling loads are expected than more complex system with medium temperature solar collectors have to be applied.

Solar heating and cooling of new buildings should be introduced in the planning phase before the building construction. Application of solar heating/cooling system must be well prepared and thought out solution. Solar thermal systems, active and passive, should constitute elements of any building envelope and be a part of standard heating and cooling installations.

To improve implementation of solar thermal it is necessary to offer any building to a client by construction companies and developers as fully ready energy efficient technology product, where solar thermal technologies are included. Solar thermal makes buildings to be attractive not only because of environmental reasons, but running costs as well.

Strong limitation to the application of solar collectors is caused by too much solar energy available in summer when the heating load (only for Domestic hot Water) is not high and a lot of solar heat must be treated as waste heat. Protection of solar heating system against too much solar gain in summer and probability of overheating of the system is a real problem even in high latitude countries. It must be mentioned, that especially in these countries the operation of solar heating systems can be problematic because of not only too much heat but also because of properties of heat transfer collector fluid that is antifreezing mixture and not always is tested and designed to operate in high temperature range (e.g. in evacuated tube collectors).

In winter a lot of heat is needed for hot water preparation and space heating. In contrary in summer only hot water demand exists. There is very poor coherency between heating energy needs and availability of solar energy. Problem of sizing a solar heating system to be big enough for DHW use and space heating loads (even partially) in winter, and to be just adequate for heating demand (only DHW) in summer can be solved by application of solar cooling. Most of solar cooling and refrigeration systems are used in middle scale (hotels, public buildings). This is expected that soon such systems will be available for domestic use. Some prototypes have been already constructed. A new concept of solar driven cooling/heating device based on a double adsorption/desorption cycle that takes place in two small tanks has been developed (Crema, A. Bozzoli, G. Cicolini, 2010). The cooling capacity of the system is 25 kW_{th} and the overall COP is in range of 0,6 to 0,7. It must be mentioned that solar cooling technology has huge potential in the future solar application mainly because of the natural synergy between solar energy availability and peak time and demand of cooling needs.

The other solution of new solar thermal technology in future is application of air collectors in a building structure. For many years application of solar collectors was limited for a very simple site- built system for drying purposes. Nowadays, the air solar systems constitute the envelope of the building and this technology can be expected to be applied in a building structure worldwide in future as solar wall technology. It should be noticed that perhaps not all data of existing solar air collectors are in official statistics. However, it should be mentioned that in Canada and the USA air solar collectors represent the solar wall technology that is very promising for the future application in buildings.

Distribution by Application of the World's Top 8 Countries related to newly installed capacity is presented in Fig.1.

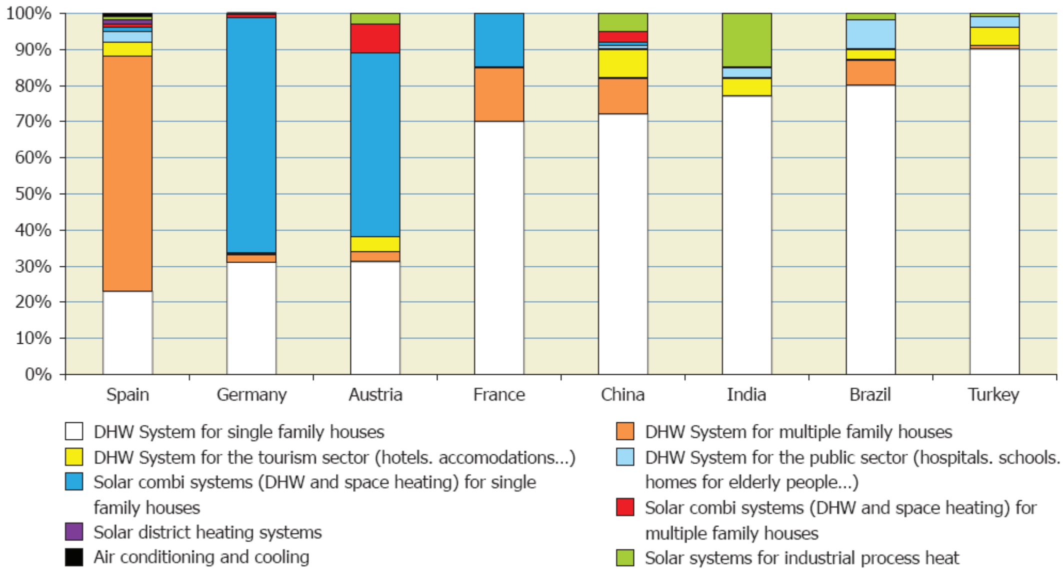

Fig.1. World's Top 8 Countries / Related to newly installed capacity (ref. Weiss, W., Mauthner, F.: Solar Heat Worldwide, IEA SHC 2010)

Usually PV modules present efficiencies in the range of 8% (a-Si) to 24% (c-Si). Performance of the PV cells decrease at higher operation temperature, what is one of the most important disadvantages of the PV technology. PV modules convert a small part of the incoming solar radiation to electricity, with the greater part being converted into heat. This effect increases their temperature, resulting to its efficiency drop. Therefore it is beneficial to extract extra heat (waste heat) during PV module operation to keep their temperature and in consequence their efficiency at the satisfactory level. The combination of PV modules with a fluid (water or air) heat extraction unit constitutes the hybrid photovoltaic/thermal (PV/T or PVT) system (Tripanagnostopoulos Y., 2006).

Very specific solar wall technology is presented in Fig.2. This is an active solar hybrid system, i.e. solar thermal coupled to solar electric PV system that constitutes the south wall facade. The black elements in the middle part of the wall (roof) are PV modules. There are air ducts under PV panels that direct the air heated by solar radiation and waste heat produced during operation of PV modules to the HVAC system. The roof (south facade) with PV thermal solar hybrid system has been installed at the 'Eco-Canteen' of the Fiat Research Center in Turin.

Fig. 2. The PV thermal solar hybrid façade (system) installed at the 'Eco-Canteen' of the Fiat Research Center in Turin

There are also other types of PV/ solar thermal hybrid systems (Souliotis, Tripanagnostopoulos, Kalogirou, 2010). A combined hybrid PV/T solar systems can simultaneously provide heat and electricity. An example of the PV/T collectors is presented in Fig.3 and its detailed structure in Fig.4.

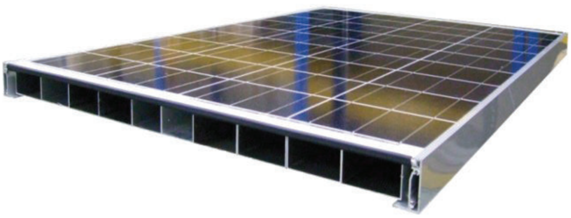

Fig.3. An example of the PV/T solar collector (M. Y. H. Othman, 2010)

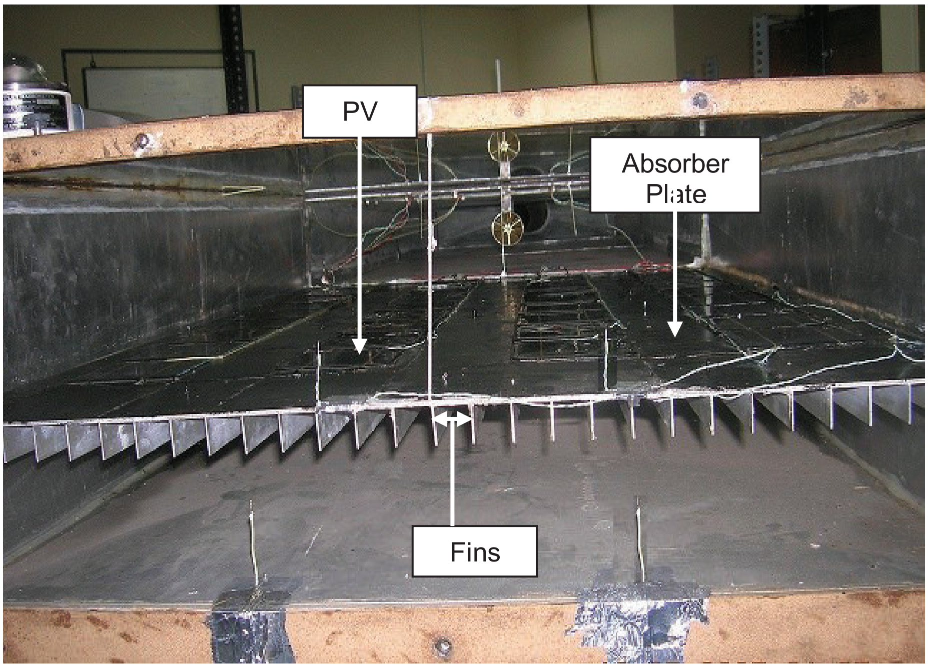

Fig.4. An example of the PV/T solar collector structure (M. Y. H. Othman, 2010)

Thus a combined hybrid PV/T solar systems can achieve a higher conversion rate of absorbed solar radiation than in a standard PV system. Even if the thermal efficiency of such system is lower than efficiency of conventional solar thermal collector, the total efficiency in such cogeneration solar system is good enough. PV/T systems are very promising technology for the future polygeneration energy generation systems.

Hybrid PV/T systems can be applied mainly in buildings for the production of electricity and heat and seems to be suitable for applications not only under high irradiation level but also under moderate ones, as in Poland.

OTHER PROSPECTS

It must be underlined that fostering development of solar thermal technologies will be possible through direct incorporation of these technologies into building (construction, installations) and improvement of storage processes. Improvement of storage technologies means to accumulate solar energy with higher density, in short and long term, and to use materials with high thermal capacity. The use of Phase Change Materials that undergo a solid-liquid transition at temperatures within the desired range, for heating or cooling purposes is another interesting issue for solar thermal applications in buildings.

In consequence of the implementation of solar active and passive technologies the energy consumed by buildings can be much reduced. One of the best options of energy conservation in buildings and implementations of renewable energies is the "solar conscious" concept of a building. The architecture of a building, including structure and materials used, is crucial for the energy demand of any building. Knowledge of solar radiation availability is useful for energy efficient architectural concept of a building and for implementation of solar active and passive systems. There is high time to integrate solar technologies into building structure and to develop hybrid energy solutions for a building, i.e. thermal/electric complementary energy systems.

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