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ScienceDirect

Energy Procedia 78 (2015) 1968 – 1973

Energy Procedia

6th International Building Physics Conference, IBPC 2015

Solar Thermal Systems For Low Energy Hotel Buildings: State Of The Art, Perspectives and Challenges

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Abstract

The implementation of energy efficiency measures, as well as the integration of renewable energy systems, are challenging tasks on the road towards the Low or Zero Energy Buildings (ZEB). This is even more the case, when considering intensively energy consuming buildings, amongst them hotels and touristic lodgings, especially when they operate in intensively seasonally visited regions, such as the Mediterranean. Even when applying the fundamentals of energy efficient design of buildings to a hotel, like the implementation of sound sun-protection schemes, the use of thermal insulation, and the use of efficient Heating Ventilating Air Conditioning (HVAC) systems, there is a significant demand for sanitary hot water, as well as for warm water for purposes like swimming pools that has to be covered. This can be ideally done by means of Renewable Energy Sources (RES) with solar thermal systems being a primary candidate, as they meet the range of temperature requirements and feature a proven efficiency, reliability and durability. For over thirty years now, solar thermal systems have been applied in hotel buildings in Greece, mostly with success, although failures were also part of the learning procedure. It is therefore of interest to present the current situation of solar thermal systems applications in the hotel sector and to review the state of the art of large scale solar thermal systems, in order to be able to determine future challenges.

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

*Keywords:*Solar thermal systems; hot water demand; hotels; energy efficiency

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Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.385

1. Introduction

Significant progress has been made in Europe over the last twenty years considering the use of RES in general, and the building sector in particular. More specifically, in Greece, 18% of the total energy production is based on RES, namely on small and large hydro, wind and solar (PV and solar thermal) systems, while Greece is considered one of the leading countries in installed solar thermal systems [1]. By the end of 2012, an installed capacity of 2,9 GWth corresponding to a total of 4,1 million square meters of collector's area was in operation. Greece has in absolute terms the second largest total installed capacity in Europe, after Germany, and also the second largest per capita installed capacity, after Cyprus [2]. At the same time, the tourism industry is contributing 16% of the Greek Gross Domestic Product (GDP), hence, representing the most important service sector of the country. In 2012 there were approximately 9.700 hotels operating in Greece with an overall capacity of 725.000 beds, 56% of which were operating on a seasonal base [3]. Although hotels represent only 0,82% of the building stock in terms of built area, they consume almost 10% of the total primary energy consumption of the building sector, with an average specific annual final energy consumption of 407 kWh/m^2 [4]. This value varies strongly with respect to the hotel type, location, class and use, but Sanitary Hot Water (SHW) accounts in all cases for a significant amount of the consumption, making therefore solar thermal systems the most suitable tool to significantly reduce the energy demand [5]. This has been understood since the early 1980s, making hotels the single most important non-residential target group for the solar technologies [6]. A first step towards the evaluation and the energy upgrade of hotel buildings took place in Greece in 2012. Using a MATLAB algorithm, hotels were classified in well separated clusters based on their electricity and thermal consumption. Based on this classification, energy efficient techniques can be proposed aiming at minimizing the energy consumption of hotel buildings [7].

2. Technological Solutions and Trends

According to the methodology widely adopted by the academic community and international organizations like IEA, active solar energy systems are classified according to the produced energy form and application, the operation principle and the working medium [8]. They can therefore be classified in the following three groups:

- According to the type of solar thermal collector (uncovered water, evacuated tube (EVC), flat plate (FPC), compound parabolic (CPC), air collectors and concentrating ones)
- According to the type of system operation (thermosiphon system vs. forced circulation system)
- According to the application (swimming pool heating, SHW production, space heating and /or cooling).

FPC are usually permanently fixed in position and require no tracking of the sun. They should be oriented directly towards the equator, facing south in the northern hemisphere and north in the southern. They are most commonly used in Europe for water heating, whilst EVC are most commonly used in Asia, in particular in China. The latter achieve higher solar gains in colder weather and for less favorable conditions and can also produce water at higher temperatures than FPC. EVC have higher efficiency at lower incidence angles, so they are more appropriate for a day-long performance. S.A.Kalogirou suggests the appropriate type of non-concentrating collector, based on the application [9]. Uncovered water collectors are used to heat seasonal running swimming pools. As they have no insulation and no cover they are susceptible to weather conditions and demonstrate high heat losses. Air collectors are used for supplementary heating or agriculture applications (drying). The distribution of the total installed capacity in operation by collector type in 2012 in Europe is presented in Figure 5 of IEA report [10].

Regarding the type of the systems' operation, thermosiphon systems are most commonly used for SHW production. Their main disadvantage is that they are comparatively tall units, which make their architectural integration more difficult. Also, extremely hard or acidic water can cause scale deposits that may clog or corrode the absorber fluid passages [11]. They are used in warm climates such as Africa, South and East Asia (except China), Latin America, Southern Europe and the MENA region (Israel, Egypt, Jordan, Lebanon, Morocco, Tunisia) and also the Gulf region. On the other hand, forced circulation systems are more common in Central and Northern Europe [10, 12]. This has to do both with the climate and operational requirements, namely the necessity to protect the storage vessel from low temperatures and the architecture and typology of the buildings, and also with socio-economic parameters. It is this combination of reasons that makes stand-alone, thermosiphon systems particularly attractive for the multi-family residential buildings that are common around the Mediterranean, also in Greece (94%), as it enables individuality in the installation, which goes hand in hand with the high degree of private ownership of residences [13]. It is also a result of reasons and circumstances, which determines the propagation of solar thermal technologies. The distribution of solar thermal systems, in Greece as well as on a global and European level, based on application types, is depicted in Fig. 1 [10, 12].

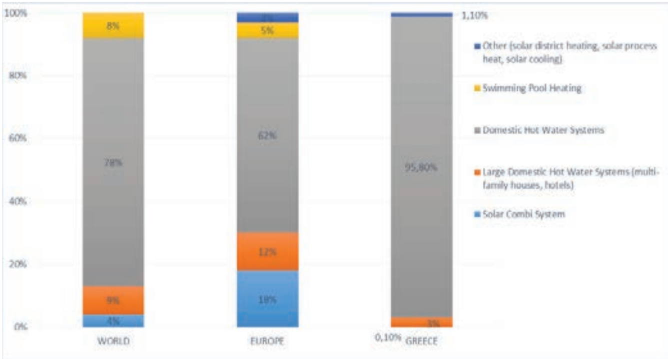

Fig. 1. Distribution of solar thermal systems by application for the total installed water collector capacity, by the end of 2012.

It is obvious that hot water production for single and multi-family houses, as well as for small hotels, is the most common application in Greece, Europe and worldwide. However, as it can be seen, there are differences even within Europe: approximately 18% of the European installed solar thermal capacity supplied heat for both domestic hot water and, albeit to a lesser extent, for space heating, as it is met in the so called solar combi-systems, whereas in Greece only 0,10% is used for solar combi-systems. The situation is quite similar in Cyprus (which has the highest installed solar collectors' capacity per capita), Italy and Spain. The two main reasons for the limited use of solar thermal systems for heating purposes are (a) the comparatively short heating period with respectively low heating loads which, at least as long as fuel prices were low, made solar heating not competitive and (b) the fact that in the European South heating systems operate mainly at medium and high temperatures, with radiating or convective/radiating heating elements, in contrast to Central and Northern Europe, where underfloor heating systems are very popular. The former systems need a feed water temperature of at least 55°C to operate efficiently (compared to the 40°C of the underfloor heating system), which a solar system cannot deliver efficiently by itself during winter. It is therefore only with the propagation of underfloor heating systems since the 2000s that combi-systems have started to become attractive in Southern Europe.

This fact had a reciprocal effect on the entire solar thermal branch in Greece: addressing the requirements of the market for thermosiphon systems, the industry focused on this type of technology, establishing its position as a leader in the installed thermosiphon systems on a European level, but not reaching the same maturity level into the provision of integrated solutions for forced circulation, central systems, as they are required in hotel applications.

3. Solar systems in the Greek hotel sector

A survey has been conducted in 2014, monitoring a sample of 69 Greek hotels, in order to evaluate the utilization, use and perspectives of solar applications already in use. The majority of the hotels is operating seasonally, with the peak being monitored at high season (July and August) and is located in areas enjoying high levels of solar radiation and of sunshine such as the Cycladic islands, Peloponnese and Chalkidiki. Within the sample, 67% of the hotels are big units (with more than 100 beds), 33,3% are 5* hotels (luxury hotels), 40,6% are 4*, 23,2% are 3* and only 2,9% are 2* hotels.

The 69 hotels feature a total installed collectors' area of 24.400m^2; the use of the solar energy yielded, with respect to the application, is presented in Fig. 2. As expected, the vast majority concerns the hot water production. Solar systems address ideally this demand, with temperature requirements between 45°C and 65°C and a very predictable daily profile. Furthermore, it is of interest to notice the two installations of solar air conditioning in operation, as they are the very first successful commercial applications of this technology on a European level. It is a fact that solar thermal systems for cooling is an emerging market with a huge growth potential in the hotel sector in Greece and elsewhere, although it is still less deployed [14]. Finally, one can observe that in hotels located in mountainous areas, which operate mainly in the winter with respectively high heating demands, combined thermal systems for heating and SHW are used.

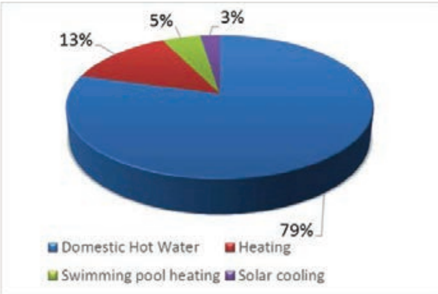

Fig. 2. Distribution of solar thermal systems by application.

Another criterion taken into consideration is the installed collectors' area. As shown in Fig. 3, 54% of the hotel units have over 100m^2 of installed collectors, making them big installations. However, it is perhaps more interesting to consider the installed collectors' area per bed, where it becomes obvious that the empirical rule of 1m^2 collector/bed which was applied successfully in the 1980s and 1990s, is not being followed anymore; the majority of the hotels (57%) have less than 1m^2 collector/bed. This decrease of the installed collectors' area per bed is a result of the use of higher efficiency systems.

Those systems are very appealing to the market, not only because of their higher efficiency and the resulting need for less area on the buildings' roofs, but also due to their short payback period (approx. 2,5 years depending on the size of the installation) and the high overall energy savings achieved [15].

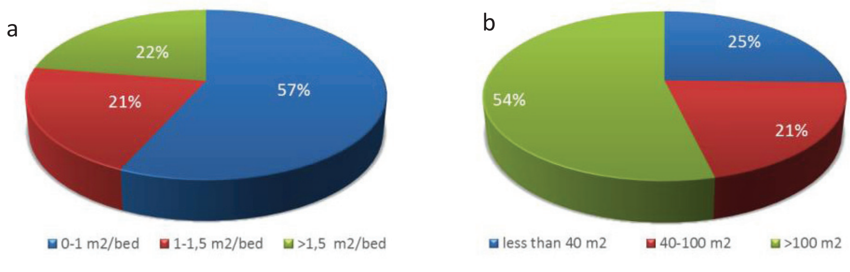

Fig. 3. (a) Installed collectors' area per bed; (b) Total installed collectors' area.

It is also of interest to consider the size of the hot water storage vessel used, with respect to the collectors' area. As it is depicted in Fig. 4, 40% of the hotels have storage vessels with a capacity of between 40 and 65lt/m^2, which is the expected value, and 20% have a larger capacity. However, in 40% of the hotels considered, the storage capacity is less than 40 lt/m^2 of collectors, which is a quite low value indeed.

This situation, which eventually results in the under-dimensioning of the storage vessels, leads to the solar collectors operating less efficiently, as they are not being utilized to their full potential. It also leads often to stagnation temperatures, and thus increases the risks of collector's failures, and to difficulties in coping with the peak demand, particularly in the case of sea-side, seasonal hotels, where almost the entire hot water demand occurs over a two hours' period in the evening. It is therefore evident that it has to be avoided.

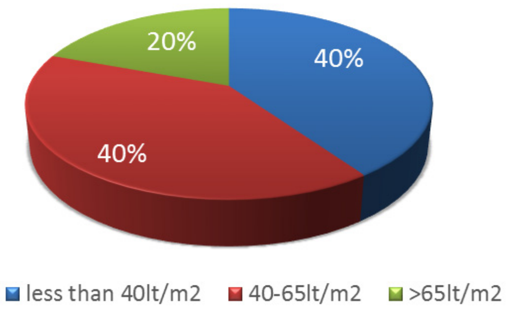

Fig. 4. Installed storage capacity per collectors' area.

Finally, it can be observed that, in the last few years, big hotel units have the tendency to install more RES systems replacing their older ones. It is in line with this development, that thermosiphon systems installed twenty years ago are gradually being replaced with forced circulation ones. A further proof for this development is the fact that there are currently several companies in the market, specializing in the field of designing and installing integrated, forced circulation solar systems. The share of the market players participated in this study is depicted in Fig. 5. One particularly interesting result is the fact that in the case of those forced circulation systems only 7.4% of the collectors are Greek. It therefore becomes clear, that although Greece is a major exporter of solar collectors, it mainly imports the know-how of the central, integrated, forced circulation systems.

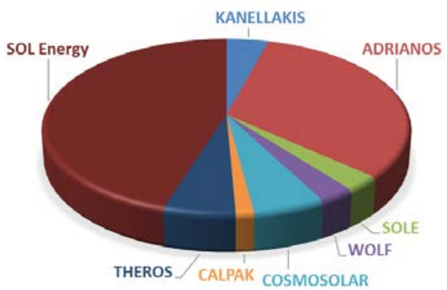

Fig. 5. Distribution of the systems based on the total installations, with respect to the system provider

4. Conclusions

Solar thermal systems have become the most widespread renewable energy systems in the building sector over the last forty years. They are efficient, reliable, cost-effective and have an appealing image to the final consumer. This applies also to the hotel sector, which is currently a major customer for the solar branch. Greece has been a success story regarding solar systems: it features a strong well established solar industry and solar systems are widely used in all types of buildings. There are, however, some aspects that deviate from this sunny picture: Even small and medium hotels are moving from the traditionally used stand-alone thermosiphon systems towards forced circulation ones, a solution that calls for integrated design and implementation of whole system solutions. Future research needs to focus on improved architectural quality of Building Integrated Solar Thermal systems (BIST) that will ensure both energy efficiency and architectural integrability. In addition, future research needs to examine with more hard facts or/and measured data, the correlation between the hotel type (luxury, 5*, 4*, 3* and mountainous, city hotels, resorts) and the installed collector's area/bed.

This study also reveals that although solar manufacturers companies used to take over the overall process of solar plant construction (production of solar collectors and storage vessels, design of the system and installation), in the last five years an increasing number of specialized companies have emerged in the market, mainly in the design and installation role. The reason for this is the fact that solar collectors' manufacturers had difficulties to provide turn-key solutions. This market gap was rapidly filled by companies specializing in the study, design, installation and commissioning of forced circulation solar thermal systems. They tend, however, to utilize mainly solar collectors and system components imported from other European countries and not from the domestic producers, leading therefore to a change in the local market. Greek manufacturers should, therefore, aim at providing the necessary integrated solutions, in order to re-gain this profitable part of the market.

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