SOLARNA TERMIČKA ENERGIJA U ZGRADARSTVU - STANJE I PERSPEKTIVE

SOLAR THERMAL ENERGY FOR BUILDINGS – CURRENT STATE AND PERSPECTIVES

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Skoro 50% potreba za korišćenjem finalne energije u Evropi i u svetu odnosi se na termičku energiju, što je znatno više u odnosu na potrebe za električnom energijom za osvetljenje i pogon električnih uređaja ili za korišćenjem energije u saobraćaju. Oblast zgradarstva zauzima značajan udeo (oko 40 %) u ukupnom korišćenju primarne energije. Ograničene količine fosilnih goriva, njihov negativan uticaj na životnu sredinu, visoke i nestabilne cene i uvozna zavisnost uticali su na intenzivniji razvoj i povećano korišćenje solarne termičke energije širom sveta. U svetu, solarno grejanje i hlađenje je najznačajniji solarni sektor, snaga instaliranih sistema iznosi blizu 500 GW_{th} i veća je od snage fotonaponskih sistema kao i snage solarnih termoelektrana. Prema podacima IEA SHC (Međunarodna agencija za energiju, program za solarno grejanje i hladjenje) za 2016. godinu, prema ukupnoj instaliranoj snazi kolektora u svetu prednjači Kina, zatim sledi Evropa, pa SAD. Izgradnjom solarne toplane za daljinsko grejanje u Pančevu, sa očekivanom isporučenom energijom od oko 600 MWh/god, Srbija takodje ima mesto na mapi sveta u ovoj oblasti. U radu je dat pregled veličine, broja, snage, tipova solarnih kolektora i drugih karakteristika izgradjenih solarnih termičkih sistema u svetu. Identifikovan je potencijal za moguću primenu solarnih termičkih sistema i razmatrani su tehnološki i drugi izazovi i perspektive za budući razvoj u oblasti korišćenja solarne termičke energije u zgradarstvu.

Ključne reči: Solarna termička energija, zgradarstvo, stanje i perspektive

Almost 50% of final energy consumption in Europe and worldwide is addressed to thermal energy, which is significantly higher than energy needs for electricity for lighting and electrical appliances and for traffic. Building sector takes a significant share (about 40 %) in total primary energy consumption. Limited amounts of fossil fuels, their negative impact on environment, high and unstable prices and import dependency of fuels caused intensive growth and usage of solar thermal energy in the world. Solar heating and cooling are the most important solar sector worldwide, where installed solar system power is about 500 GWth and it is higher than PV system power and also the power of solar thermal plants. Today, according to the total installed collector capacity, China dominates on first place, then Europe, while United States comes right after, according to the SHC Agency data for 2016. With a district solar thermal plant in municipality Pančevo, Republic of Serbia also has its place at a world solar thermal map. This paper presents a review of different sizes, number, installed power and types of solar collectors and other characteristics of built solar thermal systems worldwide. Potential for possible usage of solar thermal system was identified and technological and other challenges and perspectives for future growth in the field of solar thermal energy were discussed.

Key words: *solar thermal energy; buildings; state and perspective*

1. Introduction

Last decades global climate has changed significantly, with 1.5°C higher temperature than in nineteenth century, which further has a great impact on ecosystem, organisms and human well-being [1]. According to the literature [1], the highest warming up to 3°C is expected in "central and eastern North America, central and southern Europe, the Mediterranean region (including southern Europe, northern Africa and the Near East), western and central Asia, and southern Africa". In order to reduce the global warming as much as possible, it is necessary to reduce use of fossil fuels. Solar thermal energy is considered to be a cleanest carbon reduction technology, with the yields of 388 TWh in 2017, reduced amount of 134.7

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million tones of CO_2 worldwide [2]. In order to limit global warming to 1.5°C, the 45% of CO_2 emissions form 2010 level must be decreased by 2030 [3]. Solar energy potential, together with an economical solar system production gives the opportunity for cheep and environmental friendly energy exploration, which can be a smart solution for current global worming problems and a lack of energy worldwide. Higher initial costs of solar systems can be compensated by free solar energy and low costs in operation. Expanded development of solar systems worldwide also influenced of lower initial prices for installation of such systems. Further, the expansion of solar market influenced on higher number of new working places for workers' employment.

This paper presents the actual state in terms of solar thermal energy use worldwide. It is also commented on advantages and perspectives of solar heating and cooling, together with a current action plans and prices of solar market technology.

2. Current state in solar thermal energy use

According to the literature [4], the total final renewable energy consumption in Serbia in 2016 was 70993 TJ. The shares of used final renewable energy by sectors are shown in Fig.1. The share of used solar energy in Serbia was less than 1% [4].

Cumulative amount of electricity generated by solar systems in Serbia was 12 GWh (including only PV systems), while the amount for whole Europe was 113851 GWh, and worldwide 325098 GWh (including both PV and concentrated solar power) [4].

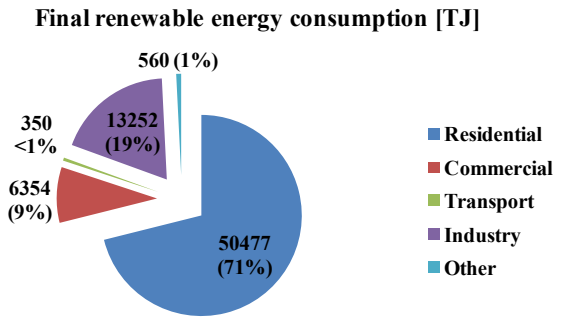

Figure 1. Final renewable energy consumption in Serbia in 2016 by sectors [4]

According to the data from Solar Heat Worldwide Report, total global solar thermal capacity of water collectors increased from 62 GWth in 2000 to 472 GWth in 2017 (Fig.2.), which means that total collectors' area increased more than seven times in this period [5]. The largest share of total installed collectors' capacity, 82.3%, is installed in China and Europe, and the rest of 17.7% is shared by US and Canada. Annual solar thermal energy yields (Fig.2.), corresponding to the installed collector capacity, increased from 51 TWh in 2000 to 388 TWh in 2017 [5]. In Europe, for 2016, 83% of all installed collectors were flat plate collectors, 14% evacuated tube collectors, and a rest of 3% unglazed water collectors [5].

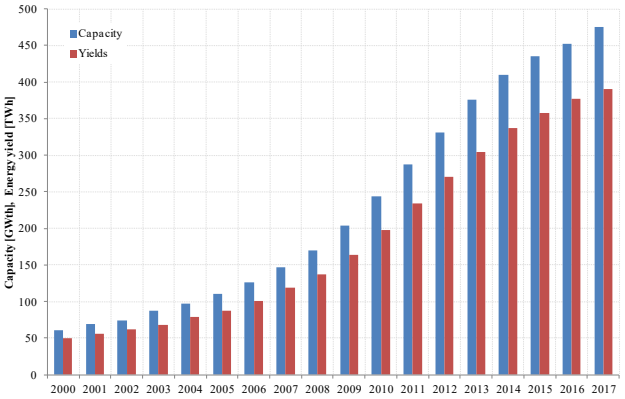

Figure 2. Global solar thermal capacity in operation and energy yields in a period from 2000 to 2017 [5]

Looking at the comparison between photovoltaic and thermal capacity growth in between 2010 to 2017 (Fig.3.), the photovoltaic systems had a growth rate of 33% in 2017, while the solar thermal systems had only 4% of growth rate. Solar thermal systems had the highest growth in a period 2010 to 2011 and after this, number of new installations decreased just to 4.2% in 2017. Positive market growth occurred in Turkey (4%), Mexico (7%) and India (26%) [5].

The most common water solar heating systems worldwide are small installations for single family houses, with about 90% of installations annually. Larger systems for residential, commercial and public buildings have been used since 1980s [5]. In Europe, large-solar thermal systems for district heating are installed in Denmark, Sweden, Austria, Germany, Spain and Greece. Perhaps it seems surprising that northern countries have the largest solar systems, from the point of lower solar irradiation during the heating season, but on the other hand, these countries have the greater needs for heating, which also influenced their development in the field of solar technologies. Republic of Serbia also has a solar district heating system in Pancevo, with a total collector field area 903

m^2 and expected annual solar yield of 600 MWh/a [6]. Number of installed solar district heating systems in Europe in period from 1983 to 2017 is shown in Fig.4 [5]. The highest number of installations was noticed in 2016, when 31 new solar district heating systems were implemented in Denmark. Looking outside the Europe, China is a leader by the number of large solar district heating systems.

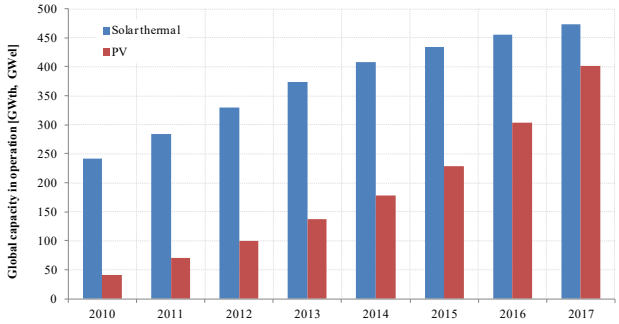

Figure 3. Global solar thermal and PV capacity in operation in a period from 2000 to 2017 [5]

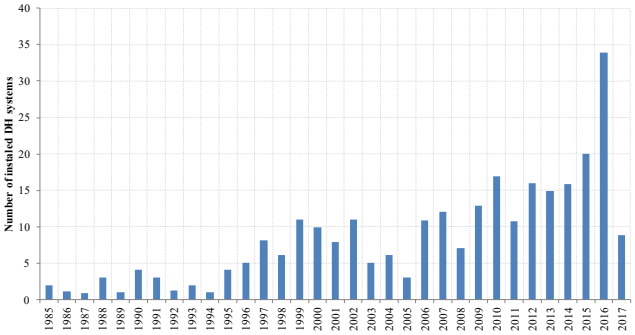

Figure 4. Large systems for solar district heating in Europe in 2017 [5]

Number of large solar thermal district heating installations by countries worldwide, together with a total installed capacity is shown in Fig.5. It can be seen that Denmark has the highest number and capacity of all installed solar district heating systems worldwide.

Looking at the data on total installed water collector capacity by type of application, until the end of 2016 in Europe and whole World, the highest percent of installations, about 63% [5], goes on domestic hot water systems for single family houses (Fig.6.).

The smallest shares can be noted for solar district heating (SDH) and solar district cooling (SDC), including also solar process heat (SPH). In Europe, about 19% of installations were solar systems both for domestic hot water and heating for single and multi family houses, while 12% were installations for public sector, tourism and multifamily houses [5].

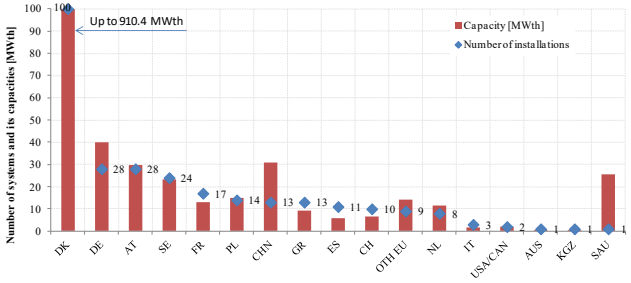

Figure 5. Large systems for solar district heating worldwide [5, 7]

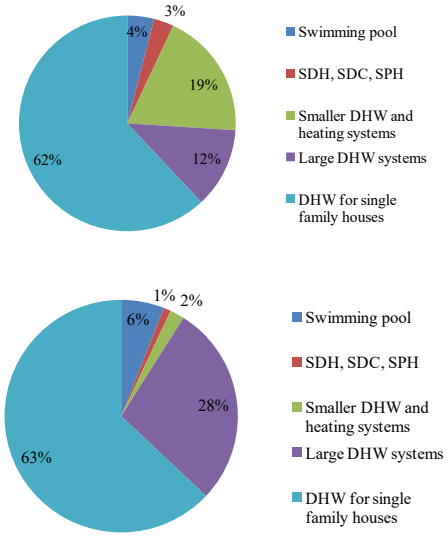

Figure 6. Shares of total installed solar thermal applications by 2016 in Europe (up) and World (down) [5]

2.1. Solar thermal cooling

Solar thermal systems for cooling have a significant advantage comparing to the heating systems in that that needs for cooling occurs in the same period when solar radiation reach its peak. In the opposite, the demand for heating is the highest when the solar radiation is the lowest during the year. About 70% of small and medium solar cooling systems were installed in Europe, while the largest solar cooling installation with absorption chiller "Desert Mountain High School, Scottsdale" is installed in Arizona, USA, with a total solar

collectors' capacity of 3.4 MWth [5]. Installed capacities, collector size and cooling capacities for different sites for solar cooling by countries worldwide are shown in Fig. 7. More than half of these systems (58%) work with flat plate collectors [5]. Some of the largest one worldwide installed in a period from 2007 to 2017 are shown in Fig.7 [5].

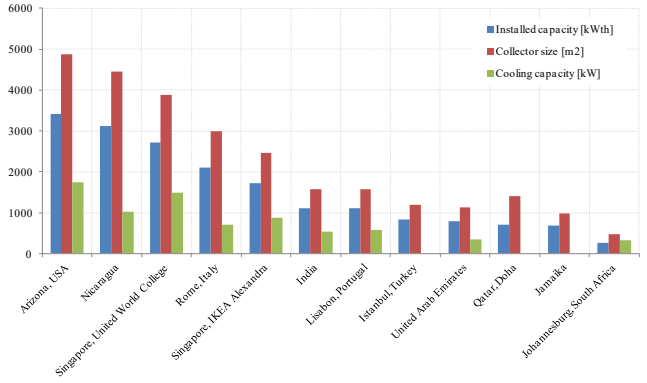

Figure 7. Installed systems for solar cooling worldwide [5]

According to Ge et al. [8], there are several possibilities for solar thermal cooling system improvements. They suggested that solar adsorption chiller could have better performances if novel concept with LiBr-water variable effect is implemented. Further, new systems with $CaCl_2$/AC-ammonia are in expansion together with the air conditioning systems driven by solar PV module. Solar PV cooling is in expansion, especially in China, because of its good performances, energy savings and stability in operation.

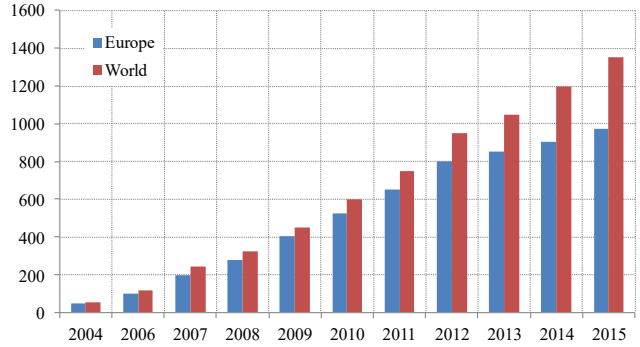

Figure 8. Number of installed solar cooling systems in Europe and worldwide [5]

Solar thermal cooling market is growing rapidly. From 2004 till 2015, the number of installed solar cooling systems increased more than 22 times [5] worldwide. The rapid growth of this market in Europe and whole world can be observed at Fig. 8. The highest number of small and medium size systems is located in Europe, with a share of approximately 70% [5] of global number of small and medium size systems worldwide.

3. Perspectives of solar thermal energy use

Last decade, a number of large-scale solar thermal systems significantly increased. According to vision 2030, a future strategic goal is to supply a 50% of heat demand for building heating and cooling through the solar systems [9]. In order to fulfill this, three main directions are marked: to develop storage technology using compact solar seasonal storage, to develop collectors from materials with better properties, which are suitable for higher temperatures and industrial use and to make improvements in research for solar cooling [9]. Solar thermal technology is considered as a highest carbon reduction perspective for the future. Besides this, it is environmentally friendly technology which provides less air pollution and fulfillment of clean energy targets (Fig.9.) [10]. Further, independence from fossil fuels is also one of the advantages of solar heating systems. It is sustainable energy which is also suitable for urban areas and easily implemental into existing DH systems and grids. Additionally, the largest cooling demands are in a good balance with solar energy availability. A great potential for sustainable energy use are PV solar cooling systems with battery storages [11].

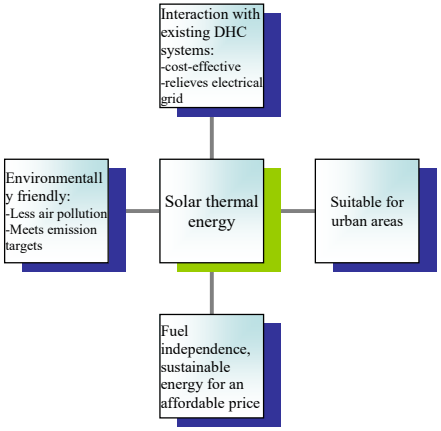

Figure 9. Solar thermal energy advantages and perspectives of usage [10]

Refurbishment of existing DH systems in a way of implementation of innovative technologies in new solar DHC subsystems leads to the more efficient plants, relief of electrical

energy grids, decrease of urban pollution, and also contributes to the EU renewable 2030 targets, where EU Commission suggested that the share of RES used in EU should be at least 27%, and later on at least 32% [12].

Perspectives of solar energy usage can be also shown through the competitive prices of heat obtained by solar thermal systems, comparing to the conventional natural gas and electricity prices in Europe. The comparison is given in Tab.1.

Table 1. Prices of solar thermal energy today and projection for 2030 [9]

Energy source	Today [Euro cent/kWh]	2030 [Euro cent/kWh]
Solar thermal	5-16	2-6
Natural gas	8,5-29	17-58
Electricity	7-33	14-66

According to the literature [9], there is a prediction that the costs of solar thermal energy will decrease around 60% with a development of technologies and market. The results of different researches worldwide showed that pay-back period for solar heating systems varies usually from 3 to 15 years, while the pay-back period for cooling systems varies from 8 to 12 years [8] depending on the type of collectors, size of the system, location and local feed-in policies. It is estimated that the specific investment cost of small solar thermal systems in Europe will be six times lower by 2030 than it was in ninety nineties.

4. Conclusions

A current legislation and EU directives demand a higher share of RES in use for heating and cooling. According to the Directive EU 2018/2001, it was proposed that the share of RES consumed in EU by 2030 should be at least 27%. In addition to achieve EU 2030 goals, it is also suggested to include solar thermal technologies in accordance with a national potential and strategies. European Solar Thermal Technology Platform suggested a 2030 vision with the goals for construction of Active Solar Buildings which could fulfill 100% of their heating needs, together with the plans for refurbishments of existing buildings using Solar Active Renovation. Solar energy provides a large scale of benefits towards EU goals regarding energy savings, fossil fuels reduction, CO_2 emission reduction, RES implementation in existing DHC networks, a growth of new, innovative technologies and markets, sustainable development and healthier urban environments. Last decades, solar heating systems have had leverage among solar systems, but now days, a special attention should be dedicated to development of solar cooling systems, having in mind the availability of solar energy in period of highest cooling demands. Also development of heat and battery storages allows the usage of solar energy during the whole year, apart from the current solar gains. Sustainability of solar thermal energy is a significant factor in future energy strategy, providing a lower dependency from fissile fuel import. District heating and cooling networks allow the dislocation of plants outside of the city centers and a transportation of energy to the households. In that manner, the area cowered with solar collectors can be extended. With an installation of solar plants as a sub-system in an addition to existing plants, it is possible to achieve savings during whole year. Initial higher costs for solar systems can be compensated by low operation costs end free solar energy.

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