Conference Proceedings

EuroSun 2016
Palma de Mallorca (Spain), 11 – 14 October 2016

Review of Solar Thermal Systems and Their Potential in Lithuania

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Abstract

Solar thermal systems with a total solar panel area varying from 2 to 204 m^2 have been installed in Lithuania for over 20 years. The market of such systems is slowly growing and the trend continues towards larger domestic hot water systems in multifamily buildings, hospitals, hotels and other large complexes. Nevertheless, there's still lack of performance reviews and analysis of these systems. The aim of this paper was to analyze medium size solar thermal systems from the perspective of energy production and economic benefit as well as to outline the differences of their actual performance compared to the numerical simulation results. A number of different solar thermal systems in Lithuania were selected for the study, and both financial analysis and performance analysis by means of simulation software were performed. Solar thermal domestic hot water (DHW) systems in question produce up to 528 kWh per year per one square meter of solar collector absorber area. However, the performance of these systems depends on the type of energy users, design solutions, equipment used and maintenance of these systems. Calculation of internal rate of return showed that a grant is required in most cases for solar thermal project to be fully profitable.

Keywords: *solar thermal systems, domestic hot water, energy prices*

1. Introduction

Renewable energy share continued to grow worldwide in recent years alongside with the increasing global energy consumption, particularly in developing countries, and a dramatic decline in global fossil fuel prices in last two years. Renewable energy provided an estimated 19.2% of global final energy consumption in 2014, and growth in capacity and generation continued in 2015.

Global capacity of glazed and unglazed solar thermal collectors rose by more than 6% in 2015, despite a market slowdown due primarily to the continued contraction of markets in China and Europe. China accounted for about 77% of newly installed solar water heater capacity, followed by Turkey, Brazil, India and the United States. Cumulative capacity of water collectors reached an estimated 435 GWth by year's end (with air collectors adding another 1.6 GWth), enough capacity to provide approximately 357 TWh of heat annually. Market development varied widely from country to country. Denmark, Israel, Mexico, Poland and Turkey reported significant growth. By contrast, low oil and gas prices in Europe and the ongoing slowdown in housing construction in China dampened these markets (REN21, 2016).

In 2014, the European market underwent a reduction in the newly installed capacity. In 2014, the market amounted to 2 GWth (approximately 2.9 million m²). This represents a decrease of 7.1 % in comparison with the previous year. The total installed capacity registered a net increase of 1.6 GWth, now reaching 31.8 GWth (45.4 million m²). This represents an increase of 5.3 % compared with the total installed capacity at the end of 2013. Only about 10400 m² (7280 kWth) of glazed solar collectors were installed by the end of 2014 in Lithuania, and the applications were mostly limited to single-family buildings (ESTIF, 2015). Only in recent years the trend continued towards larger DHW systems in multifamily buildings, hospitals, hotels and other large complexes, due to support from the government, EU and other funds. In 2016 more than 1500 m² solar collectors in over 15 hospitals will be installed for DHW and other needs.

doi:10.18086/eurosun.2016.04.15 Available at http://proceedings.ises.org

The major part of thermal energy used in public and multi-family buildings in Lithuania is supplied via the district heating network. 72.4% from all district heating produced energy was used for household purposes in 2012 (LSTA, 2012) and the price in different Lithuanian cities varies in the range from 0.044 Eur/kWh to 0.095 Eur/kWh (01.06.2016). In the last two years, district heating energy price dropped by 9.2% (LSTA, 2016). Quite frequently, natural gas, bio fuel or electricity are used for building heating systems. Switching from natural gas to bio fuel reduced the district heating energy price significantly within last two years. Due to a dramatic decline in oil and natural gas prices, conventional fuel prices decreased up to 35% in last five years as well.

The aim of this study was to review the existing medium-scale solar thermal (ST) systems and their potential in Lithuania in relation to traditional energy prices and government policies.

2. Review of Solar Energy Potential and Market in Lithuania

Average global solar irradiation in Lithuania is similar to the irradiation levels in such countries as Germany, Austria, Denmark, Poland, Latvia and Estonia with the annual potential of solar energy yield of approx. 1000 kWh/m². The daily potential in the country varies from 0.55 kWh in January to 5.8 kWh from one square meter in June; therefore, almost the whole irradiated solar energy can be collected during the warm period of the year (from April till end of October). Due to this fact, solar hot water (SHW) systems are most efficient in DHW applications in Lithuania (Kytra, 2006). Nevertheless, technical-economic potential of solar heat energy production in the country reaches up to 1.5 TWh/year (129 ktoe). The values of expected solar energy yield are increasing during the last decade as solar irradiation increased by 7% during the years of 2005 to 2014 compared to the long-term statistical data (Valancius et al., 2015b).

According to ESTIF 2014 statistics about 64 % of installed solar thermal systems in Lithuania were equipped with evacuated tube collectors. In fact the evacuated tube collectors are mostly used in small projects. Several studies showed that despite the fact that both evacuated tube and flat plate collectors are considered suitable for solar heating in Central European Climates, the evacuated tube collectors do not reach the additional expected energy yield (Trinkl et al., 2005). Flat plate collectors and evacuated tube collectors produce the same amount of energy from effective area during the summer season in Lithuania, but flat plate collector installations require much lower investment costs in most cases (Ambrulevicius, 2005; Jonynas et al., 2011; Sarka and Streckiene 2014). In recent years, the price of good quality evacuated tube collectors is slowly decreasing followed by the increase of the usage of this technology, yet there is still a lack of real efficiency and life span data at the moment. According to the European standard EN 15459:2006 the life span of solar collectors are from 15 to 25 years, but the actual life span of the vacuum varies from collector to collector, anywhere from 5 years to 15 years (Bhatia, 2014).

Some studies in Lithuania and in other countries of similar climate showed that small and medium-scale solar DHW systems with flat plate or evacuated tube collectors can produce from 335 to 523 kWh/m² of thermal energy per year, and the payback time of these systems is over eight years without the subsidies. The potential of ST systems is quite high; however, the support from government and EU funds is still necessary in most cases to achieve reasonable payback (Adomavicius, 2010; Ayompe and Duffy, 2013; Hugo and Zmeureanu, 2012; Jonynas and Valancius, 2010; Perednis et al., 2007; Valancius et al., 2015a; Valancius et al., 2015b). In Lithuania, some limited subsidy systems and funds for renewable energy installations exist since 2005. Depending on a project, it is possible to apply for a subsidy covering from 30 to 100% of initial costs. For example it is possible to get a subsidy up to 30 % for single family building, up to 40% for multifamily building and up to 100 % for hospitals. Such subsidies can be applied for solar thermal systems as well as other renewable energy installations. Evidence that the most important factor for users is the payback time and only two systems (Table 1) analyzed in this report were installed without any subsidies.

Some studies showed that relation between installation costs and area of the flat plate solar collectors (including heat storage tanks and auxiliary equipment) can vary in the range from 600 to 150 Eur/m² in SHW from 10 m² to 10000 m². The installation costs, annual maintenance and repair costs vary in wide range depending on the type of solar collectors and other components, but in general, larger SHW installations are relatively cheaper to maintain than small-scale SHW systems (Andrews et al., 2012; Leutgöb and

Rammerstorfer, 2013). Additional costs for design of the systems in Lithuania add up to 8% from the installation costs. In some cases, the costs of SHW installations in existing buildings can be up to 20% higher compared to new buildings (Valancius et al., 2015b).

The number of medium-scale SHW systems in Lithuania is still relatively low and represent the potential direction for development of these systems. There is a number of medium-scale SHW systems installed in the country varying from 60 to 204 m² of total solar panel area. Most of these systems are installed within the past few years in public buildings, hospitals and industrial facilities. The oldest still operational SHW system 77 m² was installed in 2002 in children sanatorium "Žibutė" (Kačerginė). However, it took 10 ten years for the first SHW system to be installed in multi-family building, as the first such system was launched only in 2012 (Katinas et al., 2013; Karbauskaite and Perednis, 2011; Valancius et al., 2015a; Valancius et al., 2015b).

Fig. 1: The first solar thermal system 60 m² in multi-family building in Panevėžys city and the biggest solar thermal system 204 m² in Plungė town hospital (till the end of 2015).

Some studies in Lithuania showed that public and multi-family buildings represent one of the major potential for SHW installation, as it is one of the best renewable energy alternatives for these buildings (Adomavicius, 2010; Diliunaite, 2013; Perednis et al., 2007; Valancius et al., 2015b;). More uniform DHW usage during the day is common for public or multi-family buildings, compared to the single-family houses. It is related to variability of occupants and their hot water consumption habits, and this aspect brings out a higher solar energy share without adding additional volume to the accumulation tank. Moreover, DHW consumption throughout the day presents the possibility to keep lower temperatures in solar collectors even during periods of high solar radiation. Public or multi-family buildings provide a possibility to connect several users to the same combined SHW system; therefore, the heat losses due to transformation and transportation of hot water will be incurred to a lesser extent during the system operation (Zandeckis et al., 2011).

3. Review and Analysis of Medium-Scale Solar Thermal Systems in Lithuania

Ten different ST systems in different Lithuanian cities were evaluated in this review. Most of these systems were designed for DHW applications. Flat plate or evacuated tube collectors and other equipment produced by different manufacturers were used for these projects. All of these systems are in operation for up to 5 years. Only some of the systems are equipped with heat meters or monitoring systems. Technical and economical characteristics of the analyzed systems are presented in Table 1.

Three different ST systems 4F, 5F and 3E (Fig. 3) were evaluated. All these systems are in operation from 2011 and are equipped with heat meters and monitoring systems. All of the analyzed systems have individual operational features that impacts their produced energy amounts. System 4F performs continuously from the start of the exploitation. System 5F was stopped for three weeks in August during pool renovation works. Performance of system 3E was interrupted for a few times due to system upgrades.

The measured performance of the existing ST systems was compared to the theoretical values obtained by means of simulation software "Polysun 8.1" (Velasolaris, 2015). All technical parameters of the existing systems such as inclination angle, orientation, energy demands and characteristics of the installed equipment were used as boundary conditions for the simulations.

Tab. 1: Technical and economical characteristics of the analyzed ST systems.

Description of ST systems			Total gross / absorber area, m^2	Investment per 1 m^2 gross area, Eur	Annual energy production per 1 m^2 gross area, kWh
Flat plate solar collectors	1F	SHW, main energy source – natural gas	25 / 23	519	512 (2015)
	2F	SHW, main energy source – district heating	40 / 37	516	382 (2015)
	3F	SHW, main energy source – district heating	72 / 67	418	n/a
	4F	SHW, main energy source – electricity*	114 / 106	479	488 (2013)
	5F	Indoor swimming pool heating and SHW. Main energy source – natural gas**	166 / 155	701	411 (2013)
Evacuated tube solar collectors	1E	SHW, main energy source – electricity	27 / 15	571	528 (2014)
	2E	SHW, main energy source – district heating	36 / 33	692	414 (2015)
	3E	Preheating the return water in the district heating network***	82 / 72	1079	343 (2013)
	4E	SHW, main energy source – district heating*	90 / 63	621	n/a
	5E	SHW, main energy source – district heating	145 / 77	320	n/a

* Approximate investment costs per 1 m² gross area.
** System was not in operation for three weeks during August 2013.
*** System was upgraded few times due to improper operation, therefore approximate value of the total investment is presented.

Financial analysis was performed for ten different ST systems. In this study, the assumption was made that the entire cost of the ST systems is covered during the installation and the systems were installed without any subsidies. The life span of the ST systems is considered to be 20 years. Parameters used for financial assessment of the ST systems are presented in Table 2.

Tab. 2: Parameters used for the simulations of ST systems.

Life span of ST systems, years	20
Specific district heating energy price (average), Eur/kWh	0.041
Specific energy from natural gas price (average), Eur/kWh	0,076
Specific electricity costs (standard), Eur/kWh	0.129
Index for energy prices, % per year	3.0
Interest capital, %	2.5
Running costs, %	1.5

4. Results of analysis

Analysis showed that the relation between installation costs and area of the flat plate and evacuated tube solar collectors (including heat storage tanks and auxiliary equipment) varies in the range of 320 – 1079 Eur/m² in ST systems from 25 m² to 166 m² gross area. Average price of flat plate solar collector systems is 527 Eur/m², but the investment for evacuated tube solar collector systems per 1 m² gross area varies in a wide range of 320 – 1079 Eur/m², with the average price of 657 Eur/m². Compared to the analysis made ten years ago (Perednis et al., 2007), prices of ST systems have not changed significantly.

The results of the analysis showed that ST systems with solar flat plate and evacuated tube collectors can produce from 343 to 528 kWh/m², and almost the whole irradiated solar energy – approximately 80% – can be collected during the warm period of the year (Fig. 3).

Simulations showed that analyzed ST systems in Lithuania can reduce greenhouse gas emissions from 49 to 232 kg $CO_2/m^2_{absorber}$ per year. However, CO_2 reduction per absorber area can vary in the wide range depending on the type of the system and an alternative source of energy production.

Price composition of the analyzed ST systems is presented in Figure 2. The price of solar collectors and mounting systems comprises 51 % of the total system price in cases when evacuated tube collectors are used, for example ST system 3E (Table 1).

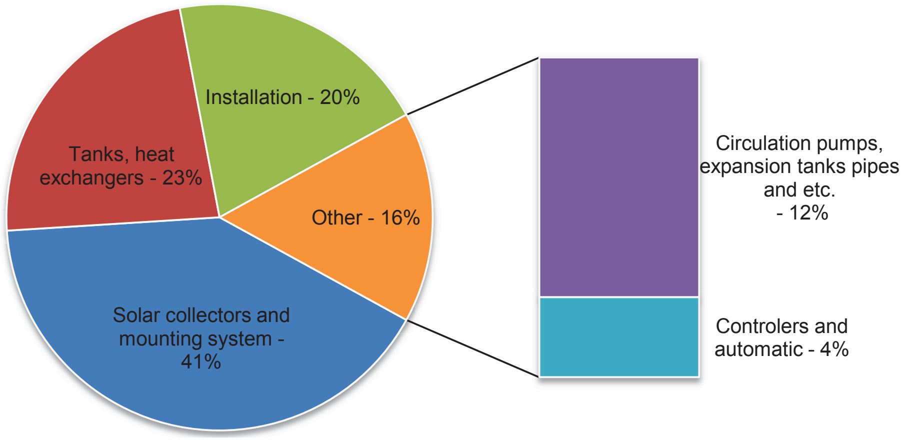

Fig. 2. Price composition of equipment in analyzed ST systems.

The financial analysis showed that heat energy generated by analyzed ST systems is not competitive in most cases in comparison with district heating (payback period from 11 to 40 years) and natural gas applications (payback period from 24 to 27 years). However, the projects were fully profitable (payback period from 6 to 10 years) in cases when electrical energy was used as an alternative to energy produced by SHW systems (Table 1). Average solar energy cost (life span is 20 years) in the analyzed cases was – 0.073 Eur/kWh.

Measured annual efficiency of the analyzed systems reached up to 44 % (4F) 39 % (5F) and 24 % (3E). The measured values of global irradiation in Kaunas city and the amount of energy produced in the analyzed systems per month are presented in Figure 3.

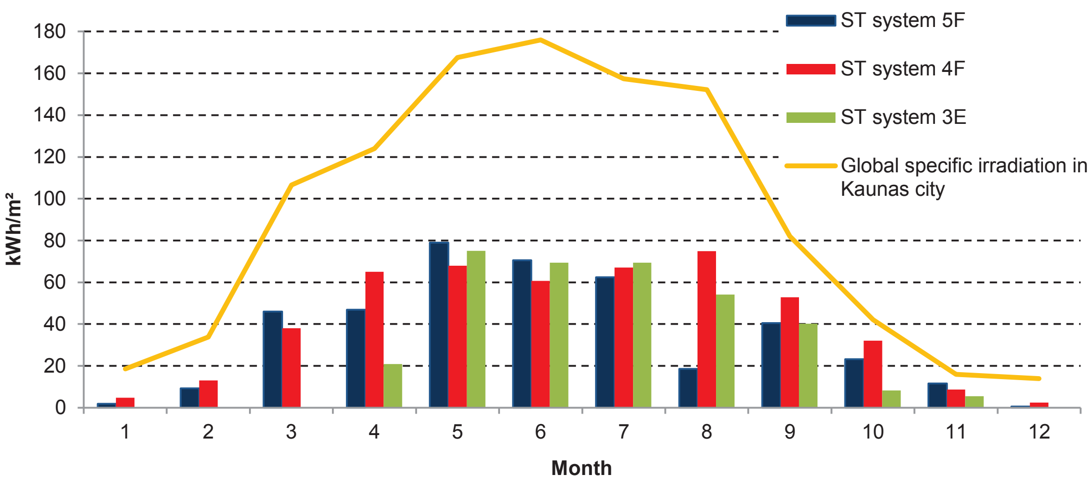

Fig. 3. Produced energy in the analyzed ST systems ($kWh/m^2_{absorber}$) per month and measured global irradiation in Kaunas city (2013).

The gap between measured and modelled data of heat energy produced by SHW systems was approx. 11 % in the analyzed cases. It can either be caused by differences in actual solar irradiation compared to the standard average data, or some peculiarities of the design and maintenance of the SHW systems.

5. Discussions and conclusions

Average price of flat plate solar collector systems was 527 Eur/m² in the analyzed cases, but the investment for evacuated tube solar collector systems per 1 m² gross area varied in a wide range of 320 – 1079 Eur/m², with the average price of 657 Eur/m².

ST systems with evacuated tube collectors do not reach significant additional expected energy yield. ST systems with solar flat plate and evacuated tube collectors can produce from 343 to 528 kWh/m² of thermal energy and reduce greenhouse gas emissions from 49 to 232 kg $CO_2/m^2_{absorber}$ per year.

The results of the analysis showed that in the analyzed cases the gap between measured and modeled data of heat energy produced by ST systems was approx. 11%. From the economic perspective, the system with flat type solar collectors used for DHW production is profitable if compared with the electrical energy as an alternative.

The most expensive equipment in ST systems are solar thermal collectors. In the analyzed cases, from 28% (flat plate collectors) to 51% (evacuated tube collectors) of initial investment is required to cover the costs of solar collectors itself.

The market growth of ST systems in Lithuania and other countries depends on the policy of the governments. The payback period of ST systems in most cases is too long (from 6 to 40 years) to ensure the stable growth of ST applications without the governmental grants. Despite the long payback period the market of ST systems is slowly growing and the trend continues towards larger DHW in multifamily buildings, hospitals, hotels and other large complexes due to support from EU and other funds.

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