Review of Combined Solar Thermal and Heat Pump Systems Installations in Lithuanian Hospitals

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Abstract

One of the major part of energy demand of a building goes to heating and hot water in countries with a cold climate. It is now clearly recognised that modernization of public buildings must be a mix of measures and not only cover the renovation of building components (e.g. roof, walls, windows etc.), but also HVAC systems and heating sources. Aim of any renovation of a public building is to improve the physical aesthetic, the microclimate in the building and reduce primary energy demands. Seventeen projects with solar thermal systems and heat pumps were implemented in Lithuanian hospital buildings by using Swiss and Lithuanian state funding in 2016.

This paper presents the cases and monitoring data of three different integrated solar thermal and heat pump systems in Lithuanian hospitals and prospect of solar thermal and heat pump systems in relation to traditional energy prices, technical barriers and government policy as well as potential of these systems.

Keywords: renewable energy sources, solar thermal systems, heat pumps

1. Introduction

Heating and hot water is the main energy consumption of a building in countries with cold climate such as Lithuania. Big part of sustainable energy measures is directed to the buildings as they are one of the largest energy consumers. Combined solar thermal (ST) and heat pumps (HP) systems constitutes as one of the solutions and its implementation can considerably influence sustainable energy usage and economy.

The building sector accounts for 40% of the total energy consumption and 36% of CO_2 emissions in Lithuania and EU countries (Eurostat, 2017). Space heating and hot water accounts for about 26% of all final energy consumption in the EU. In the recent years, the European Commission has set the new target of reducing the CO_2 emissions by 90% for the building sector by the year 2050 (Eurostat, 2017). More than 17% of the primary energy savings potential of the EU is related to the building retrofit for 2050 as reported in the 2014/15 European work program (European Commission, 2015).

Lithuanian building heating sector is quite unique where district heating network occupies more than 55% of the total thermal market and the average price in Lithuanian cities is 0.057 €/kWh (LSTA, 2018). The other thermal energy sources used for building heating systems are natural gas (11.9%), bio fuel (25%), coal (5.2%) and in some cases electricity (0.22%) (EHPA, 2017). Natural gas prices in Lithuania in 2017 varied from 0.38 to 0.64 €/m^3 for residents, depending on total gas consumption per calendar year. Electricity prices varied from 0.077 to 0.124 €/kWh, depending on selected tariff (Regula, 2017). Despite of small fluctuation in recent years, the prices of traditional energy are slowly growing.

The number of medium-scale ST systems in Lithuania is still relatively low and represents the potential for development of these systems. There is a number of medium-scale ST systems installed in the country varying from 50 to 250 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 operating ST system with 77 m² of total solar panel area was installed in 2002 in children sanatorium "Zibute" (in Kacergine town). However, it took 10 years for the first ST system to be installed in multi-family building, as the first ST system in this type of building was launched only in 2012 (Katinas et al., 2013; Karbauskaite and Perednis, 2011; Valancius et al., 2015a; Valancius et al., 2015b).

Only about 14800 m² (10360 kWth) of glazed solar collectors were installed by the end of 2016 in Lithuania, and the applications were mostly limited to single-family buildings (ESTIF, 2017). Only in recent years the trend continued towards larger ST systems for multifamily buildings, hospitals, hotels and other large complexes, due to the support from the government, EU and other funds. More than 1500 m² of solar collectors in over 17 hospitals was installed in 2016 (Valancius et al. 2016).

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Because of relatively low traditional energy prices, infrastructure (such as usage of district heating network) of Lithuania market and cold climatic conditions the HP market in Lithuania started to develop only at the beginning of this century and is growing slowly. Despite government subsidies only 1660 units of different HPs were sold in Lithuanian market in 2016. In total there are already over 7000 HP's in Lithuania, which has a population of about 3 million people. HP is by far the most popular source of heating for single-family houses, and HPs are slowly replacing gas and solid fuel boilers as well as district heating in existing buildings. Compared to 2015 the sales of air source HP increased by 48.3% and of ground source HP and water source HP decreasing slowly (EHPA, 2017). That is because of increased efficiency of aerothermal HPs and lower investments compared to other HP types.

The price of thermal energy and other energy needs for buildings are the most important factors that influence the renewable energy market. The growth of this market depends on subsidies in most cases. 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.

Nevertheless, that ST and HP systems have been installed in Lithuania for over 20 years there is still a lack of performance reviews and economic analysis of these systems. The aim of this study is to review three existing combined ST and HP systems in Lithuanian hospitals in relation to traditional energy prices and environmental aspects as well as future potential of these systems.

2. Review and analysis of solar thermal and heat pump systems in hospitals

Three different combined ST (from 24 to 95 m^2) and air source HP's (from 19 to 74 kW) systems in different hospitals were evaluated in this study. Two of these systems were designed for domestic hot water (DHW) applications and one for DHW and swimming pool heating. All of these systems are in operation for up to 2 years. All systems are equipped with heat meters, electrical meters and monitoring systems. All of these systems are operating fully automatically. The primary energy source is ST systems, HP operates only when the ST systems are not working (cloudy days) or when the power of ST system is too low. In most cases ST systems operates all-round the year, HP systems operates only till the temperature of -10°C. When the temperature is lower than -10°C it is more efficient to use district heating or gas boiler energy. Technical and economical characteristics of the analyzed ST and HP systems are presented in Table 1. The subsidy from Swiss and Lithuanian state funds for these projects covered 100% of the total investments and only a technical supervision was paid by hospitals.

Fig. 1: View of combined ST and HP system in one of the hospitals.

The measurements were performed in 2017 and the performance of these systems was compared to the theoretical values obtained by means of simulation software. All technical parameters of the systems, such as inclination angle of solar collectors, orientation, building energy demands and characteristics of the installed equipment, were used as boundary conditions for the simulations.

Table. 1: Technical and economical characteristics of the analysed ST and HP systems.

No.	Description of ST and HP systems	ST total gross / absorber area, m^2	HP heating capacity kW / COP (A2/W35)	Total investments, Eur
1	System for DHW, with secondary traditional energy source – natural gas	24 / 22	33 / 3.4	55877
2	System for DHW and recirculation, with secondary traditional energy source – district heating	60 / 55	19 / 3.5	68300
3	System for DHW and swimming pool heating, with secondary traditional energy source – district heating	95 / 88	74 / 3.5	112190

According to Lithuanian norms of hygiene (HN 24:2003) temperature of DHW in system must range from 50 to 60 °C in order to avoid *legionella* bacteria breed. Due to this condition air source HP's seasonal coefficient of performance (SCOP) cannot reach high values (especially in cold climates). The results of the analysis showed that ST systems with solar flat plate type collectors can produce from 263 to 433 kWh/m² per year, but almost the whole solar energy (approximately 80%) can be collected during the warm period of the year. Experimental data shows that air source HP system used for DHW preparation operated with an average SCOP from 2.42 to 2.61 in the Lithuanian climate. Despite the lower SCOP than expected (>3.5), customers are content with these systems (see Table 2).

Table 2. Results of analysis of ST and HP systems.

No.	ST annual energy production, kWh		HP annual energy production, kWh	SCOP of HP	Average price of HP produced energy, Eur
	Total	Per 1m² gross area			
1	6320	263	13320	2.42	4.54
2	21981	366	19150	2.48	4.43
3	41240	433	26350	2.61	3.83

The gap between measured and simulated data of thermal energy produced by ST systems is approx. 7 % in the analyzed cases. It can either be caused by differences in actual solar irradiation compared to the standard average data, or some discrepancies (heat losses in the piping system, hydronic misbalance, dirty collector surface etc.) in the design and maintenance of the ST systems.

Simulations showed that analysed ST systems in Lithuania can reduce greenhouse gas emissions from 49 to 232 kg CO_2/m² absorber per year. However, CO_2 reduction can vary a lot depending on the type of the system and alternative source of energy production.

3. Potential of solar thermal and heat pumps systems in Lithuania

District heating networks are well developed in Lithuania and other Baltic countries since the end of 20th century. District heating network in Lithuania occupies more than 55% of total thermal market. ST and HP systems integration in to district heating networks as well as ST and HP systems for industrial processes can play an important role in the energy transition of the heat sector in Baltic countries.

The refurbishment of district heating system or integrating new systems into existing or new building establishments is one of the major approaches to increase the overall energy efficiency in urban areas. Beside the good examples of technologies used in Denmark (Trier, 2015; Rama and Mohammadi, 2017), Norway, Sweden (Winterscheid et al. 2017), Austria, Germany (Bauer et al. 2010; Lauterbach et al. 2012) and other European countries (Hugo and Zmeureanu, 2012) further markets are developing or emerging. In recent years the solar district heating market boomed in Denmark, not because of subsidies but due to its competitive price in comparison to biomass and gas (Trier, 2015; Flynn and Siren, 2015). A study performed in Finland and Denmark (Rama and Mohammadi, 2017), showed that centralized ST system can provide cost savings from 7 to 21 % and the pay-back times between 10 to 11 years for centralized systems were recorded.

The largest ST district systems are installed in Denmark, with the biggest one in 2016 in Silkeborg city, with aperture are of 156694 m² and total capacity of 110000 kWth. A study in Latvia (Soloha et al. 2017) in municipality with 20000 inhabitants showed that with ST district system would be possible to supply 10% to 78% of the total heat demand. Study presented in 2017 (Ge et al. 2017) showed that large scale district water heating systems and hybrid solar photovoltaic and thermal systems are the most promising solutions that attract extensive attentions.

ST and HP energy market development can have the following advantages:

- decrease the consumption of primary fuels and save resources that can be redirected to other sectors;
- minimal environmental impact during whole life cycle;
- flexibility to combine ST and HP systems with all types of auxiliary heat supply systems;
- energy independence as most of fossil resources are imported;
- increase in local employment as ST and HP systems can be installed and produced by the local market participants and thus can have positive influence on the country economics.

In parallel with growing interest about HP systems, photovoltaic systems (PV) producing electrical energy are also gaining bigger interest. Electricity is used for operation of the HP compressor and the circulation pump in the HP system. The implementation of the HP as a heat source significantly improves the overall efficiency of the energy sector so it is being promoted by the European Union (Directive 2009/28 / EC of the European Parliament and of the Council, EU heating and cooling strategy 2016). According to Lithuanian legislation, the HP is rated as an effective source for compulsory certification of the energy performance of new buildings. When installing a HP for building heating and DHW the only external energy source that is necessary for the household is electrical energy so alternative electricity generation significantly reduces the household's operating costs.

As long as in Lithuania individual consumers were not able to "store" excess energy in distribution networks, the prospective of the combined HP and PV power plant was poor, as the thermal energy needs of the building are almost the opposite to the potential of solar electricity. As this option is currently being offered for Lithuanian consumers, the possibilities of payback of the combination HP and PV systems came into the field of interest. The calculations carried out by Rupeika (2018) shows that the payback period of the combined HP and PV system for individual house in Lithuania is relatively long (~20 years), therefore these types of systems could be implemented after the decrease in installation costs or additional financial support from the government.

4. Discussions and conclusions

Combined ST and HP systems claim to become the solution and its implementation can considerably influence energy and economy. However, the performance of these systems depends on the type of energy users, design solutions, equipment used and maintenance of these systems.

In analysed cases SCOP of HP's vary from 2.42 to 2.61, because of requirements of high temperature (50÷60°C) of DHW. ST systems produced from 263 to 433 kWh/m² of thermal energy per year, depending on equipment used. ST and HP system for DHW and swimming pool heating was the most efficient.

The renewable energy market growth in Lithuania and other countries strongly depends on the government policy. The payback period of renewable energy sources installation in most cases is too long to ensure the stable market growth without the governmental grants. Despite the long payback period the market of renewable energy sources in buildings is slowly growing and the trend continues towards larger systems for multifamily buildings, hospitals, hotels, swimming pools and other large complexes.

With a good development district heating neatwork's Lithuania and other Baltic States have a huge potential in ST and HP's integration in to district heating networks. ST and HP's for industrial processes can equally play an important role in the energy transition of the heat sector in Baltic countries.

5. References

Bauer, D., Marx, R., Nußbicker-Lux, J., Ochs, F., Heidemann, W., Müller-Steinhagen, H. German central solar heating plants with seasonal heat storage. Solar Energy 2010 (84), 612-623. DOI: 10.1016/j.solener.2009.05.013

EHPA 2017. European heat pump market and statistics report 2017.

European commission 2015. Draft horizon 2020 work programme 2014–2015 in the area of secure, clean and efficient energy.

Eurostat 2017. European commission. Consumption of energy [accessed 8 November 2017]. Available at: https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings

ESTIF, 2017. European heat thermal industry federation. Solar thermal markets in Europe. Trends and market statistics 2016. November 2017.

Flynn, C., Sirén, K., 2015 Influence of location and design on the performance of a solar district heating system equipped with borehole seasonal storage. Renewable Energy 81, 377-388. DOI: https://doi.org/10.1016/j.renene.2015.03.036

Ge, T., Wang, R., Xu, Z., Pan, Q., Du, S., Chen, X. et al. 2017. Solar heating and cooling: Present and future development. Renewable Energy 93, 466-483. DOI: 10.1016/j.energy.2015.08.098

Hugo, A., Zmeureanu, R., 2012. Residential solar-based seasonal thermal storage systems in cold climates: building envelope and thermal storage. Energies 5, 3972-3985. DOI: 10.3390/en5103972

HN 24:2003 "Geriamojo vandens saugos ir kokybės reikalavimai". Lithuanian legislative system, 2003.

Katinas, V., Karbauskaitė, J., Perednis, E., Valančius, R., 2013. Efficiency analysis of combined biomass and solar energy in Lithuania. Clean Techn. Environ. Policy 15(4), 667-676. DOI: https://doi.org/10.1007/s10098-012-0534-x

Karbauskaitė, J., Perednis E., 2011. Kačerginės vaikų sanatorijos šilumos energijos vartojimo mažinimo galimybės. Energetika 57(1), 20-25. DOI: https://doi.org/10.6001/energetika.v57i1.2040

Lauterbach, C., Schmitt, B., Jordan, U., Vajen, K., 2012. The potential of solar heat for industrial processes in Germany. Renew. Sustain. Energy. Rev. (16), 5121-5130. DOI: 10.1016/j.rser.2012.04.032

LSTA 2018. Lietuvos šilumos tiekėjų asociacija. Vidutinė šilumos kaina gyventojams (po perskaičiavimų) [accessed 15 February 2018]. Available from Internet: http://lsta.lt/lt/pages/apie-silumos-uki/silumos-kainos

Rämä M, Mohammadi S., 2017. Comparison of distributed and centralised integration of solar heat in a district heating system. Energy (137), 649-660. DOI: http://dx.doi.org/10.1016/j.energy.2017.03.115

Regula 2017. Valstybinė kainų ir energetikos kontrolės komisija. Visuomeniniai tarifai AB "Energijos skirtymo operatorius" nuo 2017 m. sausio 1 d. [accessed 9 January 2018]. Available at: https://www.regula.lt/elektra/Puslapiai/tarifai/visuomeniniai-tarifai-ab-ENERGIJOS-SKIRSTYMO-OPERATORIUS-nuo-2017-m--sausio-1-d.aspx

Rupeika I., 2018. Hibridinės šilumos siurblio oras-vanduo ir saulės elektrinės sistemos gyvenamajam namui tyrimas, Master's thesis. Kaunas university of technology, Faculty of electrical and electronics engineering.

Soloha, R., Pakere, I., Blumberga, D., 2017. Solar energy use in district heating systems. A case study in Latvia. Energy (137), 586-594. DOI: 10.1016/j.energy.2017.04.151

Trier D., 2015. Towards solar district heating with more than 70% solar fraction. Energy Procedia 70, 580-586. DOI: 10.1016/j.egypro.2015.02.16

Valančius, R., Jurelionis, A., Jonynas, R., Katinas, V., Perednis, E., 2015a. Analysis of medium-scale solar thermal systems and their potential in Lithuania. Energies 8(6), 5725-5737. DOI: https://doi.org/10.3390/en8065725

Valančius, R., Jurelionis, A., Vaičiūnas, J., Perednis, E., 2015b. Dimensioning of solar thermal systems for multi-family buildings in Lithuania: an optimisation study. Journal of sustain. architec. civil eng. 11(2), 32-40. DOI: 10.5755/j01.sace.11.2.12459

Valancius, R., Jurelionis, A., Vaiciunas, J., 2016. Review of solar thermal systems and their potential in Lithuania. Proceedings of EuroSun 2016 Conference of ISES Europe, October 11-14, 2016, Palma de Mallorca, Spain. DOI: 10.18086/eurosun.2016.04.15

Winterscheid, C., Dalenbäck, J., Holler, S., 2017. Integration of solar thermal systems in existing district heating systems. Energy (137), 579-585. DOI: https://doi.org/10.1016/j.energy.2017.04.159