Analysis of Heat Pumps Operated by Solar Photovoltaic Systems for District Heating Systems in Lithuania

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Abstract

More than half of all buildings in Lithuania are heated through the district heating systems. Biofuel, natural gas, oil and coal are the most popular fuels, and the usage of waste from incineration is growing rapidly. In smaller towns, boiler houses fired by coal or peat run the district heating systems

Although the use of biofuels and gas is efficient, considered somewhat clean, and inexpensive but the use of polluting fossil fuels raises many questions. It poses a big challenge how a heat production system can be cost effective, low maintenance and environmentally friendly.

This study aims to review and analyse the possibilities of using geothermal energy via heat pumps, and solar photovoltaic systems for heat production in district heating systems in Lithuania.

Keywords: renewable energy, photovoltaic systems, heat pumps, geothermal energy, district heating, energy prices

1. Introduction

Renewable energy segment has continued to grow worldwide in recent years, alongside increasing global energy consumption, decreasing investment in many renewable energy sources, and declining global fossil fuel prices. Furthermore, in a lot of countries, the fluctuating price of fossil fuels has had a serious impact on energy security. Several alternative resources can provide clean, continuous, and renewable energy, such as solar, wind, biomass, hydro, and geothermal energy. Many studies showed that photovoltaic systems (PV) have become the cheapest source of electrical power [PV Magazine 2017; Forbes 2019, DW 2020]. The efficiency of heat pumps increased in last years and price dropped at the same time. Geothermal technologies for heating and cooling grids is still on the development phase, but some studies and demonstration projects showed promising results [Bernati 2016; Think Geoenergy 2020].

Lithuania is a country in the Baltic region of Europe, with an area of 65300 km^2 and a population of 2.8 million. More than 53 % of all buildings in Lithuania are heated through the district heating systems. Biofuel, natural gas or oil are the most popular fuels, and the usage of waste incineration is growing rapidly (see Fig. 1). In smaller towns, there are boiler houses fired by coal or peat [LSTA 2020]. Lithuanian district heating (DH) networks can be classified as conventional network grids with temperatures range in the order of 60–120 °C.

Photovoltaic market blossomed in Lithuania only in 2013. Small-scale solar photovoltaic systems became more attractive after the national energy distribution operator offered the possibility of electrical energy 'storage' in the grid after 2015. Only in recent years, photovoltaic system prices have dropped significantly, and a subsidy system for renewable energy sources in single-family buildings, public buildings, factories, etc. has been started [Valancius et al. 2018a].

In 2020, the prices of natural gas for citizens in Lithuania varied from 0.28 to 0.47 €/m^3, depending on the total consumption per calendar year. Electricity prices currently vary from 0.095 to 0.149 €/kWh for households depending on the selected tariff [Ignitis 2020].

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This study aims to review and analyse the possibilities of using heat pumps, geothermal energy, and solar photovoltaic systems for heat production in district heating systems in Lithuania.

2. Review of Lithuanian District Heating Market

The year 1939 could be entitled as the start of the DH in Lithuania when the power station with 3 "Gebrueder Wagner" steam boilers of the total 2 MW (3 t/h) power was installed to supply thermal energy for a hospital complex in Kaunas City – Kaunas Clinics. The WW II interrupted the development of the sector and the next big installation occurred only in 1947 when it started to supply steam for the paper factory from the nearby Petrašiūnai power station (Kaunas). During period 1949-1955 other stations in the biggest cities of Lithuania (Vilnius, Klaipėda, Šiauliai, Panevėžys) started to work catering both industrial and residential building demands. The speed of the development of DH systems in Lithuania or supplied energy quantity reached its peaks within the period 1967-1990. The total length of the DH network was almost 3000 km in 2017. [LSTA 2020]

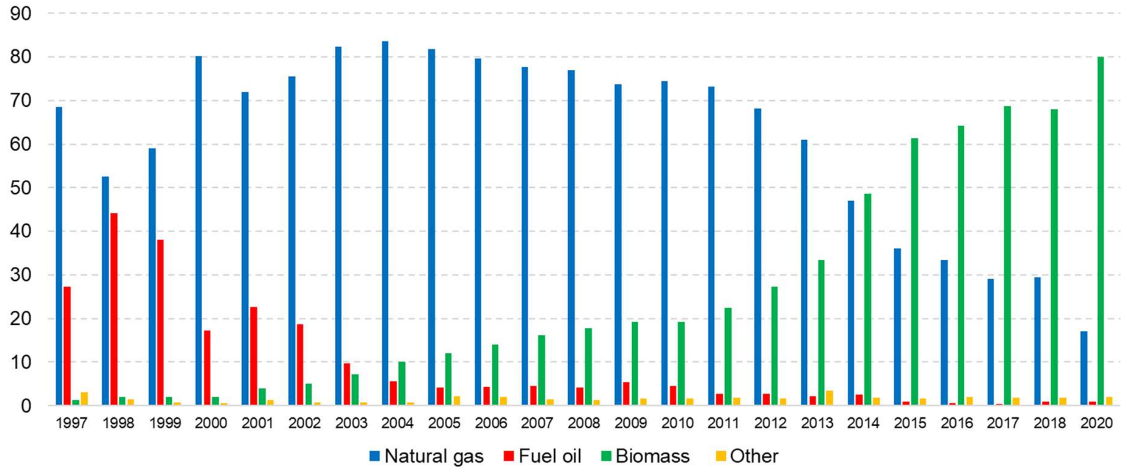

Fig. 1: The structure of fuel in DH production; 1997 – 2020 [LSTA 2020]

According to the statistics of 2017, the annual thermal energy production in DH plants was about 9000 GWh with an installed capacity of approximately 7700 MW. A difficult but also promising period for the DH sector was after Lithuania regained independence from the Soviet Union in 1990. The fossil fuel (gas and oil) prices increased severely but at the same time, all modern worldwide renewable technologies became available. The biggest challenges were to decrease the share of fossil fuel to ensure energy independence for the country and to decrease heat losses in pipeline systems that were relatively high when compared with modern European countries.

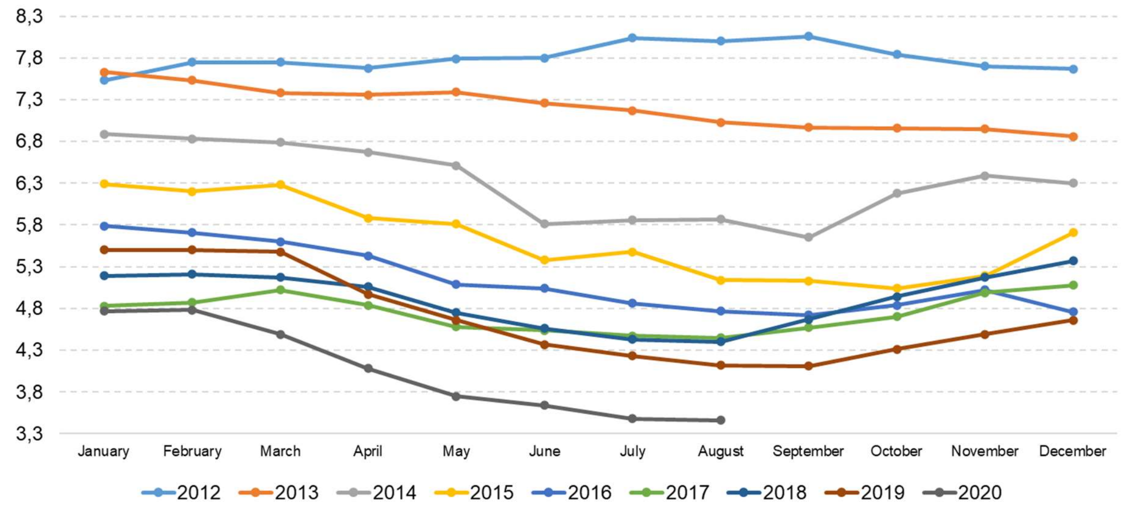

Fig. 2: Thermal energy supplied to DH prices in Lithuania ct/kWh (VAT excluded); 2012-2020 [ENMIN 2020]

Fig. 1 indicates that the oil share started to decrease but natural gas still was the main fuel for quite a long period. Now the most important energy source in the Lithuania DH sector is biomass.

Another technical challenge that still has the potential to be mitigated is the thermal energy transition losses in the DH network. Lithuania, between 1996-2018, decreased it twice to 15% but still didn't reached the heat losses of the modern Western European countries which consist of approx. 10% [Andrews et al. 2012].

The main consumers of the DH in Lithuania are apartment residents (72%), public building users (14%), and private business sector (14%), but apartment residents that make up the greater part sometimes cause payment problems for DH suppliers [ENMIN 2020]. DH systems service about 76% of buildings in the cities or 53% of buildings in the country totally [REGULA 2020]. The price of DH energy supplied for a final user depends on the exact supplier and fluctuates a little during different months but had a tendency to decrease during the recent years (see Fig. 2).

3. PV Systems, Heat Pumps and Geothermal Energy for District Heating Systems in Lithuania

3.1. PV Market in Lithuania

Large-scale solar photovoltaic systems only blossomed in 2013 due to a very good purchase price. Small-scale (up to 10 kW) solar photovoltaic systems became more attractive after the national energy distribution operator offered the possibility of electrical energy 'storage' in the grid after 2015. Only in recent years, photovoltaic system prices have dropped significantly, and a subsidy system has been started [Valancius et al. 2018].

The cost of solar modules and the installation of solar photovoltaic systems has dropped significantly in recent years, and efficiency has increased. At the begging of 2020, the price of small (up to 10 kWp) domestic rooftop PV system in Lithuania has dropped to 780-1000 EUR/kWp. Since 2015 legal entities can install solar photovoltaic systems with a two-sided metering system. It is not allowed for the installed capacity of a solar photovoltaic system to exceed the permissible power consumption set for the facility.

During 2020 the record amount of 9 million EUR is planned for the subsidies to PV systems. The record subsidies in the amount of 4.5 million EUR are planned for the installation of remote solar PV systems or the purchase of the part in solar PV parks. Also, 4.5 million EUR will be allocated to solar PV systems in single-family houses. The compensation for 1 kW of installed solar PV capacity is 323 EUR [APVA 2020].

Also, the compensation in the amount of 100 % of installation cost can be received for schools, hospitals, and other public buildings. Only a feasibility study and a design for the building of a solar PV system have to be prepared on their own expenses. According to the promotional measures for industrial facilities, there is a possibility to receive the support from 30 to 80 % of investments for sustainable resources equipment [APVA 2020]

Some studies and calculations showed that if the state (government) support has been received the payback period of a solar PV in a single-family house varies from 4 to 7 years. The payback period for larger facilities is from 3 to 6 years [LSEA 2020; Valancius et al. 2018]. The payback period depends mainly on the proper selection of the system, the cost of installation and equipment chosen.

The fact that solar power plants can already fully compete with traditional energy sources is also evident by the rapidly growing number of solar power plants in Lithuania, as well as the ongoing tenders for the design and installation of new solar power plants.

More than 1800 new clients were connected between May and November of 2019, in comparison between the years 2015 and 2018 only about 1100 new connections were made. From 2016 to 2020 the number of consumers who produced energy increased from 248 to more than 3000. This number is increasing every week by an average of 80 new producing consumers [ENMIN 2020a].

Thus, the synthesis of a heat pump and a solar photovoltaic system can be an efficient, economical, and environmentally friendly way of producing heat has already been proven in small single-family home systems [Valancius et al. 2018a; Valancius et al. 2019].

3.2. Heat Pumps Market in Lithuania

Heat pumps (HP) have been finding their way into the Lithuanian market since the beginning of the 21st century, and currently, there are many good practice examples in the country, especially in the residential and public sectors. The financial confidence of households has led to increased acquisition of relatively more expensive and yet easier to maintain systems. Growing housing completions also helped the market to boost the usage of HPs. Price decrease and stimulating economic factors pushed up the market growth [Valancius et al. 2019].

A heat pump use is economically advantageous in Lithuania, and the market share of these systems is growing. Studies have reported seasonal performance factor (SPF) ranges within 1.8 and 5.6. The lower SPF values are typically attributed to air source heat pumps (ASHPs), whereas the higher efficiency is achieved by ground or water source heat pump systems [Valancius et al. 2019].

Costs of heating and other energy needs for buildings are the most important factors that influence the renewable energy market. It is evident that in most cases the growth of these markets depends upon subsidies. In Lithuania, limited subsidy systems and funds for renewable energy installations existed since 2005. Depending on a project, it is possible to apply for a subsidy covering from 40% to 100% of initial costs. For example, it is possible to get a subsidy of up to 50% for a single-family building, up to 40% for a multifamily building, and up to 100% for hospitals.

About 8938 units of different HPs were sold in 2017 in Lithuania [Valancius et al. 2019]. It shows that HPs have become the most popular choice within newly constructed, single-family residential buildings and their owners. Current trends indicate that HPs are also slowly replacing gas and solid fuel boilers, as well as district heating in existing buildings. Compared to previous years the sales of HPs in 2017 increased significantly. This growth can be attributed to increased efficiency and reduced capital expenses for ASHP installations. On the other hand, the price reduction of solar photovoltaic systems and new storage technologies helped to grow, not only installations of solar photovoltaic systems, but HPs as well.

The main factor hindering market growth in Lithuania is the high initial cost of these HPs. The payback period of HP systems in most cases is too long to ensure the stable growth of HP applications without governmental grants. Despite the long payback period, the market of HP systems is slowly growing, and the trend continues towards larger HP systems in multifamily buildings, hospitals, hotels, and other large complexes due to support from the EU and other funds [Valancius et al. 2019].

3.3. Geothermal Energy in Lithuania

Researches on the use of geothermal energy in Lithuania started more than 30 years ago. Reviewed geological and geophysical data showed that there is a geothermal anomaly of high energy potential at greater depths in Western Lithuania (see Fig. 3). Its uniqueness is clearly shown by the heat flow indicators: in the background of the surrounding geothermal field of intensity 40–50 mW/m^2, the intensity of the anomalous field of Western Lithuania is 90–100 mW/m^2. The surveys showed that geothermal waters in the south-western part of Lithuania lie at a depth of about 1,200 m, and their temperature reaches about 50 degrees [LGA 2020; Visegrad Post 2016].

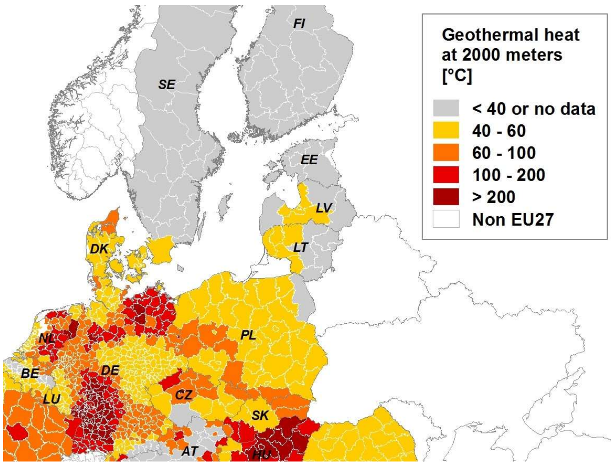

Fig. 3: Geothermal heat at 2000 meters depth [Halmstad and Aalborg Universities 2013]

The cost-effective temperature of about 150ºC, which can be directly used for heating buildings, is found in Lithuania in crystalline bedrock. The minimum depth is in the southern part of Western Lithuania and on the southern coast, where the 150ºC isotherm is 4.3-4.5 km deep. In other areas of Western Lithuania, this temperature is deeper - from 5 km (eg in Klaipėda) to 6 km. For comparison, in the eastern part of Lithuania, its depth reaches 7-8 km [LGA 2020].

3.3.1. First Geothermal Plant in Baltic States

Klaipėda Geothermal Power Plant - was the first geothermal heating power plant in the Baltic States. The construction was commenced in 1997. The project was supported by the Danish Environment Agency and the World Environment Fund, also a loan was received from the World Bank. Klaipėda Geothermal Power Plant operated 4 wells. The pumps pumped 38°C heat geothermal water from a Devonian layer at a depth of 1135 meters. Up to 700 m³ of water could be obtained from the two wells per hour, however, the ground took back only 450 m³ of water. In summer, the plant supplied heat to about half of Klaipėda, in winter it produced enough energy for about 10% of the city. The capacity of the geothermal power plant was 10-35 MW. Geothermal loop flow rate - 160–210 m³/h [LGA 2020].

It was not easy for a state-owned company to introduce new technologies and promoting ecological ideas to gain a foothold in the energy market. Suppliers of traditional heat sources were reluctant to let competitors in. With the start of the operation of the geothermal power plant, the operation load in traditional boilers decreased and fossil fuels were burnt less. Although this power plant is a good example of how geothermal water can be used to solve heating problems, however, the most appropriate management model for the company that would help to reconcile two goals of expanding alternative energy sources and ensuring their economic viability were difficult to achieve. Without price regulation, it was difficult for a loss-making company to repay its loans in the first year. The managers of the company managing the power plant had offered to use part of pumped water for other purposes as well - for medical treatment, fish breeding, road irrigation, and heating of swimming pools.

The company's operations were suspended in 2017, the main reasons for which were high liabilities of the company and a fall in the cost of energy production from traditional energy sources. Investors who were willing to lease this heating company were sought and could not be found. At the beginning of 2019, the company was declared bankrupt. The geothermal power plant is currently conserved and is not monitored. It is not clear whether and how much it would cost to revive the operation of the geothermal power plant.

3.3.2. The Possibilities of Geothermal Energy Usage in Vilkaviškis City

At the beginning of the 21st century, it was proposed to build a power plant in Vilkaviškis and use these waters for heating of the district's apartments and houses, medical therapy, and other purposes. The German company Geothermie Neubrandenburg was interested in the possibility of building a geothermal water power plant in Vilkaviškis. They invested 100 thousand marks in this project. It was estimated that the construction of the power plant should cost about 11 million dollars, and that money could pay for itself in 5 to 10 years. However, after failing to find funding for this project, it was not launched.

In 2009-2010, the possibility of constructing a power plant was floated again. It was planned to build a 7.5 MW geothermal power plant that would significantly reduce the area's carbon footprint. This power plant was supposed to cost 6.3 million EUR and to be built by 2017 but the real work did not start.

Once again, in 2015 it was returned to the ideas of the project implementation. The German company Geothermie Neubrandenburg visited Lithuania again and offered to continue cooperation and seek funding sources.

After receiving the support from the leaders of Vilkaviškis district, at the beginning of this year, it was returned to the ideas of using geothermal energy for heating buildings, hot water preparation, and medical purposes. Whether the project will not be stopped again the time will show.

4. Application Possibilities, Perspectives and Limitations

The use of PV systems and heat pumps in heating networks has good prospects in Lithuania and other countries. Such systems, where the electricity produced by PV can be used for the energy-requiring heat pump, have already found application in single-family homes and other small or medium-sized systems (see Fig. 4).

The required high temperatures of heat carrier is one of the main technical factors limiting the application of geothermal energy and heat pumps in district heating networks in Lithuania. The temperature, depending on the district heating network, the season, and the ambient air temperatures, varies from approximately 60 to 120 degrees. In most cases, it is technically difficult for heat pumps to reach such temperatures, or they do not operate as efficiently as in low-temperature heating systems. The transfer of heating networks in large cities to lower temperatures would be complicated, due to existing traditional heating systems and energy inefficient buildings. However, a reduction of heat carrier temperatures would be possible in small district heating systems by renovating heat supply networks, as well as home heating and hot water systems.

Another factor that impedes the installation of geothermal energy and heat pumps in district heating networks is the relatively low cost of heat produced and supplied in most Lithuanian cities. Especially in cities where heat is produced by burning biofuels.

Also, large initial investments compared to other heat production methods (e.g. burning gas or biofuels) are not attractive to investors. While on the other hand heat pumps and geothermal heating systems have some of the lowest operating and maintenance costs.

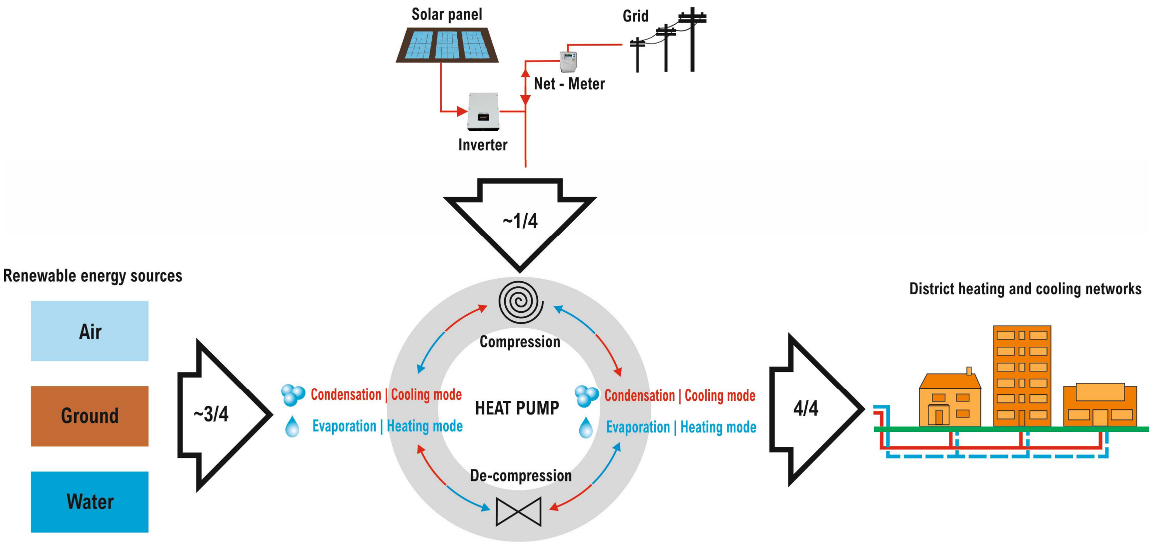

Fig. 4: The principal scheme of a heat pump operated by a PV system for district heating and cooling networks

Though attempts have been made to evaluate the use of geothermal energy and heat pumps in district heating systems, none of the projects have been implemented. In recent years, several studies and calculations have been carried out on how to use absorption heat pumps to raise the temperature of the return heat carrier, several such projects have already reached the design stage.

Although the installation of geothermal energy, heat pumps, and solar PV systems in district heating networks is promising, however presently heat production and supply companies have used the support to invest only in the installation of solar PV systems up to 500 kW to cover electricity needs.

5. Discussions and Conclusions

The high temperature required for heat supply is the main disadvantage of the efficient use of heat pumps. The reduction of temperature of the supplied heat carrier is an important issue for the efficient use of HPs in district heating networks.

The cost of PV systems has fallen rapidly in recent years and different subsidy systems were launched in Lithuania. However, the installation of solar PV systems to satisfy the needs of district heating networks has started recently.

Although the use of combinations of geothermal technologies, heat pumps, and solar photovoltaic systems in district heating systems is promising, this technology is not yet comparable to traditional energy sources, especially when it comes to the price of kWh of energy produced. This was also shown by the example of Klaipėda Geothermal Power Plant as well as in the implementation of other projects.

The state (government) support for the installation of such systems is essential for this technology to spread faster in Lithuania. Also, some good demonstration examples would help to reveal the advantages of this technology for heat producers and suppliers.

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