

Geothermal Potential and Energy Use, Country Update for Lithuania

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ABSTRACT

Lithuania has a large unutilized geothermal heat production potential due to enhanced geothermal gradient (up to 42°C/km) in the SW of the country. The geothermal anomaly follows the geometry of the Middle Proterozoic “hot” granitoid intrusions rich in radiogenic heat producing elements. Additional increase in heat flow is also associated with thermal blanketing effect, where the heat is preserved in the rocks at depth due to 2 km thick sedimentary cover above the intrusions. Since the abandonment of the Klaipeda Geothermal Demonstration Plant (KGDP) in 2017 due to prevailing injection degradation issues, no new geothermal installations have been achieved in Lithuania. However, in the past 3 years research has been renewed on geothermal potential evaluations for Devonian hydrothermal complexes as well as abandoned or close to depletion Cambrian and Silurian oil fields using existing infrastructure.

1. INTRODUCTION

1.1 Thermal energy production

In Lithuania, heating and cooling make up 26% of the total final energy consumption. Most of the thermal energy is produced in thermal power plants or boilers (Fig. 1) that use ~73.1% RES and biodegradable fraction in municipal waste (wood and its byproducts, straw, lignin, biogas and grain waste), 14.6% natural gas, 7.1% municipal and other non-hazardous waste, etc. (Fig. 2). Part of thermal energy is also produced at installations using energy from chemical processes, whereas no energy is produced at larger geothermal installations (Fig. 1).

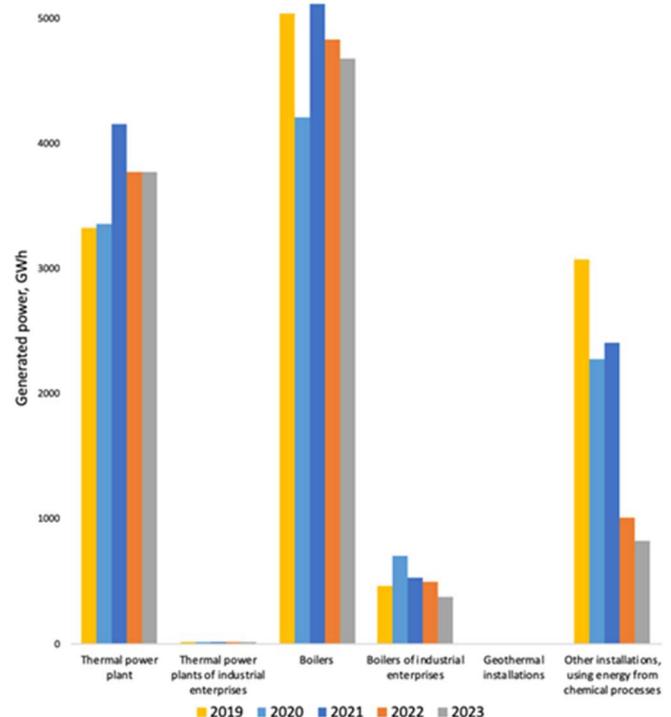


Figure 1: Total thermal energy production by place of production, GWh (please check references: <https://osp.stat.gov.lt/lietuvos-aplinka-zemes-ukis-ir-energetika-2023/energetika/atsinaujinantys-energijos-istekliai> <https://interreg-baltic.eu/project-posts/energy-equilibrium/energy-system-and-storages-infrastructure-in-lithuania/>).

2. GEOLOGICAL SETTING AND GEOTHERMAL POTENTIAL

Lithuania is located on the eastern side of the Baltic sedimentary basin and has a geothermal anomaly in the SW of the country due to intruding Middle Proterozoic cratonic granitoids rich in radiogenic heat producing elements such as Th, U and K (Sliupa et al., 2010).

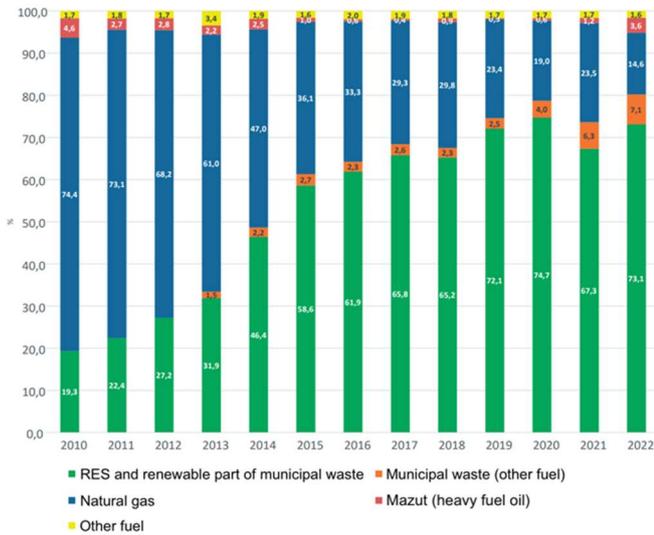


Figure 2: Primary fuel structure in the Lithuanian district heating sector (please check reference: <https://osp.stat.gov.lt/lietuvos-aplinka-zemes-ukis-ir-energetika-2023/energetika/atsinaujinantys-energijos-istekliai>).

The geothermal gradient in this area reaches up to 40°C/km. The increased geothermal gradient also overlaps with the thickest sedimentary cover in the country (>2000 m in thickness) (Fig. 3), that additionally increases the heat flow due to the thermophysical insulation of the rocks (e.g., the temperature conductivity of Silurian clays reaches 6 W/km), which protects heat dissipation at greater depths. That creates several potentially prolific zones for geothermal energy utilization. Two best known geothermal complexes within the anomaly are the Lower Devonian and Cambrian aquifers. The Lower Devonian aquifer is constrained to depths shallower than 1200 m, and it is composed of unconsolidated heterogeneous sands of Pärnu-Kemeri formation that show temperatures of up to 46°C. The Cambrian formation, located at depths greater than 1940 m in the main Gargzdai fault zone area, is composed of tight sandstones with temperatures reaching up to 96°C (Makauskas et al 2024).

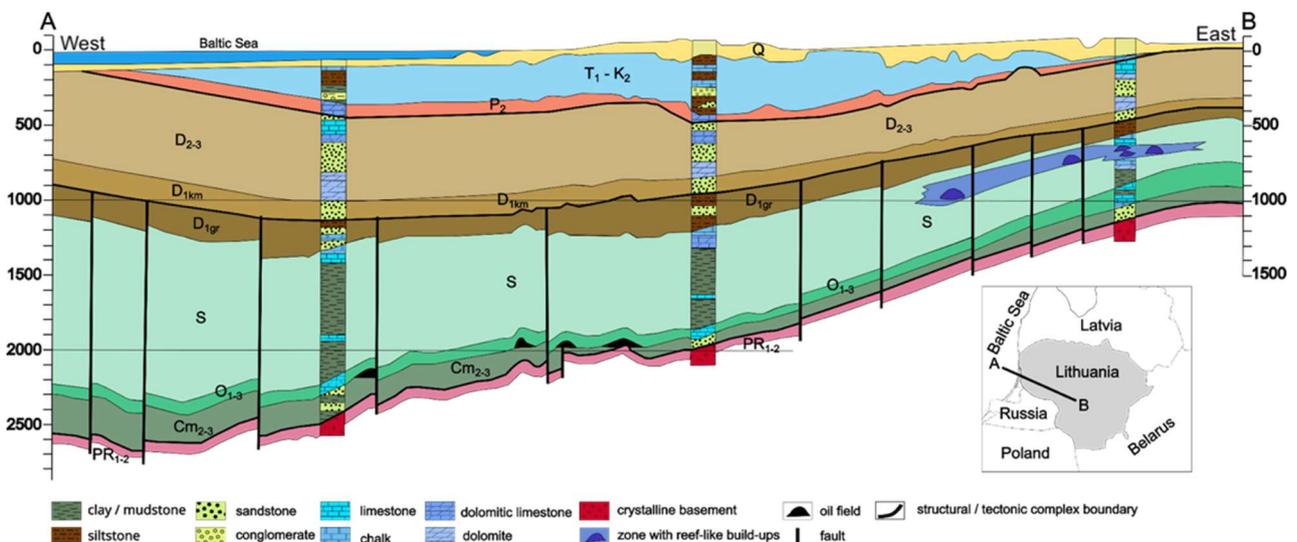


Figure 3: Schematic geological cross-section throughout western Lithuanian territory (A-B profile as marked on the Lithuanian map in the lower right corner) with oil fields within Cambrian marked in black and reefogenic deposits in Central Lithuania marled in blue (modified after Jacyna et al 1997). D_{1km} is Devonian Kemeri, S – Silurian, Cm₂₋₃ - Cambrian formations.

2.1 Hydrothermal potential

Recently studies on geothermal potential evaluation in Lithuania have been renewed because funding has been initiated for two projects from the Lithuanian Research Council. The studies include geothermal potential evaluation of Cambrian and Devonian formations, as well as Silurian reef-like structures. The methods involve detailed analysis of the information collected by the oil industry from the exploration and production wells, and geothermal energy production modelling for the oil fields that are currently abandoned or close to depletion. Moreover, Klaipėdos energija, AB has been investigating the re-opening of the Klaipėda Geothermal Demonstration Plant and has invested in

the re-evaluation of KGDP well longevity and performance studies.

One of the studies has evaluated repurposing of abandoned oil and gas wells within the Cambrian reservoirs that was the primary target for oil exploration since 1990 (Makauskas et al 2024). After geological screening of the existing and depleted hydrocarbon reservoirs with high water production rates, mechanistic box models were developed for the selected sites. The findings showed that with a well spacing of 1300 m, it is theoretically feasible to produce heat at a rate from 38 to 187 GWh annually. Nausodis site reservoir showed the most promising results (potential energy produced of around 1.87×10^3 MWh)

due to its significantly high thermal output, attributed to a substantial production rate resulting from a large reservoir thickness and a high Net-to-Gross (NTG) value. Diegliai, Vilkyciai, and P. Siupariai sites showed similar thermal outputs, owing to their common geological properties. Genčiai site exhibited a comparatively lower potential (Kaminskaite-Baranauskiene et al. 2024) (potential energy produced of around 3.84×10^4 MWh) due to lower reservoir temperature and poor production rates.

Another study by Kaminskaite-Baranauskiene et al (2024) has evaluated Silurian reef carbonate formations, that are considered a secondary oil target in Lithuania after the Cambrian sandstone reservoirs. Geothermal potential was calculated for the doublet systems using the existing oil exploration infrastructure. The heat production rates of well doublets range from 0.000044 to 0.24 MW. Kudirka site has the largest reservoir volume and hence the largest reservoir heat potential of 250 GWh. However, due to large formation heterogeneity, recovery factor is only 11%. Within the Kudirka reservoir structure, 6 well doublets could be arranged from the existing 16 exploration wells, at the average distance between the producing-injecting wells of around 700 m. The doublets would produce around 2836 MWh during the heating season, whereas the closest Vilkaviskis town with around 9500 population would require around 10^4 MWh. However, since reservoir formation temperature is $<36^\circ\text{C}$, heating to the required district heating temperatures of $>60^\circ\text{C}$ would increase the capacity of the doublets to around 1^580^000 MWh, which would cover the heating needs of the nearby towns and more. Pavasaris reef has got 2 wells penetrating the reef, thus one doublet could be arranged with geothermal capacity of 0.241 MWh. However, the available thermal energy is limited due to hydrogeological closure and small reservoir size (11.2×10^3 MWh). Other reefs are also small, isolated structures, thus their heat potential is low.

2.1 Petrothermal potential

The largest Zemaiciu Naumiestis intrusion (ZNI) is as large as 30×45 km with a thickness of ca. 4 km (Sliupa et al 2005, Sliupa et al 2010). According to the well measurement and modelling data the temperature within the granitoid intrusions ranges from $80\text{-}90^\circ\text{C}$ at the top of the intrusion to $190\text{-}200^\circ\text{C}$ at the bottom (Ciuraite 2009). The prospective temperature of 150°C for energy generation is predicted at the depth of about 4.5 km. That is an economically reasonable depth for a geothermal plant.

The crystalline basement in Lithuania is unevenly fractured, however tectonic zones may exist with potentially large fracture zones (Sliupa et al 2008). The authors found that within the geothermal anomaly, the heat generation of crystalline basement rocks reaches $2.5\text{-}7.5 \mu\text{W}/\text{m}^3$, and the highest values ($<13\text{-}19 \mu\text{W}/\text{m}^3$) are associated with the ZNI intrusion.

2.1.1 HDR (Hot Dry Rock) activities in Lithuania

Lithuanian geothermal developer Lavastream, has announced plans to build a geothermal plant in the Klaipeda city. The plans assume harnessing the HDR resources using EarthStore and HeatCycle technologies developed by Sage Geosystems Inc. to supply heat to the Klaipeda city district heating system, and to store and trade electricity by using pressure-based method.

The initiative includes drilling two wells to depths of 3 to 3.5 km and creating two artificial reservoirs - one per well in the crystalline basement. Operating in a "huff and puff" mode, similar to the GeneSys project in Hanover, Germany, it aims to achieve a heat generation capacity of $25 \text{ MW}_{\text{th}}$ and an electric storage capacity of $6\text{-}10 \text{ MW}_{\text{el}}$ or $60\text{-}160 \text{ MWh}_{\text{el}}$.

3. GEOTHERMAL UTILIZATION

3.1 KGDP plant status

The KGDP plant consists of 2 production wells (2P and 3P) drilled at a depth of 1135 m in Lypkiai site on the eastern edge of Klaipeda city. The plant used geothermal water of approximately 100 g/l of mineralization at a temperature of 39°C from the Devonian Kemeriai formation. The operation of the geothermal station was stopped in 2017 due to the drastically declining re-injection of the used brine. It was thoroughly reported in Country Updates (2000,2005,...) since 2000, e.g. Radeckas et al. (2000).

3.2 Geothermal aquaculture: Fish farming

Klaipeda University is at the forefront of research on integrating geothermal resources into aquaculture, particularly through the TETRAS project (Tetras 2021-2027), which focuses on recirculating aquaculture systems (RAS). The study explores the feasibility of using mineral-rich geothermal brine, extracted from deep reservoirs exceeding 1,000 meters, as a natural and cost-effective substitute for artificial sea salts in aquaculture. This approach is being tested on commercially valuable species such as whiteleg shrimp (*Litopenaeus vannamei*) and rainbow trout (*Oncorhynchus mykiss*), with experimental trials conducted at the University's Marine Research Institute. Initial findings indicate that shrimp cultivated in diluted geothermal brine exhibit growth performance, survival rates, and stress resilience comparable to or better than those raised in conventional artificial seawater systems. By utilizing Lithuania's unique geothermal resources, this research not only enhances sustainable food production and energy efficiency but also contributes to cost reduction and environmental sustainability in aquaculture. Conducted in collaboration with Klaipeda Science and Technology Park and industry partners such as AB Akola Group, the initiative demonstrates the potential of geothermal-aquaculture synergies to create innovative business opportunities and position Lithuania as a leader in sustainable seafood production.

3.3 Heat pump (geothermal and other) market in 2023–24

Despite a decline in sales across Europe, the heat pump market in Lithuania remained generally stable in 2023–24. Following the outbreak of the war in Ukraine in 2022, Lithuania experienced a significant spike in gas and electricity prices. These prices stabilized within six months, primarily due to the liquefied natural gas (LNG) terminal in Klaipėda, through which Lithuania has been importing gas from Norway and other countries for a decade, completely independent of Russian gas supplies. However, the heat pump market in Lithuania was impacted by supply shortages, particularly from German manufacturers, who faced capacity constraints in meeting their domestic demand, resulting in wait times of nearly six months for German or Scandinavian products. In this context, Asian manufacturers (especially from China) adjusted Lithuania's heat pump import structure in their favor, particularly in the air-to-water heat pump sector.

In 2024, the heat pump market faced significant pressure as gas prices dropped to EUR 0.06/kWh, while electricity prices in the NordPool LT trading zone reached as high as EUR 0.30/kWh (a clear example of irrational price divergence!). The development of the heat pump market was supported by government subsidy programs for modernizing the heating systems in existing buildings, administered through the Environmental Projects Management Agency and the Lithuanian Energy Agency (based on Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC). Subsidies for heat pumps ranged from 30% to 70% of the investment cost, depending on the heat source, integration of domestic hot water preparation, and the rated capacity parameter (P_{rated}). The criteria for subsidization were not overly strict, requiring only to fill in the parameter values specified in the applicant's declaration. This subsidy practice continues today.

Another factor boosting the heat pump market is government subsidies for solar power installations (EUR 325–255/kW) and the “net metering” electricity billing system for prosumers (likely transitioning to a “net billing” system in the future). Lithuania has some of the strictest standards for new building construction, mandating A++ energy class (near-zero energy consumption) buildings, which reduces the demand for heating systems. A popular solution is to install a solar power system and use an electric boiler for heating under the “net metering” system. In addition, heat pump systems simplify the certification of buildings to A++ class, practically eliminating heating and cooling costs.

Due to these factors, Lithuania follows a broader European trend of installing more lower-efficiency air-to-water systems and fewer shallow geothermal systems with vertical borehole probes, particularly in the single-family home market, with a ratio of approximately 12:1.

The geothermal borehole market is supervised by the Lithuanian Geological Survey. Since 2015, regulations on the design, installation, and decommissioning of geothermal boreholes have been enacted, tightened in 2021, requiring mandatory registration of even the smallest geothermal borehole systems (344 systems were registered in buildings in 2024). For systems exceeding 50 kW, geophysical surveys and a mandatory Thermal Response Test (TRT) to determine rock thermal conductivity are required, using modeling software such as Earth Energy Designer (EED).

Although the absolute number of geothermal system installations is decreasing, their installed capacities are going up. In commercial buildings, ground-to-water heat pump systems with capacities ranging from 150 to 300 kW have become increasingly common and no longer considered unusual. Overall, the impact of European “green directives” promoting renewable energy systems and phasing out fossil fuels is particularly evident in the commercial sector. In 2024, the European Commission allocated EUR 20 million to support the conversion of heating systems in regional industrial companies in Central and Western Lithuania from fossil fuels to renewable sources, with a subsidy intensity of up to 85%. In 2024, two flagship heat pump projects, each with 700 kW capacity, were implemented: the second phase of the BOD Group's high-tech project (following the first phase in 2012 with 800 kW capacity and 16'000 m of boreholes) and a food logistics center near Vilnius (45'000 m², with 14'000 m of boreholes drilled).

4. CONCLUSIONS

Lithuania holds significant untapped geothermal potential, particularly in the southwest, where a geothermal anomaly (up to 42°C/km gradient) is driven by radiogenic granitoid intrusions and thick sedimentary cover. Despite the 2017 closure of the Klaipėda Geothermal Demonstration Plant due to injection issues, recent research has revitalized interest in geothermal energy. Studies targeting Devonian and Cambrian aquifers, as well as Silurian reef structures, indicate viable heat production from abandoned oil fields, with reservoirs like Nausodis showing high potential (up to 187 GWh annually). Plans for a new HDR geothermal plant in Klaipėda using advanced technologies further signal progress. Supported by government subsidies and EU „green directives“, the heat pump market remains stable, favoring air-to-water systems over geothermal ones, though commercial installations (150–300 kW) and flagship projects (700 kW) demonstrate growing capacity. Innovations in geothermal aquaculture also enhance sustainability for fish farming. These efforts position Lithuania to leverage its geothermal resources for sustainable energy and heating solutions.

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