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Development of Renewable Energy in Lithuania: Experience, State and Trends

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In recent decades, the growing number of citizens and improving life quality have increased energy consumption in the world and Europe, as well as in Lithuania. Despite the fact that an increasing number of countries are focusing on the development of renewable energy, most of the energy is produced by using fossil fuels. As a result, climate change is being felt more than ever before. One of the ways to mitigate climate change is the development of renewable energy sources in the world, Europe and Lithuania. Last year, Lithuania produced 5,142 TWh of electricity, which accounted for 47% of the country's total electricity consumption, and 22.2% of all electricity consumption was generated using renewable energy sources. According to the Lithuanian National Energy Independence Strategy, 70% of electricity will have to be produced in Lithuania by 2030, reaching 100% by 2050. However, electricity imports and resulting energy dependence are still a major challenge in Lithuania. To address the ambitious goals of eliminating energy dependence and developing climate-neutral technologies, the last decade has seen the focus on the development of renewable energy, and wind energy in particular. Forecasts for the future suggest that by the middle of the century, the country will be producing electricity mainly from renewable sources including onshore and offshore wind energy, large- and small-scale solar energy, and bioenergy systems.

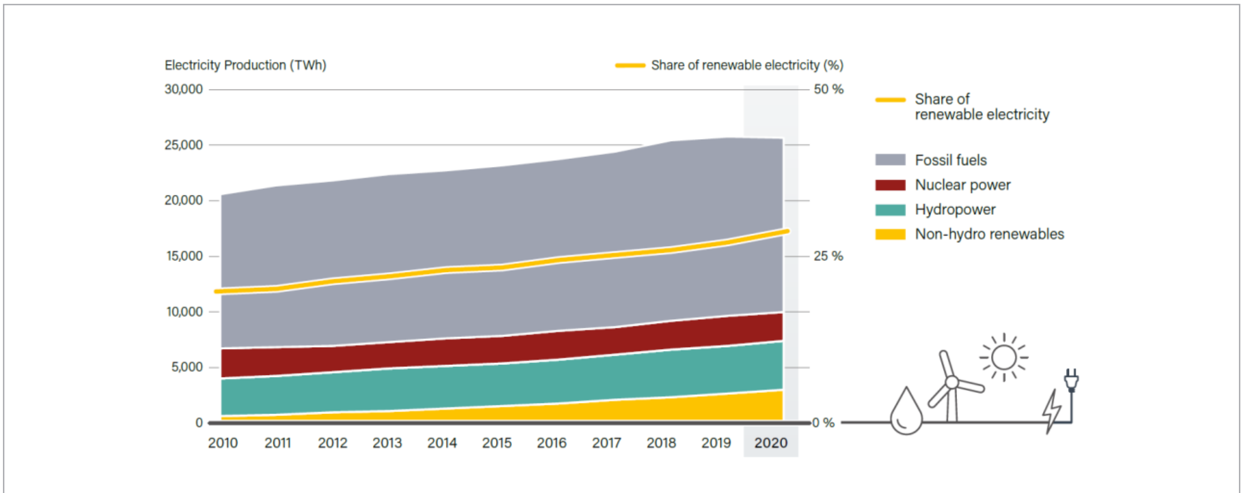
Keywords: renewable energy, energy dependence, climate change.

Introduction

During the last decades, climate change has been felt more than ever. Despite huge efforts to mitigate climate change, anomalous phenomena including floods, droughts, forest fires and surface erosion indicate signs of the limit reached. Many international and national agreements, law, green policy and initiatives around the world and EU, such as Green Deal or Circular Economy ideas, have been suggested; however, faster transformation to neutral carbon economy and technologies is needed (Ammari et al., 2021; Qadir et al., 2021; Liu et al., 2019). The sector of renewable energy plays a significant role in green transformation (Li et al., 2020; Tahir et al., 2021). Renewable energy is used in thermal, transport and power sectors. However, the share of renewable energy sources (RES) in thermal and transport sectors is not very significant across the world, respectively 10.2% and 3.4% in 2018. RES accounted for 27.1% of global power generation in 2018 and 29% in 2020 (Fig. 1) (REN21, 2021).

In terms of the global power generation, the main pillar consists of fossil fuels such as natural gas, coal or oil; the second largest is nuclear power; however, does not play a very important role in increasing the share of energy sources (Jurasz et al., 2020, Gan et al., 2020). Hydropower is the leading sector, but it has not been growing as fast as modern renewables such as wind power and photovoltaics. Modern renewables generated 9% of the global electricity demand in 2020; in addition, some countries indicated significant shares of solar and wind energy: Denmark – 63%, Uruguay – 43%, Ireland – 38%, Germany – 33%, and Greece – 32%. Most of the EU countries are leaders of modern renewable energy systems development (REN21, 2021).

Fig. 1. *Renewable electricity in the world (REN21, 2021)*



Assessing the annual usage of renewable energy sources for energy production reveals that Lithuania achieved the set goals of the European Union in 2020: energy production should have accounted for at least 23%. This indicator was achieved and exceeded: renewable energy sources in 2020 in the final energy balance accounted for 27.36%. However, the share of RES in electricity generation was 20.17% (Lithuanian Energy Agency, 2021; Ministry of Energy of the Republic of Lithuania, 2021). The goals of the National Energy Independence Strategy state that, by 2030, the share of RES in the final electricity balance should reach 45%, and in 2050, it should be 80% (National Energy Independence Strategy of Lithuania, 2018). Based on experience, future prospects and opinions of researchers, it is likely that the focus will be on wind and solar energy (Marčiukaitis et al., 2016). However, a deeper analysis is needed to assess future energy development prospects in the Lithuanian energy sector.

The paper presents a review of renewable energy used in the development of electricity production in Lithuania: its potential, state, and future trends and scenarios; in addition, it discusses opportunities and challenges in achieving sustainable energy goals.

Methods

The review of the state and trends of renewable energy development in Lithuania presents a comprehensive study of the situation. The research provides the 2000–2020 data including different physical parameters:

- solar and wind energy potential;
- installed power capacity;
- produced electricity;
- actual power generation;
- actual power consumption;
- RES share in the electricity sector;
- RES share in the final energy consumption;
- RES penetration level.

The paper analyses the progress of the current renewable energy sources and their conformity to the goals and future scenarios of the National Energy Independence Strategy of Lithuania by 2030 and 2050. In order to better understand the impact of economic factors on energy development, macroeconomy data, gross domestic product (GDP) at current prices as well as purchasing power standard per capita are analysed.

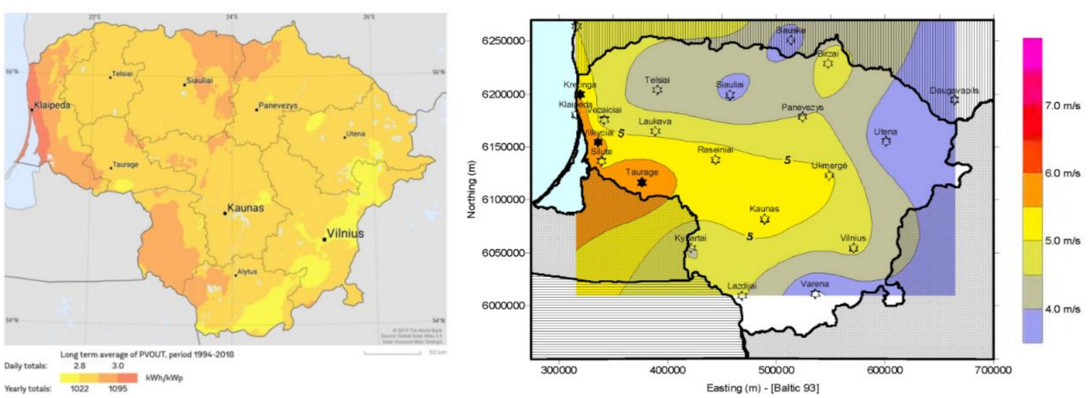
Results and Discussion

Renewable energy potential in Lithuania

The definition of modern renewable energy sources basically can be understood as solar and wind power. These power sources can be described as variable, considering unstable power generation and dependence on meteorological conditions (Romo-Fernández et al., 2011; Wang et al., 2011). Solar irradiation and wind speed potential in Lithuania are presented in Fig. 2.

Solar irradiation in Lithuania varies from 1,000 to 1,200 kWh/m^2 per year. Higher solar energy potential is fixed in the western part of the country and, on the contrary, lower in eastern part of Lithuania. The central and the remaining part of the country indicates a solar radiation parameter to be around 1,100 kWh/m^2 per year. The highest wind speed zones are fixed in the coastal zone of the Baltic Sea (the western part of Lithuania). Average wind speed zones are situated around the central part of Lithuania (UNDP, 2003). The eastern part of the country is covered by forests and,

Fig. 2. *Solar irradiation (kWh/m2) and wind speed potential (m/s) in Lithuania (Solargis, 2021; UNDP, 2003)*



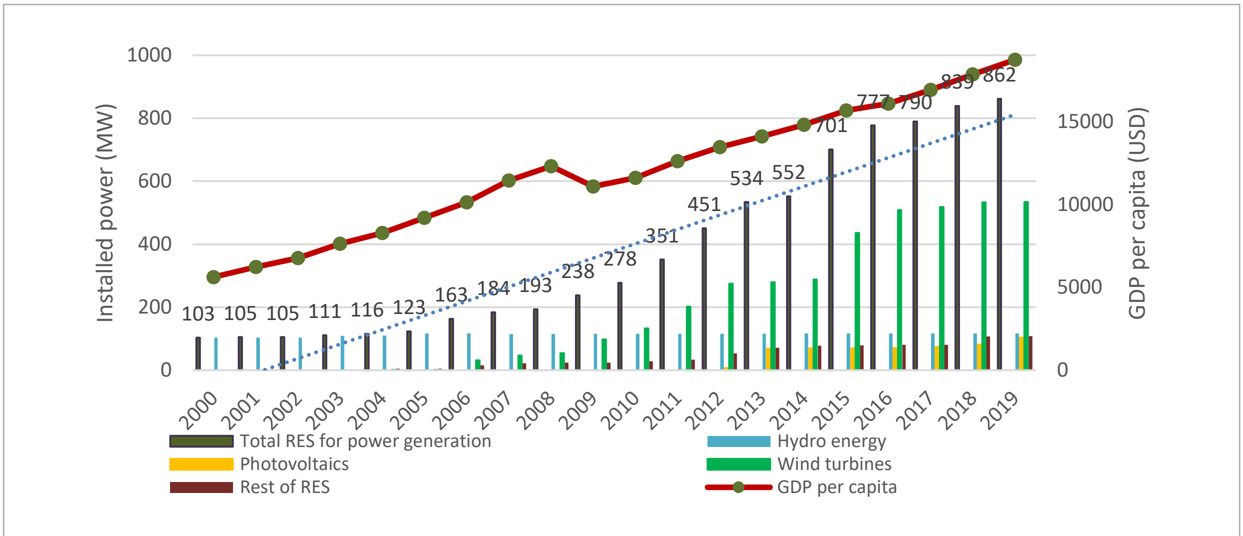
as a result, there are lower wind resources resulting in a less promising perspective in the wind turbine development (Kudelin and Kutcherov, 2021; Bartczak et al., 2021).

Renewable energy in Lithuania

The relation between the installed power of RES and GDP is presented in Fig. 3. During the last two decades, installed power grew more than 8 times from 103 MW in the year 2000 to 862 MW in 2019. The growth during the last ten years reached 300%, which means that, since 2009, significant capacity of renewable energy was added every year. In terms of gross domestic product (GDP), the indicator increased more than 3 times from 5,620 USD in 2000 per capita to 18,730 USD per capita in 2019. During the last ten years, GDP grew 1.6 times (Statistics Lithuania, 2021; Eurostat, 2021).

In the period 2000–2005, the installed power of RES did not grow very rapidly (103–123 MW). Significant growth of RES started with the development of large-scale wind turbines in 2009 with added 44 MW wind power capacity. Significant wind power growth continued until 2016. In terms of solar energy, substantial growth was recorded in 2013 with added 61 MW

Fig. 3. *Installed power of RES and GDP in Lithuania 2000–2019 (Statistics Lithuania, 2021; Eurostat, 2021)*



installed power of photovoltaics. However, later this growth was very slow due to decreased feed in tariffs for electricity production from photovoltaics. The remaining part of RES consists of biofuels, biogas and waste incineration power plants. This share of RES does not play a significant role in power generation; it has been growing slowly but constantly since 2006.

The relation between RES installed power and GDP can be observed; however, GDP grew constantly during the last two decades (except during the economic crisis in 2007–2009), but installed power of renewable energy sources significantly increased only in the last decade with modern renewables. The European Union law and obligations, support schemes and national strategy were the main pillars for RES breakthrough in Lithuania (Horstink et al., 2021).

Large-scale wind turbines generated 63% of the total RES produced electricity in 2020. JSC “Vilniaus šilumos tinklai” generated 13% of electricity, while small-scale hydro power stations generated 8% of power (Fig. 4) (Baltpool, 2021).

In order to illustrate the role of variable (modern) renewables, Fig. 5 presents monthly electricity parameters and the percentage part of large-scale wind turbine power generation. Maximum power output was registered during the winter period with RES amounting to 66.5–68.4%, with lowest values during the summer period; RES reached 45.5% in August. The difference between the highest and lowest values amounted to 22.9%, which means high variations of power supply. The remaining part of RES generated power was stable. However, it requires deeper analysis before the development of large-scale systems such as photovoltaics in order to ensure power reserve.

Wind turbines are the largest renewable energy generator in Lithuania with two-thirds of generated power from RES. However, wind turbines are dependent on local wind conditions; therefore, energy production varies accordingly. Lithuanian power consumption per hour and wind turbine power output in 2020 is presented in Fig. 6.

Fig. 4. *Electricity production from different RES in 2020 (Baltpool, 2021)*

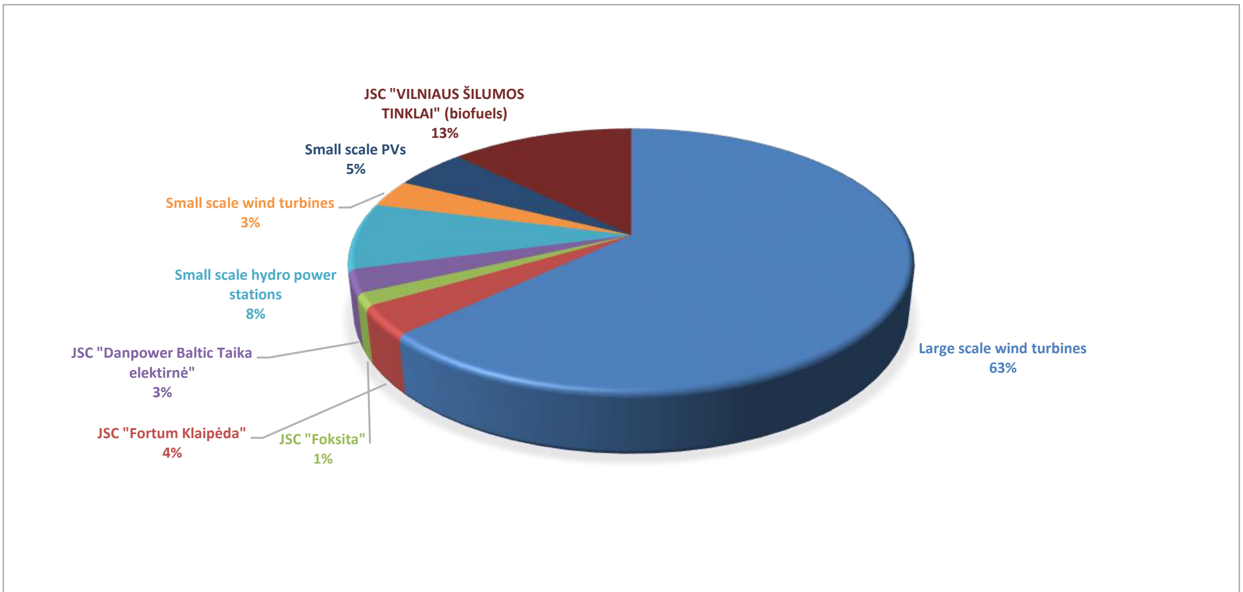


Fig. 5. *Monthly produced electricity by RES in 2020 (Baltpool, 2021)*

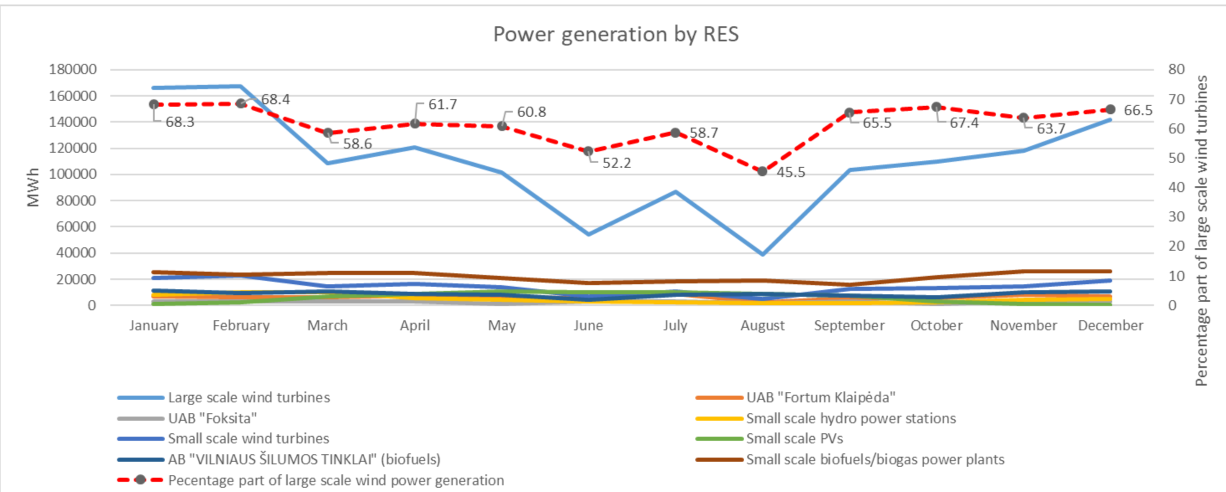
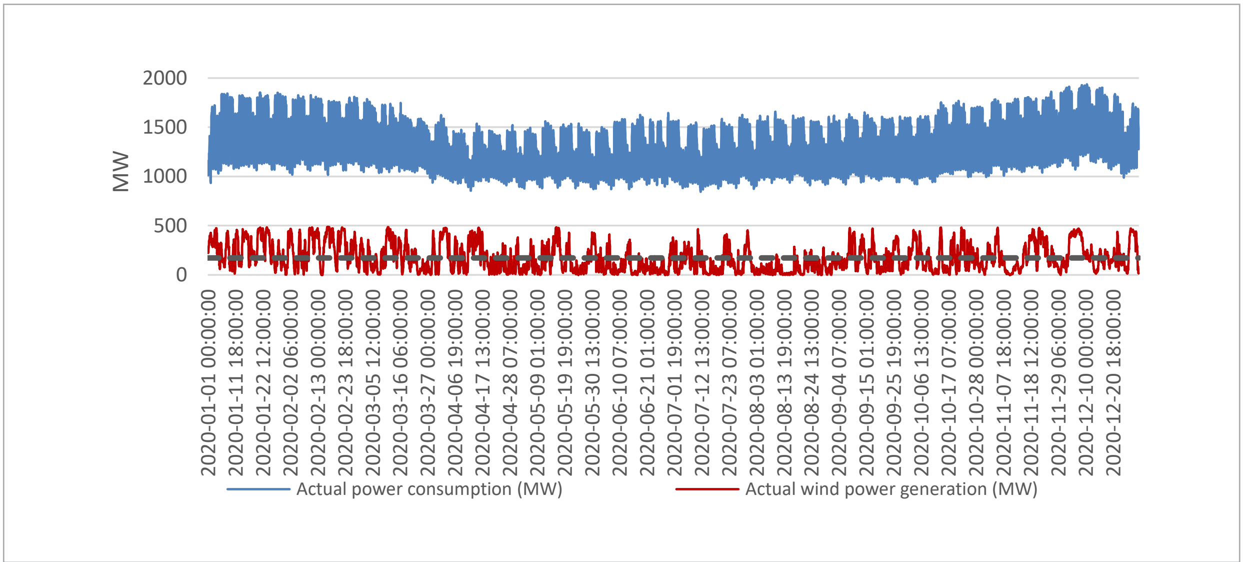


Fig. 6. *Hourly power consumption and wind turbine power generation in 2020 (http://litgrid.eu)*

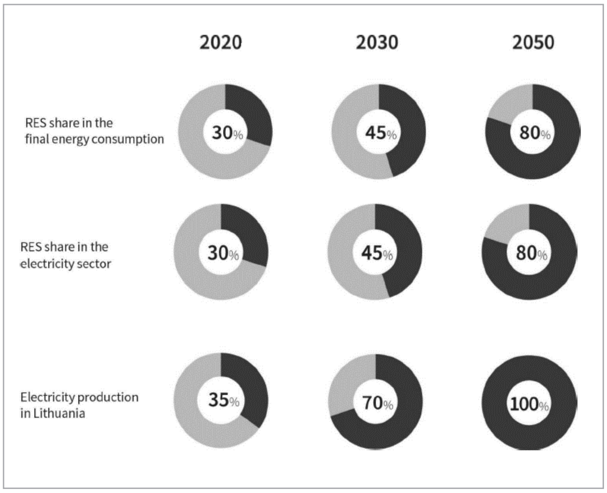


The highest power consumption during the winter period and the lowest in summer were registered respectively at 1,935 MW and 842 MW in 2020. The difference between the highest and the lowest power consumption equalled 56%. At the maximum, wind energy generated 486 MW during the winter period; however, there was a moment when power was not generated. Regarding the power demand in Lithuania and power generation of wind turbines, power demand is easier to predict with lower power demand during weekends and depending on seasonality. Wind power generation presents substantial power variations, especially in spring and autumn periods. Average annual power demand was 1,348 MW, while wind turbine generation reached 172 MW with a 13% average generation of the total Lithuanian power demand. The highest wind energy penetration was recorded at 50% on 16th and 11th of July.

RES development trends

The perspectives and trend of power generation are presented in the National Energy Independence Strategy of Lithuania. The strategy is clearly oriented to climate neutral technologies and presents short-term, mid-term and long-term goals respectively for the years 2020, 2030 and 2050 (Fig. 7).

Fig. 7. *Strategic goals of electricity production in 2030 and 2050 (National Energy Independence Strategy of Lithuania, 2018)*

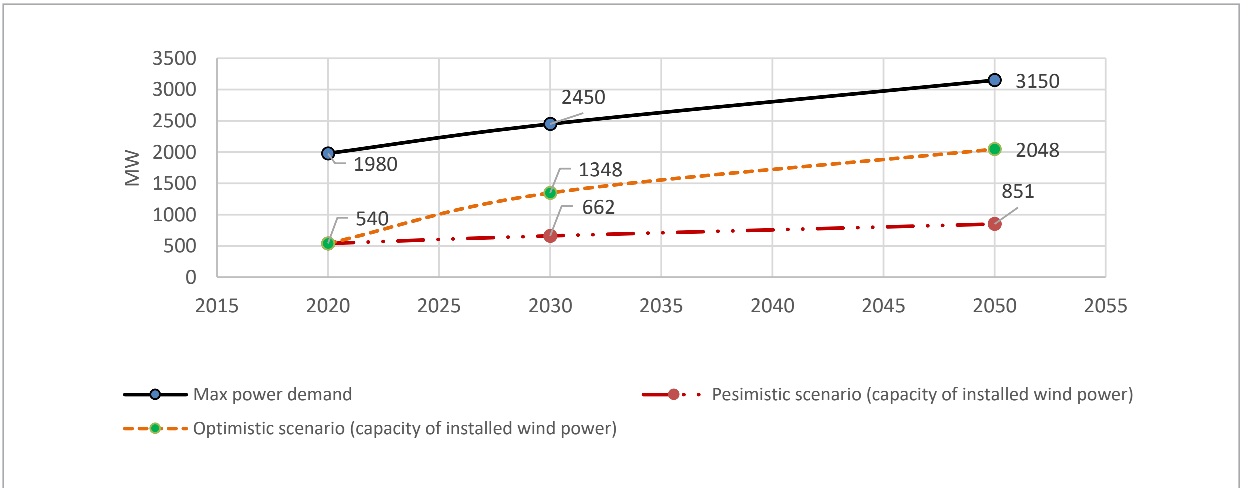


According to the analysed document, production of electricity in Lithuania should grow up to 70% by 2030 and 100% by 2050. In comparison, 47% of final electricity consumption was produced in Lithuania in 2020. Moreover, at the same period, 22.2% of final electricity consumption was produced by RES. The goals of RES for final electricity consumption are 45% and 80% by 2030 and 2050, respectively. To achieve that, RES power generation has to be increased twice in the next decade. The share of RES in final energy consumption includes energy for transport, electricity and heating. The same numbers of the RES share are observed in the electricity sector. However, by 2050, the share of RES has to reach 100% in the district heating sector and 50% in the transport sector.

The forecasted peak power demand and installed power of wind turbines based on optimistic and pessimistic scenarios is presented in Fig. 8. Electricity peak demand of 2,450 MW in 2030 and 3,150 MW in 2050 is predicted.

Considering the 540 MW installed power of wind turbines in 2020, Lithuanian peak power demand was calculated at 27%. Based on the above data, pessimistic scenarios of wind turbines installed capacity for 2030 and 2050 were calculated with 662 and 851 MW, respectively. However, according to the National Energy Independence Strategy of Lithuania, optimistic scenarios for the same period were projected as well. It was estimated that electricity production in wind turbines should reach 55% by 2030 and 65% by 2050. Based on these numbers, the optimistic scenario presents the capacity of installed wind power of 1,348 MW by 2030 and 2,048 MW by 2050. As a result, the installed power of wind turbines should grow 2.5 times over the next decade.

Fig. 8. *Predicted power peak demand and installed power of wind turbines*



Discussion

For nearly thirty years (1983–2009), the Lithuanian electricity sector was based on local nuclear power generation in Ignalina Nuclear Power Plant. However, when the second nuclear power block was closed, the Lithuanian electricity sector became very dependent on the import of electricity. As a result, at the same period, a large-scale RES project was started to develop with wind energy playing the main role. Unfortunately, the installed power of RES grew very slowly in 2017–2020. Despite this fact, 47% of final consumption electricity was produced in Lithuania in 2020. Renewables produced 22.2% of final electricity consumption in 2020, while the remaining part of produced electricity relied on fossil fuels because of lower price of natural gas (Tahir et al., 2021). The main RES for electricity production was wind energy with 540 MW installed capacity, the second was photovoltaics with 169 MW capacity, and the third came hydro energy with 128 MW installed power. According to the National Energy Independence Strategy of Lithuania, the RES share in the electricity sector will reach 45% by 2030 and 80% by 2050. To achieve these ambitious goals, wind energy should be the main source with two-thirds of electricity production from RES with 2,000 MW installed power. As a result, the capacity of wind turbines should increase 4 times with large-scale offshore wind turbines on the Baltic Sea coastline, including onshore wind turbines. Photovoltaics will play a very important role with increasing installed power capacity. However, to reach this goal, the share of prosumers will grow from 30% to 50% in the period 2030–2050. The renewable energy development cannot be separated from transport and heating sectors (Pitanuwat et al., 2020). Therefore, in future, research will have to project mobility and heating issues including smart buildings and cities, and hydrogen systems as energy capacitor and energy source for transport (Come Zebra et al., 2021; Fernández-Guillamón et al., 2019; Li et al., 2020; Wang et al., 2019).

Conclusions

The breakout of large-scale renewable energy development during the last decade was identified with 3 times increment capacity of RES installed power. Dependence on electricity import was one of the main reasons for the installation of new local generators. However, the relation between GDP per capita and capacity of RES was weak in the period 2000–2010. The same relation was stronger in the period 2010–2020. Thus, GDP per capita is not the main factor determining faster development of RES. According to these results, it can be concluded that the European Union and the national energy policy, strategic goals and objectives have the greatest impact on the development of renewable energy sources. Based on the current situation, it can be assumed that, in the future, renewable energy sources will play an increasingly important role in the energy security sector.

Large-scale wind turbines provide the main renewable energy source for power generation in Lithuania with two-thirds of generated electricity during the last few years. Small-scale wind turbines, photovoltaics and hydro energy each produced 3%–5% of the total demand of electricity. The penetration level of large-scale wind turbines varies up to 50% with a significant role of wind turbines during the night period. According to the current potential of renewable energy sources and the current situation in Lithuania, it can be stated that the percentage part of the respective sources will remain similar in the future.

Strategic energy independence goals are based on fully local power generation by the middle of this century. The main role for power generation is based on large-scale offshore and onshore wind turbines, as well as large-scale and small-scale photovoltaics including prosumers. As a result of that, the main issue related to increasing capacity of RES is energy storage and power system balancing. Therefore, the development of renewable energy sources must be considered not only from a social and environmental, but also from an economic point of view, ensuring secure and reliable energy supply and storage, low energy prices and diversification of different renewable energy sources.

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